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Lead beneficiary	GEOMAR
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Action Progress Report #2

Reporting period: 1 Jan 2021 – 30 Apr 2022

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Executive summary

The EuroSea project has been running for about 2.5 years by the writing of this report, a bit past the halfway point of the project. This report covers months 15 – 30 of the action, i.e. a good portion of the mid-term period of EuroSea. Since the last action progress report (December 2020), EuroSea has made a lot of progress in all work packages and, although we see some delays, mostly related to the COVID-19 pandemic and related issues, these are not affecting the project much and could all be mitigated. The progress of the WPs is summarized below, and is described in more detail in the main part of this report. As an innovation action, EuroSea is keeping a close eye on creating impact and on creating services and products that will last past the lifetime of the project. There is no single big-item ticket that the project is focusing on, but progress along many lines from the international coordination, over design to improved forecasting. In addition, EuroSea has produced a number of targeted services and products for ocean health, operational services and climate, and more products are scheduled to be ready by the end of the project.

1. EuroSea positioning in relation to other developments and summary of progress

During this period there has been increased interest and understanding for the importance of sustained ocean observations and forecasting by many stakeholder groups on the international level. For instance, during UNFCCC COP26 in Glasgow we observed an increased interest in, and understanding for, the ocean's role in climate. In particular this is evident for carbon and heat uptake. EuroSea partners represented at COP26, and WP7's work is in particular supporting the work on the ocean's role in climate, and supporting the observing effort. Similarly, we see an increased interest from UNEP in creating information in support of sustainable coastal ocean use and ecosystem health, and UNEP is starting up GEMS Ocean in response. This is very much in-line with activities by WP1 and WP6 of EuroSea. Also, for operational services, there is an increasing demand for ocean data to support weather and ocean forecasting, in particular from WMO. Work Packages 4 and 5 are leading the efforts in EuroSea for forecasting and operational services that link well with these ambitions.

A major activity that has ramped up during this period is the launch of the UN Decade of Ocean Science for Sustainable Development. Several EuroSea members are in leading positions in various decade programs and projects. However, we have not yet launched any EuroSea activities directly into the decade, but we are working on a strategy to do so in order to increase impact and sustainability of EuroSea products.

On the EU level, DG Mare has launched the ocean observations initiative and EuroSea has provided well thought out and coordinated response to support this, as we regard this to be an important activity that can potentially change how we operate ocean observing in the EU. One of the main objectives of EuroSea is to strengthen the European Ocean Observing System (EOOS) and position that to be able to support the ocean observations initiative. EuroSea is supporting key components of EOOS and used unused travel funds to improve the website of EOOS. EuroSea is also in close contact with the G7 FSOI office and we have been able to elevate our activities and create synergy.

Overall, EuroSea is well positioned in the European and international landscape for ocean observing and forecasting. We are improving coordination and harmonization with the aim to create an integrated ocean observing and forecasting system. EuroSea is working closely with end-users and is creating products targeted for ports, coastal communities, fisheries, aquaculture and local authorities, for instance. EuroSea has been flexible to adapt to the changing landscape and situation as it develops.

Below is an overview of the activities on a work package level. A more detailed report from the work packages is provided later in the main part of this report.

WP1 - Governance and Coordination of ocean observing and forecasting systems

Work package 1 is tasked with supporting the ocean observing and forecasting system coordination and governance at both the international and European level. In order to do so, WP1 has organized international and specialized workshops for seagrass, macro algae and for marine debris to improve technical implementation, governance and integration. WP1 has been improving the European Ocean Observing System (EOOS), that we consider to be an important component to better coordinate within Europe. EOOS has received an updated website, improved governance with a Resource Forum in place and an active operations committee. WP1 is also overseeing the activities around Ocean Best Practices, which is an important component to improve interoperability of observations and data. WP1 is also organizing "Foresight workshops" and the first one on "Ocean Technology, platforms and artificial intelligence" was implemented very successfully. The planning for the next one has started. Additionally, WP1 is leading a task on finding solutions to legal bottlenecks with regards to ocean observing, which we should be able to communicate during the last period of EuroSea. Based on advice from the International Scientific and Technical Advisory Board (ISTAB), WP1 has added a new task on gap analysis of the European Ocean Observing System and has been able to hire a scientist on unused travel funds.

WP2 - Ocean Observing System Design

The overall objective of WP2 is to apply the systems design processes on the EuroSea observing system in support of the European Ocean Observing systems. WP2 will define the requirements of EuroSea based on the societal benefits, providing a direct link to societal challenges related to the larger Atlantic and Mediterranean basins and the European Blue Growth strategy. These requirements will be translated into strategic recommendations about sustained monitoring of EOVs and identified in existing observing networks in support of specific demonstrators. In this way, WP2 will deliver guidance to improve existing elements and/or implement new ocean observing components to EuroSea.

In particular, WP2 is co-developing a precise framework to increase the readiness level for the regular and sustained delivery on the Essential Ocean Variables (EOVs) and Essential Climate Variables (ECVs) which are needed to build the relevant climate and ocean indicators. WP2 has consolidated the initial list of indicators across the wide range of stakeholders and end-user groups represented within WP4-7 and has undertaken a specific study on one of such indicators: Marine Heat Waves.

WP2 has been working on providing objective guidelines to improve existing elements of the Atlantic and Mediterranean Sea Observing system. This has been done based on Observing System Design Experiments that rely on physical and biogeochemical (BGC) models. During this period, the physical experiments have been implemented and are currently under evaluation. The task on the biogeochemical Argo design was completed during the first report period.

WP2 has further conducted Observing System Simulation Experiments (OSSEs) to improve the design of multi-platform in situ experiments aimed at validating the future Surface Water and Ocean Topography

(SWOT) satellite observations. The OSSEs have been completed and different sampling strategies and reconstruction methods are currently under evaluation to provide recommendations for stakeholders.

WP3 - Network Integration and Improvement

This WP oversees key aspects of integration of European observing technology / networks for its optimal use in European (e.g. EOOS) and global initiatives (e.g. GOOS) and, in parallel, addressing national interests. This is focused around observing networks, either based on technology (mooring, tide gauges, glider, floats, ships, etc.), or thematic networks (e.g. metagenomics, data, scientific issues). The advancement of the technology coordination follows the Readiness level approach outlined in the Framework for Ocean Observing (FOO) and adapted to European needs such as improving internal/group integration, creating and updating a comprehensive set of Best Practices, advancing governance and ensuring efficient data and metadata delivery to European data integrators. WP3's work required adapting to the landscape as shaped by the pandemic, in particular the in-person workshops - a major tool towards objectives - have been reorganised as virtual events with the positive aspects of enhanced participation, something which is expected to continue at least for another year. During this progress report period three deliverables were accomplished: New Tide Gauge Data Flow Strategy (D3.3), HF-Radar Governance (D3.4), and (D3.5) ASV Network structure roadmap.

Important progress was made on the task of integration where a major result has been achieved, with the publication in Frontiers in Marine Science of the position paper entitled "Ocean Integration: the needs and challenges of effective coordination within the ocean observing system"[1]. This paper lays out the roadmap for increased integration by articulating nine challenges to achieve integration, and possible solutions.

The work of WP3 will continue during the last period of EuroSea with several targeted activities to strengthen the efficiency of individual networks based on their respective needs and the efforts to harmonize data flow and increase integration.

WP4 - Data integration, Assimilation, and Forecasting

The objective of WP4 is to ensure that new or consolidated in situ observation data sets are integrated in the Copernicus Marine global and regional North East Atlantic and Mediterranean Sea modelling and forecasting systems. This will implement ensemble forecasting at regional level, improve the use of in-situ data for satellite validation, develop ship-based time series pilot products and produce new carbon synthesis products and assess the skill of ocean variables from the Copernicus Climate Change seasonal forecasting systems. WP4 has strong links with the Copernicus Marine and Climate Services. This ensures that EuroSea research and development activities can be integrated in the Copernicus Marine and Climate Change Services, thus reaching TRL7 and 8 at the end of the project.

In task 4.1, the Copernicus Marine global 1/12° system analyses were compared to mooring observations to refine the assimilation efficiency in the tropical oceans. To improve the Copernicus Marine BGC global system, BGC Argo observations were successfully used to optimize the PISCES model parameters in its 1D-version. The task 4.2 team proceeded to design and perform the experiments to assess the direct impact of the assimilation of the glider profiles in the Copernicus Marine MED-MFC PHY and SOCIB WMOP systems. The historical monthly dataset provided by the Copernicus Marine INS-TAC will be assimilated in both MED-PHY and WMOP systems for the intercomparison. The task 4.3 team is developing a foundation for the 10-day lead time ensemble forecasting in the Mediterranean Sea. The development of statistical pdf estimation

[1] https://doi.org/10.3389/fmars.2021.737671

to be used to perturb heat and water fluxes in the 1/16-degree ensemble model runs has continued. The team has also produced a first suite of initial-condition ensemble forecasting experiments. Task 4.4 partners have validated S3A/B altimetry-derived across-track geostrophic currents against HF radar and ADCP currents in the south-eastern Bay of Biscay. BGC Argo arrays were used for the validation of ocean colour satellite missions (S3A&B). In task 4.5, the development of a ship-based time series pilot product including data from eleven sites around the globe is ongoing; the task also contributed to the release of the GLODAPv2.2021 in August 2021. Task 4.6 has assessed the skill of seasonal forecasts of SST, OHC and SSH from two different seasonal forecasting systems contributing to Copernicus Climate Change Service. The verification has been completed for spatial maps and is currently being done for the EuroSea Indicators.

WP5 - Coastal Resilience and Operational Services Demonstrator

WP5 provides a demonstration of the end-to-end connection from observations - including a new generation of multi-parametric monitoring station - to their wider availability and use by a wide variety of stakeholders by combining and incorporating existing CMEMS and satellite products into novel decision-making tools for policy and planning. The work package is dedicated to the development of new coastal management products that include downscaling of ocean analyses and forecasts for port and adjacent cities' operations. Thus, WP5 provides demonstration of improved end-to-end connection from a new generation of stakeholder co-designed observations to their wider integration and use in innovative software tools.

The WP5 team has continued to make extensive use of conferencing technologies to overcome the difficulties posed by the COVID-19 pandemic. The technical specifications of the multi-parameter measurement stations (with core sea level measuring capabilities) have been completed for all stations and the instrumentation for Barcelona has been built and tested and is planned for installation in April 2022. Capacity-building work associated with the Buenaventura installation will be undertaken at the same time, which will facilitate the Colombian installation shortly thereafter. Travel restrictions in Italy have resulted in difficulties finalising the location for the instrumentation in Taranto, but it is hoped that these will be resolved shortly.

The reconstruction and quantification of the various contributions to relative sea level in the Mediterranean Sea has been completed. This involved combining tide gauge observations with altimetry data and fingerprints of land-mass changes through a Bayesian spatiotemporal model. Coastally-retracked altimetry data were generated using gridded altimetry datasets from the Copernicus Marine Environmental Monitoring Service (CMEMS), combined with tide gauge and vertical land motion data and formed inputs to a purpose-built Bayesian spatiotemporal model. The resulting estimates of sea level rise have been published and the methodology is to be documented in a scientific paper, which is under development.

The prototype sea level planning and visualization tool for the Humber region of the UK is complete and has received positive reviews from existing and potential stakeholders at national and regional events. For the new coastal management product, Oceanographic Services at the service of Ports and Cities (OSPAC), downscaled wave and circulation forecasts systems have been developed for both Barcelona and Taranto and two hydrodynamic operational tools have been developed for Barcelona, whilst work has commenced on development of the same for Buenaventura. Development and validation work for circulation and wave models in Taranto has made good progress. The OSPAC demonstrator software, a one-stop shop of met-ocean indicators and tools for the management and decision support at Ports and coastal Cities, has been completed during this period and is operational for the port and city of Barcelona, providing information from measuring instruments and operational downscaled ocean model forecasts under restricted access.

WP6 - Ocean Health Demonstrator

The overall objective of WP6 is to develop a shared understanding of water management among end-users in aquaculture, fisheries, tourism, environmental agencies and scientists by working together to co-create products that help to identify and foresee "Extreme Marine Events" threatening marine ecosystems, resources and related businesses and to support adaptive management decisions.

The role of WP6 in EuroSea is to highlight the importance of the ocean observing system in water resource management and ocean health through the development of products and services that detect, monitor and forecast anomalous and extreme events (e.g. marine heat waves, deoxygenation, eutrophication etc.) threatening marine ecosystems, resources and related businesses. In this second reporting period, WP6 partners and co-developers have progressed well with a number of new in-situ observing initiatives and data applications underway, designed to address the needs of a diverse array of national and regional stakeholders (environmental and fisheries scientists and managers, ecologists, MSFD policy makers and the aquaculture industry).

Key areas of progress in the Ocean Health demonstrator include advances in the development of some data products in Task 6.1 (e.g., web-based tool in the Mediterranean). In T6.2, linking CMEMS environmental variables with fishery stock, analyses showed that there are links between CMEMS variables and fish stocks. In T6.3, advancement was made on the delivery of NRT in-situ ocean observing data to CMEMS (and EMODnet) and the reanalyses model development, co-designed as a tool to support MSFD environmental assessments, is well underway with a positive response from HELCOM members on the proposed products under development. Finally, in T6.4, the first of two data buoy systems was built based on aquaculture requirements and was co-designed to support monitoring at fish farms. Buoy deployments at two sites will take place later this year.

WP7 – Ocean Climate Indicators

WP7 addresses innovative ways to assess the role of the oceans and seas in the Earth's climate through the development, evaluation – including uncertainties - and dissemination of ocean climate indicators and their value for the three pillars of sustainable development: economy (e.g. blue economy), societal (e.g. policy) and environmental sectors (e.g. climate science). WP7 will generate a feedback loop between EuroSea, climate and ocean services, the economy sector, and decision makers by co-examining ocean climate indicators, assessing their uncertainties and quantifying their economic value. WP7 will provide user-relevant products for ocean climate monitoring and deliver ocean forecasting indicators in support of improved ecosystem management, risk management and blue growth.

WP7.1 is evaluating observing strategies and data products needed to determine the economic value of the (variable) ocean carbon sink of European relevant deep convection regions. The analysis is based on operational carbon assessments using a combined observing and modelling approach. The assessment of existing air-sea CO2 and interior ocean carbon storage data products, methodological approaches and data flows are investigated. Regional high-resolution model simulations of partners are used to test different observational network strategies in the Mediterranean Sea and Labrador Sea. Techniques to estimate the time integrated ocean uptake of excess carbon (Cant) using different parameter combinations and observation platforms are further investigated.

WP 7.2 has successfully published an analysis of societally-relevant predictions of ocean variables and indicators in seasonal forecast systems and has achieved advancements with respect to stakeholder engagement activities. In particular, planning, development and launch of a stakeholder engagement strategy is expected to lead to the creation of user-defined ocean monitoring indicators.

WP7.3 is focused on upscaling the spatio-temporal coverage and quality of carbon flux estimates over the tropical Atlantic. This is being achieved through a Tropical Atlantic Observing System (TAOS) optimization demonstration using an integrative multi-platform approach. The task is aiming for closing observational gaps for carbon observations through PIRATA (pCO2 @8N38W), BGC-Argo (pH) and Autonomous Surface Vehicles (ASVs; pCO2) and using a neural network (CANYON). Progress in this task has been significantly affected by the pandemic, but a major part could be compensated through successful external additional funding for the ASV mission following the withdrawal of an external partner. Consequently, BGC Argo float deployments and ASV missions have been successfully performed during 2021, although the extension of the Brazilian PIRATA array is still subject to further delay (deployment cruise scheduled for April 2022).

WP8 - Communication: Engagement, Dissemination, Exploitation, and Legacy

The objectives of WP8 are to support the project's demonstration WPs towards their business exploitation, as well as the project itself towards sustaining the project's results, enabling and fostering science-policy and public-private partnership interfaces. WP8 is delivering communications, stakeholder engagement and business exploitation support to the project. WP8 is enhancing collaborative, inclusive, and strategic stakeholder dialogue that enables exploitation of the project's results and products in the business sector. The WP also provides tangible support and guidelines on intellectual property rights and business development along the Responsible Research and Innovation principles and best practice in knowledge and technology transfer.

EuroSea WP8 continued to work remotely with promotions online. Despite the "zoom and email fatigue", WP8 managed to engage with EuroSea partners productively and operationally for the provision of online news and twitter post contents. 43 news pieces were published on the website between January 2021 and March 2022, and the number of Twitter followers is currently 1140. The EuroSea 2nd Anniversary Webinar was a success and was prefaced by a workshop with the European Commission, which also was well attended and productive. The EOOS Technology foresight workshop organised by WP1 and other partners took place online from 22 to 24 March and was supported by a dedicated outreach plan.

During the reporting period, the update of the Exploitation Strategy and further work on the impact monitoring table, which will soon appear online, was achieved. A WP8 highlight activity was the release of a policy brief[2] on ocean observing for Blue Growth prepared with a group of 10 EU projects, which dedicate part of their work to ocean observations and data, that will also be featured at the European Maritime Day conference 2022 (19-20 May 2022, Ravenna). There, WP8 will highlight priorities of this policy brief and discuss with a broad range of users and stakeholders on how to achieve observations, marine data and services that respond to the requirements of the European Green Deal.

Overall, experience from this reporting period indicates that the EuroSea communications are well regarded by our communication targets, are well taken up, and needed by the community and users. This comes as a positive sentiment especially further to the first ISTAB report, that highlighted the quality and timeliness of the EuroSea communications. To help our community to communicate more effectively in online space, we organised a training session for online presentations with a communications expert and professional facilitator. The training received very positive feedback from the participants and will help EuroSea partners

[2] https://doi.org/10.5281/zenodo.5576120

prepare short videos for dissemination of their EuroSea work via the EuroSea YouTube channel, Twitter account, and the website. During the reporting period, the WP8 staff allocation has been severely disrupted with one partner leaving the project and another substantially reducing their WP8 contribution in the remainder of the project. The WP8 co-leaders took the heat and committed extra staff capacity to fill these gaps. The transfer was successfully achieved by the end of the reporting period and was virtually unnoticed in the EuroSea communications.

WP9 - Project Coordination, Management and strategic ocean observing alliance

The management of EuroSea has been functioning during this period. Main activities are interaction and coordination within the project, with monthly Steering Committee meetings to foster interaction and to find joint solutions to increase impact of EuroSea. WP9 is also responsible for interaction with the project and policy officers at the European Commission. During the period WP9 has actively been working with the commission to relocate resources and to (successfully) mitigate issues that has emerged. WP9 has been keeping the consortium informed about external and internal activities and news through regular newsletters, roughly on a monthly basis.

WP9 is also leading the interaction with the sister project Blue-Cloud, TechOceanS and NAUTILOS (projects from the same call). WP9 has also coordinated interactions with a number of other projects, such as Arctic Passion, iAtlantic, and several more. We are always striving for synergy and cooperation. WP9 is working closely with the whole consortium to connect to European and International events and organizations.

2. Work package progress reports

WP1 - Governance and Coordination of ocean observing and forecasting systems

Lead: IOC-UNESCO, CO-lead: EuroGOOS

Objectives
• Support observing system coordination and governance both on international (e.g. GOOS, JCOMM, GCOS, G7, OceanPredict, and GEO) and at European level in supporting EOOS/EuroGOOS implementation.
• Deliver foresight into societal relevance, drivers and governance for ocean observation systems, new technologies and system sustainability.
• Strengthen the Ocean Observing system, with a focus on European needs, through extending the BioEco networks, monitoring of marine plastics, and supporting delivery for assessments, SDG indicators etc.
• Development of key components of EOOS structure and implementation of the GOOS 2030 Strategy.
• Step change in availability and identification of Ocean Best Practices.
• Support ocean observing status monitoring and visualization.

Summary of progress towards WP objectives

To support observing system coordination and governance both on international (e.g. GOOS, JCOMM, GCOS, G7, OceanPredict, and GEO) and at European level in supporting EOOS/EuroGOOS implementation.

(T1.1.5) The first OceanPredict/EuroSea workshop has been organised and will take place in late June early July. Several WP within the EuroSea project were involved in its organisation and topics were selected in collaboration with the OceanPredic community. (T1.1.1) The EOOS governance has been completed with the first Resource Forum meeting taking place in November 2021 and work underway to update the EOOS Strategy.

Deliver foresight into societal relevance, drivers and governance for ocean observation systems, new technologies and system sustainability.

(T1.3.2) The foresight on technology workshop has been organised under the auspices of the EOOS Technology Forum. The workshop is an UN Ocean Decade activity framed under two UN Ocean Decade goals: a clean, healthy and resilient ocean. The workshop has been organised around panel discussions that explore the technological developments required to achieve these goals. (T1.3.3) A small task team has been set up to help organise the workshop on funding sustainability of ocean observing. Because the topic is very broad, the organising team will discuss the focus for this particular workshop. (T1.4) legal frameworks have been analysed with initial findings provided as an internal milestone. Additionally, a report about an IOC Experts workshop on ocean observations in areas under national jurisdiction has been finalised. All these activities will help understand the required adaptation for ocean observing design within EEZ

Strengthen the Ocean Observing system, with a focus on European needs, through extending the BioEco networks, monitoring of marine plastics, and supporting delivery for assessments, SDG indicators etc.

(T1.1.2) Working on identifying the biological monitoring networks in Europe has continued with an additional 164 active networks added since the Delivery was finalised, taking this work beyond the requirements of the project. Additionally, two biological networks (macroalgae and seagrass) have been engaged in workshops and improve coordination and work on improving standards. (T1.1.3) The establishment of IMDOS is getting closer and work in establishing new partnerships with UNEP GPML and GEO Blue Planet progressing well. In addition, the first draft of the Marine Plastics EOV specification sheet has been prepared.

Development of key components of EOOS structure and implementation of the GOOS 2030 Strategy.

(T1.1.1) The EOOS Operations Committee work is progressing, discussing communication requirements to support the GOOS NFP among other topics. Additionally, a new task team was formed by the EOOS OC to develop a business plan to establish a European OceanOPS and enable European national and regional systems to assess and monitor the performance of the observing system and identify opportunities for coordination and collaboration. The vision of a European OceanOPS is similar to what the European Commission intends to achieve through its "Sharing responsibility in ocean observing in Europe and EuroGOOS led a consortium submitted an offer on a call for CINEA tender. If successful, close links will be maintained with EOOS.

Step change in availability and identification of Ocean Best Practices.

(T.1.1.4) Dialogue continues with WP within the EuroSea project to instigate and foster the creation of best practices including through the creation of tools and instructional videos and providing infrastructure support to facilitate the process. This has led to the creation of a new best practice, three additional under development, the development of a modelling best practice template for the OBPS repository. Importantly, a task team has been created to help translate European ocean best practices for under resource regions in Africa, which will lead to a real step change in availability of ocean best practices.

Support ocean observing status monitoring and visualisation.

(T.1.2) Regional dashboard has been developed for the Mediterranean and Baltic Seas and the Arctic Ocean in 2021 performing an intercomparison of monitoring tools (OceanOPS, EMODnet and EuroGOOS ROOS) to check their capacity to provide assessment tools on the performance of the observing system. Input was sought from stakeholders to understand requirements about the monitoring tools and there has been progress in the expansion of the OceanOPS scope by including other networks such as FerryBox and a network of fishing vessels.

Gap analysis of European Ocean Observing System

(T.1.5) Based on recommendations from the EuroSea advisory body (ISTAB), EuroSea has initiated a new task in WP1, which was made possible by using less funds for travel than initially anticipated (due to the pandemic). A work plan and a methodology have been tailored in order to systematically identify gaps in the EU ocean observing system and to give actionable recommendations accordingly. Key literature components were identified with the help of the WP1 partners to map thoroughly the literature tackling different aspects of the EU ocean observations, such as projects, reports, peer-reviewed articles, and data portals. Moreover, gaps and recommendations are being extracted while attending specialised workshops during which various key actors of the EU ocean observing system are present. The gaps are classified based on the GES of the MSFD and the phenomena and threats of Copernicus in order to cover all field of observations related to societal needs.

Detailed progress per task (or subtasks)

Task 1.0: Coordination

WP1 team online meetings have been held to discuss activities, actions and planning of next steps, plus additional topical task meetings as required in the second half of 2021. However, this has changed to monthly meetings on the first Tuesday of every month with alternate times to account for the spread of the team in the different time zones. This allows every team member to attend at least every two months. The meetings have been helpful by providing a good overview of the teams' activities and finding opportunities to collaborate. For example, marine microplastic task 1.1.3 lead collaborated in a workshop organised by the GOOS Bio-Eco Panel in task 1.1.2.

Task 1.1: Observing and forecasting system coordination, national, regional, global

Subtask 1.1.1 EOOS GOOS Implementation

Task leader: EuroGOOS, Partners: IOC-UNESCO

The EOOS governance was completed in November 2021, with the establishment of the Resource Forum. This governance body represents the funders and resource providers of ocean observing and will support the long-term sustainability of ocean observing in Europe. The EOOS Resource Forum is seeking to collaborate with the EOOS OC to expand the National Focal Points survey undertaken in 2020 to include national funding bodies to provide more accurate information about the funding structure and sustainability of the national systems.

A redesign of the EOOS website was completed in January 2022, providing an engaging and informative site where the ocean observing community can engage with EOOS. The website has had ~ 1200 new unique users since its launch.

The EOOS Operations Committee met in September 2021 and March 2022, and had an inter-sessional meeting in February 2022. The OC created a task team to develop a business plan to establish a European OceanOPS service, which was identified as a priority during the EOOS OC 2nd meeting. The task team includes infrastructure network representatives and five GOOS National Focal Points. This activity is still underway with the task team identifying potential funding sources that could help establish this service. A recent call for tenders by the European Commission is closely related to the aim of the European OceanOPS and EuroGOOS was leading the tender proposal. If successful, close communication will be kept with OceanOPS to ensure alignment is sought.

An update of the EOOS framework Strategy is under development. A review about the implementation activities of the current strategy was undertaken and will be used to update the Strategy and create a new implementation plan.

Subtask 1.1.2 Strengthen and extend BioEco monitoring networks throughout the European Seas

Task leader: IOC-UNESCO

In D1.2, submitted on 26 February 2021, we identified 363 marine monitoring programs in Europe that monitor at least one Essential Ocean Variable (EOV). These EOVs include phytoplankton, microbes, zooplankton, benthic invertebrates, fish, birds, turtles, marine mammals, seagrass, macroalgae, hard coral. We have continued to identify marine monitoring programs and currently have a database that highlights 527 active marine monitoring programs, including subprograms. More monitoring programs will continually be added through workshops and engaging with various researchers and networks.

In an effort to strengthen and extend networks throughout the European Seas, we organised two online workshops. The online macroalgal workshop titled 'Towards a Coordinated European Observing System for Marine Macroalgae' was undertaken between November 23 - 25, 2021. The workshop was co-chaired by Professor Lisandro Benedetti-Cecchi (University of Pisa, Italy) and Professor Isabel Sousa-Pinto (University of Porto, Portugal). With ~60 attendants around Europe, the workshop engaged researchers, funders, managers and others to advance macroalgal monitoring in Europe. On the first day, the workshop engaged speakers on Data availability and integration with different data platform by Ward Appletans (Ocean Biodiversity Information System) and Joana Beja (EMODnet), Funding opportunities by Rodrigo Ataide (European Commission), Macroalgal sector in Europe and needs for ocean observation by Zoi Konstatinou and Maris Stulgis (European Commission), Safe Seaweed Coalition : altogether to power the seaweed revolution through collaboration by Vincent Doumeizel (United Nations Global Compact), The challenges in marine macroalgal restoration by Simonetta Fraschetti (University of Solento, Italy), Integrating macroalgal observations into global networks (e.g., Marine Biodiversity Observation Network (MBON), Global OCean Observing System (GOOS) and Convention on Biological Diversity (CBD)) by Frank Muller-Karger (University of Florida, USA) and Nic Bax (The Commonwealth Scientific and Industrial Research Organisation) and Integrating marine litter into macroalgal monitoring. Days two and three involved discussions around monitoring protocols and integrating across the different methods led by Nova Mieszkowska (visual surveys, University of Liverpool, United Kingdom), Aschwin Engelen (eDNA, Centre for Marine Sciences, Portugal), Chuanmin Hu (remote sensing, University of South Florida, USA) and Victor Martinez Vincente (remote sensing, Plymouth Marine Laboratory, United Kingdom). Workshop summary and recommendations will be presented in D1.4, due July 2022.

The online seagrass workshop was recently convened, March 22 - 24, 2022. The workshop was co-chaired by Lina Mtwana Norlund (Uppsala University, Sweden) and Richard Unsworth (Swansea University, Wales) and set out to identify the 100 Priority Questions for Conservation, Monitoring and Research of Seagrass Ecosystems in Europe. A scientific paper will be published from this workshop, and workshop summary and recommendations will also be presented in D1.4, due July 2022.

Subtask 1.1.3 Developing capacity and coordination for a sustained ocean observations of marine plastic contaminants

Task leader: IO PAN

An official Satellite Activity of the UN Ocean Decade: Clean Ocean Laboratory on "One Integrated Marine Debris Observing System (IMDOS) for a Clean Ocean"[3] on 17-19 November 2021 was co-organized with GEO Blue Planet EU coordination office and Mercator Ocean International. The aim was to share knowledge and discuss the growing threat and multidimensional problem of marine debris to marine ecosystems, ocean and coastal users; and to present the state-of-the-art around transdisciplinary approaches, monitoring technologies and modelling, networks and digital ecosystem contributing to global marine debris observations.

A peer-reviewed paper on IMDOS[4] was published in the inaugural supplement on ocean observing in Oceanography, an official magazine of The Oceanography Society.

[3] https://www.eu4oceanobs.eu/ocean-decade-lab-satellite-activity

[4] Maximenko, N., A.P. Palacz, et al. (2021). An integrated observing system for monitoring marine debris and biodiversity. Pp. 52–59 in Frontiers in Ocean Observing: Documenting Ecosystems, Understanding Environmental

Expert advice was provided to the Ministry of Environment Government of Japan to develop a global data hub and data synthesis products on surface floating microplastics (attended three international expert workshops).

Further advice was provided to the H2020 EUROqCHARM[5] project as a member of the Stakeholder & Advisory Committee, with focus on integrating in global coordination of sustained marine plastic observations the project outcomes related to standardisation and harmonisation of methods for microplastic observation.

The concept of IMDOS and the role of civil society groups was introduced during the Kick-Off event of the UN Ocean Decade Project "Odyssey"[6]. The event aimed to unlock the hidden potential of new observing approaches and civil society initiatives to contribute to sustained global ocean observations.

New collaborations and discussions on future partnerships with UNEP GPML and GEO Blue Planet, critical to implementing the IMDOS vision, have been initiated. An international Interim Steering Committee of IMDOS has been formed to oversee the development of initial Terms of Reference and their initial implementation.

In addition, the first draft of the new Marine Plastics Debris Essential Ocean Variable Specification Sheet has been prepared.

Subtask 1.1.4 Ocean Best Practices

Task leader: IEEE, Partners: IOC-UNESCO, SOCIB

Dialogues with WP have been ongoing to encourage and support the creation of best practices in all EuroSea WP. The initial work with WP3 has led to one new best practices document and three more are being planned. OBPS has provided Infrastructure support, for example by contributing to the licenses and discussion on Jupyter Notebook publication in OBPS. Discussions with WP5, 6 and 7 to document practices in applications have been ongoing and further efforts are needed.

Planning for a workshop on Best Practices at EuroSea GA is underway. The workshop is to support the creation of best practices within the EuroSea project, and includes the identification of use cases to be presented and the creation of additional best practices templates for use by EuroSea work packages.

A best practice template for ocean modelling, (WP1.1.5) was developed and support has been provided to the organisation of the ocean prediction and observing system design workshop by EuroSea/OceanPredict communities. Ongoing discussions are undergoing to explore further collaborations to expand the creation of ocean modelling best practices.

As a recognition that supplementing best practices documents with alternative communication channels such as video-based descriptions and social media is necessary to foster their creation, we are supporting the production of a short best practice video. The video is an example of best practices on baitless underwater video observations and is a collaboration with Domique Peltier and EuroSea. Instructional videos on OBPS and documentation of best practices are also other tools provided.

Changes, Forecasting Hazards. E.S. Kappel, S.K. Juniper, S. Seeyave, E. Smith, and M. Visbeck, eds, A Supplement to Oceanography 34(4), https://doi.org/10.5670/oceanog.2021.supplement.02-22.

[5] https://www.euroqcharm.eu/en

[6] https://www.oceandecade.org/actions/ocean-decade-odyssey/

A task team was implemented on best practices in Coastal Observations in Under-Resourced Countries. The task team is focused on translating the European ocean best practices for application in resource limited regions of Africa.

With capacity development a core element for adoption and effectiveness of best practices, pilot videos have been created to understand approaches for improved capacity development. OBPS is also addressing the need for non-English access to best practices.

In collaboration with GOOS, OBPS has developed a process for endorsement of best practices. After successful testing of the pilot, enhanced search capabilities to expose all ENDORSED practices were created.

Proceedings of OBPS workshop IV were completed and delivered as EuroSea deliverable D1.3. An OBPS Workshop V was held in Oct 2021 and included topics of interest to EuroSea, and the planning of the OBPS 2022 workshop is underway. This workshop will take place virtually from Oct 5 to Oct 19 2022 and EuroSea has been invited to propose a session.

Additional activities include a presentation on best practices was given at Ocean Sciences Meeting 2022, and the implementation of a European Projects Community in OBPS to support cross-project opportunities.

Subtask 1.1.5 Strengthening links to the leading edge of global forecast and prediction

Task leader: MetOffice

This task includes the organisation of two workshops to strengthen the link of EuroSea with OceanPredict and the wider global ocean science community. The planning for the first workshop is almost completed and will take place at the Met Office, Exeter, UK, 29 Jun-1 Jul 2022. The organisation of this event so far included:

- Various remote pre-planning meeting with WP1 lead to agree on workshop organisation strategy (Mar – June 2021)
- Invitation of workshop organising committee members from many of the EuroSea WPs (Jul 2021)
- Confirmation of 10 plus committee members (Aug 2021)
- Organisation of several workshop planning meetings to set up workshop agenda (Aug -Dec 21)
- Exchange with EuroSea communication WP on event announcements, event hosting, etc. (Dec 21)
- Creating of the EuroSea/OceanPredict workshop web pages (Jan- Feb 2022)
- Announcement of the workshop date and location (Feb 2022)
- Completion of workshop website registration and abstract submission facility (Mar 2022)
- Planning of on-site workshop organisation (facilitating hybrid workshop, security, catering, etc.) Mar 2022

Task 1.2: Observing system status monitoring

Task leader: IOC-UNESCO

The first internal milestone of this task (Jan 2021) about 2020 Ocean Observing System Status report was dedicated to the Mediterranean Sea. We took this opportunity to approach this question from different stakeholders' points of view to demonstrate the diversity of attendees and needs. We use the OceanOPS monitoring system to report and assess the strengths and weaknesses of this system to achieve this task.

2021 OOS status reports: The second internal milestone due in December 2021 focuses on the Mediterranean Sea, the Baltic Sea and the Arctic Ocean in 2021. For each region, we used 3 different "Ocean Observing monitoring tools'' (OceanOPS, EMODNET Physics and EuroGOOS Regional OOS) to monitor the status of the ocean observing system in the region. We have analysed the same sample: "operational platform in 2021" with the three tools and compared the results. We also analysed the capacity of each tool to deliver the statistics and maps necessary to assess and report the status of the ocean observing system in the region.

Users survey: In June 2021, we surveyed different profiles of OOS system stakeholders to build a more accurate view of what is expected from an OOS status report. The results of the survey are displayed in the deliverable D1.6.

Integration of new data flows use cases: During the last 15 months, integration of new data streams outside the scope of OceanOPS was undertaken. We focused our efforts on 3 networks: Animal Borne Ocean Sensor[7], an emerging OCG network, a fishing vessels network coordinated by the Berring data collective[8], and the ferrybox network[9] already well known in the European landscape of Ocean Observing.

First development of a simplified monitoring and reporting tool: Tools to facilitate the status report of the OOS have been specified and implemented in the last 15 months based on OceanOPS existing system. This included the development of simplified access to monitoring tools and reporting capability.

Specification for future development toward GOOS National Focal Points and Regional Ocean Observing System: Future development has been specified based on requirements from NFP and ROOSs chairs.

Task 1.3: Foresight
Task leader: EMB, Partners: EuroGOOS, IOC-UNESCO, GEOMAR

Subtask 1.3.1 Identifying existing initiatives in foresight in ocean observation, emerging strategies and roadmaps
Task leader: EMB

This task was already completed in the previous reporting period.

Subtask 1.3.2 Foresight workshop 1: Ocean technology, platforms and Artificial Intelligence
Task leader: EuroGOOS, EMB

The EOOS Technology Forum will be used as a mechanism to deliver the EuroSea Technology Foresight workshop. This workshop has been titled: The technology of the science we will need for the ocean we want, and took place on the 22-24 March. The workshop has been endorsed as a UN Ocean Decade activity and includes participants from Europe, America and Canada. This workshop has engaged beyond what was required by the EuroSea project and has attracted high profile keynotes and participants to the workshop. There are over 200 registrations from diverse countries within Europe, Africa and the American continent. This event is also contributing to an increase in traffic in EOOS new website, where EuroSea support was essential and is bringing increased attention to EOOS framework.

Subtask 1.3.3 Foresight workshop 2: Sustainability of the Ocean Observation system
Task leader: EMB, Partners: IOC-UNESCO

We've identified a small task group within WP1 at the end of 2021 to help define a Task Statement and identify some experts (~8) to advise on the aims, programme and format of the workshop, planned to take

[7] https://anibos.com/about/
[8] https://berringdatacollective.com/
[9] https://www.ferrybox.org/

place in early 2023. A brainstorming meeting took place in March 2022 to discuss possible focus topics on this complicated theme (Ocean observing sustainability). A draft Task Statement is being drafted to prepare the workshop, which includes a motivation to attract the experts and participants to the workshop.

Task 1.4: Legal aspects of ocean governance and impact on the observing system
Task leader: GEOMAR, Partners: EMB

Analysis of hard and soft law frameworks and mechanisms to enable adequate adaptation of ocean observing system design at a regional and global level were undertaken. To help with the coverage of the European legal frameworks, a guest scientist was hosted for three weeks to prepare a preliminary report on these aspects. A report with initial findings regarding ocean observing in legal frameworks was circulated as an internal milestone. Towards the end of the current reporting period two thought pieces will be published as briefs: one dealing with the international legal framework concerning ocean observing in exclusive economic zones and one on the legal framework concerning ocean observing in the European Union.

Preparation of a report on the outcomes of the 2020 IOC Experts Workshop on ocean observations in areas under national jurisdiction was finalised in late 2021.

Formulation of responses to the European Commission's initiative for the joint planning of ocean observations and monitoring in Europe was undertaken and provided to a public consultation of the European Commission about their ocean observing initiative. A session was held at EuroSea's nnual meeting to gather input.

Task 1.5 Gap analysis of European Ocean Observing System
Task leader: GEOMAR, Partners: IOC-UNESCO, EuroGOOS

This new task has started based on the recommendations from the ISTAB and made possible by having unused funds for travel (due to the pandemic) with the appointment of a new member in the WP1.

The first stage of this task's work consisted in defining a clear work plan and a systematic methodology in the gaps analysis of the EU ocean observing system. This has been conducted through the assessment of the available literature (peer reviewed as well as public reports and deliverables) tackling various aspects of the EU ocean observations, from its physical, chemical and biological components, to its direct use in specific societal benefits such as in monitoring particular phenomena or challenges that can interest different kind of audiences (scientific community, stakeholders, policymakers, and the public). Therefore, information on gaps are extracted and classified based on: 1- the Good Environmental Status (GES) descriptors required by the Marine Strategy Framework Directive (MSFD) with which Member States need to comply, 2- the phenomena and threats highlighted by Copernicus, and 3- other aspects of gaps that can be related to specific type of observations (physical, chemical, biological, modelling), data FAIRness, data policies, observational networks, interdisciplinarity, technology, satisfaction of end-users, coordination and management.

Key literature components were identified with the help of the WP1 partners to map thoroughly the literature highlighting different aspects of the EU ocean observations, such as projects, reports, peer-reviewed articles, and data portals. Moreover, gaps and recommendations are being extracted from current specialised workshops during which various key actors of the EU ocean observing system are present. This is crucial to get the feedback of various communities that are producing and also using the EU ocean observations, on the urgent gaps from their own perspective, in order to ultimately provide realistic and actionable recommendations that can have common agreement and can thus be applied to improve the EU ocean observing system. The result of the analysis will be published as an article, and a new deliverable for WP1 (D1.9) will contain a detailed report.

Cooperation and interaction with other EuroSea WPs

Co-operator	WP activities
All WPs	• Joint participation in the workshops on stakeholder identification and assessment • Encouragement to participate in the upcoming OBPS Workshop VI • Workshop planning for EuroSea Annual Meeting 2022 • Supporting workshop planning for ocean prediction and observing system design for the inclusion of discussions on best practices • Collaboration to develop workshop agenda / session descriptions of the EuroSea/ OceanPredict workshop on Ocean Prediction and Observing System Design (29 Jun-1 Jul 2022), i.e. WP1 (coordination), WP2-WP3-WP4-WP5-W6 (science advisory), WP8 (communication)
WP3	• Presentation at WP3 meeting (Task 1.1.4 Ocean Best Practices) • Cooperation and interaction with operational networks: Glider networks, Ferry boxes, SOT (Fishing vessels) and data management tasks (Task 3.10). • Collaboration to draft the D3.7 “Network harmonisation recommendations”
WP5	• Dialog on documentation of best practices
WP6	• Dialog on documentation of best practices
WP7	• Dialog on documentation of best practices
WP8	• Collaboration in dissemination of EOOS Technology Forum Foresight workshop information • Collaboration in dissemination of the launch of EOOS new website

Cooperation and interaction with other projects and initiatives

Co-operator	WP activities
OceanOPS, EMODnet, Coriolis In situ TAC, OBIS, EuroGOOS FerryBox Task Team, EuroGOOS Fixed Platforms Task Team and GOOS National Focal Points for Sweden, Spain, Portugal, Malta and Finland	• Proposal development for European OceanOPS
Ocean Biodiversity Information System (OBIS)	• Cooperation
Global Ocean Observing System (GOOS)	• Cooperation for establishment of Marine (Plastics) Debris as a new EOV and facilitation of co-located oceanographic and marine litter observations • Joint work on endorsement processes for best practices

Co-operator	WP activities
MarBIOME, a European Commission tender led by the AirCentre	• Cooperation
SCOR working group C-GRASS	• Engagement with SCOR working group C-GRASS that has identified seagrass monitoring programs and data availability globally; the success of the C-GRASS project has facilitated the advancement of the EuroSea seagrass workshop
GEO Blue Planet, UNEP Global Partnership on Marine Litter, IOCCG Task Force on Remote Sensing of Marine Litter and Debris, JAMSTEC, SCOR WG FLOTSAM etc.	• Development of global coordination of an Integrated Marine Debris Observing System (IMDOS)
EU MSFD Technical Group on Marine Litter	• Cooperation for development of common sampling protocols for marine litter and coastal biodiversity monitoring
Ministry of Environment, Government of Japan	• Collaboration for support of global data hub for surface ocean floating microplastics, and development of an observing network •
UN Ocean Decade Programmes including GOOS Programmes such as OceanPractices, CoastPredict, Ocean Observing Co-Design as well as MarineLife2030, OASIS, etc.	• Cooperation
OceanPredict	• Engagement on means to implement best practices across the ocean observing value chain including modelling and forecasting

Co-operator	WP activities
	• Development of the agenda / session descriptions of the EuroSea/OceanPredict workshop on Ocean Prediction and Observing System Design[10] (29 Jun- 1 Jul 2022), i.e. OS-Eval TT (Observing System Evaluation), DA-TT (Data Assimilation), MEAP-TT (Marine Ecosystem Analysis and Prediction), COSS-TT (Coastal Ocean and Shelf Seas).
Ifremer (France) and SAEON (South Africa)	• Creation of a task team on adapting best practices to regions of limited infrastructure
European projects for Marine Research Infrastructure (JERICO, GROOM II)	• Cooperation and interaction
UN decade projects (Odyssey, Caleidoscope)	• Cooperation and interaction
TechOceans, MBARI, University of South Florida, CNR, UN Ocean Decade, Geo-Topic-Hydrographie, IOC-GOOS	• Cooperation and interaction for the organisation of the EOOS Technology Forum / EuroSea technology Foresight workshop
US National Academy	• Input on workshop process on Sustaining Ocean Observations
DG MARE, UNESCO's Intergovernmental Oceanographic Commission, Surface Ocean - Lower Atmosphere Study international research project	• Regular contact

Achieved main results

Deliverables		
D1.3	Report of OBPS Community meeting	✓
D1.5	Marine Plastics EOV and common sampling protocol	✓

[10] https://oceanpredict.org/events/eurosea-oceanpredict-workshop-on-ocean-prediction-and-observing-system-design/#event-overview

Internal Milestones		
iMS24.1	EOOS Advisory Committee Meeting and report	✓
iMS25.1	EOOS Operational Committee Meeting and report	✓
iMS26	Report on initial findings regarding ocean observing in legal frameworks	✓
iMS24.2	EOOS Advisory Committee Meeting and report	✓
iMS25.2	EOOS Operational Committee Meeting and report	
Others (optional)		
	EOOS website re-design	✓
	Formation of EOOS Operations Committee task team to develop a business plan to create a European OceanOPS	✓

WP2 - Ocean Observing System Design

Lead: CSIC, CO-lead: ENS

Objectives
• Apply the systems design processes of the Framework for Ocean Observing (FOO) on the EuroSea observing system in support of connected and integrated European Ocean Observing systems for the broader Atlantic Ocean and Mediterranean Sea.
• Define the high-level requirements of EuroSea based on the societal benefits, providing a direct link to societal challenges related to the larger Atlantic and Mediterranean basins and the European Blue Growth strategy. These requirements will be translated into strategic recommendations about sustained monitoring of EOVs and linked with LR7 and LR8 societal relevant indicators.
• Identify the requirements in existing observing networks in support of specific demonstrators (WP5,6,7).
• Deliver guidance to improve existing elements and/or implement new ocean observing components to EuroSea using various techniques, including OSSEs and data assimilation to optimally merge in-situ and satellite observations with models to provide accurate estimates for indicators.

Summary of progress towards WP objectives

The overall objective of WP2 is to apply the systems design processes of the Framework for Ocean Observing (FOO) on the EuroSea observing system in support of connected and integrated European Ocean Observing systems for the broader Atlantic Ocean and Mediterranean Sea. It builds on the H2020 AtlantOS achievements and takes on its legacy to further develop them within the Galway and Belém agreements objectives. WP2 specific objectives are:

- To define the high-level requirements of EuroSea based on the societal benefits, providing a direct link to societal challenges related to the larger Atlantic and Mediterranean basins and the European Blue Growth strategy. These requirements will be translated into strategic recommendations about sustained monitoring of EOVs and linked with LR7 and LR8 societal relevant indicators.
- To identify the requirements in existing observing networks in support of specific demonstrators (WP5,6,7) and different operational services (subseasonal and seasonal climate and extremes predictions, ocean weekly forecasts and CS3 and CMEMS Copernicus services)
- To deliver guidance to improve existing elements and/or implement new ocean observing components to EuroSea using various techniques, including OSSEs and data assimilation to optimally merge in situ and satellite observations with models to provide accurate estimates for indicators.

The work undertaken in WP2 is in direct support of the EuroSea demonstrator activities (WP5, 6, 7), the observing network integration and improvement (WP3), data integration, and assimilation and forecasts (WP4). The work focuses on verifying the EOVs and indicators, analysing the gaps of existing systems and possible upgrades [task 2.1] as well as carrying out system design studies [task 2.2] and [task 2.3].

Task 2.1 has the objective of developing Indicators for observing system networks (WP3), demonstrators (WP5-7) and verification of forecasts (WP4). During the last period we have consolidated the initial list of indicators across the wide range of stakeholders and end-user groups represented within WP4-7. This has been achieved by conducting additional but more focused discussions through general meetings and surveys with the different groups. The process has led to a better understanding of the stakeholder groups' requirements in terms of indicators and associated EOVs/ECVs. The achievements have been provided as a Milestone (MS10). As not all indicators have simple metrics or are they clearly defined, we have undertaken a specific study on one of such indicators, the Marine Heat Waves. This study is currently in progress. To complete the task, during the last 12-month period (that will end on October 30th, 2022), we are working with WP3 in providing observing requirements for such indicators.

Task 2.2 has the goal to deliver objective guidelines to improve existing elements and/or implement new components of the Atlantic and Mediterranean Sea Observing system. The general approach is based on Observing System Design Experiments that rely on physical and BGC models, or statistical techniques that realistically represent the space-time variability of the EOVs to be observed, both methods optimally merge in situ and satellite observations. During this period the OSSEs have been performed and are currently under evaluation. Their precise analysis will show how evolution of the Argo and mooring network will benefit to the global system at ¼° corresponding to the future CMEMS global system at 1/12°.

Task 2.3 has the objective to improve the design of multi-platform experiments aimed to validate the Surface Water and Ocean Topography (SWOT) satellite observations with the goal to optimize the utility of these observing platforms. Observing System Simulation Experiments (OSSEs) have been conducted to evaluate different configurations of the in situ observing system, including rosette and underway CTD, shipborne ADCP, velocities from surface drifters, and Argo vertical profiles, together with conventional satellite nadir altimetry. Simulations from high-resolution models have been used to simulate the observations and the ocean "truth" to represent fine-scale sea level and surface ocean velocities. Different methods have been tested to reconstruct the simulated observations: optimal interpolation, data assimilation and machine learning techniques. The capacity of the reconstructed fields to represent the sea level and surface current variability of the nature run models at the scales and with the expected accuracy of the future SWOT satellite mission are evaluated considering different configurations of in situ observations.

Detailed progress per task (or subtasks)

Task 2.0: Coordination

Coordination of WP2 activities has progressed as planned. We have been able to meet deadlines and reporting has been completed on time.

The WP2 co-/leaders participated in all the monthly Steering Committee meetings, reported about the WP progress and discussed cross-WP work. WP2 presented intermediate results and reported about the task progresses during the plenary session at the EuroSea Annual Meeting 2021. In addition, a science talk with more details on T2.3 was given at the scientific lunch session at the same event. Meetings with all WP2 partners, dedicated task meetings and cross-task meetings were organised and conducted. WP2 participated in the internal workshop organized by WP4 to interface upstream data (observational and model) and contributed with the list of products produced by T2.3. WP2 colleagues from the partners CSIC and IMT met with WP6 colleagues from the Marine Institute and CSIC-ICMAN to discuss a possible machine learning task force. Furthermore, WP2 representatives participated and presented in the EuroSea Mid-Term Review and EuroSea Policy meeting in September 2021 and October 2021, respectively. Moreover, WP2 participated in the NautilOS-EuroSea synergy meeting on Observing design, the EuroSea Anniversary Webinar and the EuroSea-OceanPredict meeting preparation.

Task 2.1: Developing Indicators for observing system networks/Demonstrators
Task leader: ENS, Partners: CSIC

Following the initial task plan, we have been working with the following WPs to consolidate the indicators for the different stakeholders and end users of ocean information represented in EuroSea via the WPs 4 (Seasonal forecasts), 5 (Coastal Resilience and Operational Services), 6 (Ocean Health), and 7 (Climate).

To do so, the different steps were conducted as follows:

- We organized separated meetings with each WP to re-assess the definition of the set of indicators initially designed during the first 18 months of the project (for some of the WPs the concept of indicator versus EOVs/ECVs was relatively clear, for others it was not the case).
- For indicators in each WP, we discussed and co-defined the requirements in terms of spatio-temporal extent and resolution. In future steps, we should also extrapolate requirements in terms of accuracy.
- We then defined the EOVs/ECVs sets associated to each indicator and their requirements.
- Some of these requirements are associated directly to observed EOVs/ECVs, but most of the them are related with analyses, reanalyses or forecasts products. Hence, the definition of requirements in terms of observed EOVs/ECVs is less straightforward. In the ongoing discussions and OceanPredict 2022 Workshop we should take into account how precisely link the observing system capabilities in delivering indicators defined via numerical analyses, reanalyses and forecasts. Indeed, improvement in the skill of these indicators is not entirely linked with the distribution of observations. Pathways in how to assess more quantitatively the impact of observations on these indicators should be developed via OSEs and OSSEs. However, such exercise goes well beyond the various OSSEs assessments funded in EuroSea.
- We have now started to discuss pathways to provide requirements in terms of those EOVs/ECVs related with EuroSea indicators to observing system networks

The requirements in terms of indicators among the various EuroSea stakeholders and end-user groups is very different, even for a same indicator such as “Sea Level” or “Sea Surface Temperature”. Indeed, some stakeholders assess such indicator at the scale of an ocean basin or marginal sea delivered monthly, whereas many end users are interested in a more regional if not local assessment of this same indicator and delivered at a daily frequency. Also, some end users have slightly different “definition” or “expectation” for a same indicator (for example in terms of upper ocean temperature marine farmers or fisheries are more interested in the temperature at 20 m of depth instead of the Sea Surface Temperature). Hence, we developed a exploratory study with WPs 4-7 on Marine Heat Waves (MHWs). Indicators of MHWs are not yet homogeneous or standardized across the scientific community. Moreover, as they are defined by different metrics (such as MHWs intensity, number, duration etc), they are relatively complex. Also, the same name of indicator is used for basin-scale events as well as more regional and local declinations but there is no direct connection, at present, in the definition of the two. Finally, MHWs are commonly defined via the SST EOV/ECV whereas end users are already aware that these phenomena are not exclusively a phenomenon limited to the first few meters of the water column. The work undertaken in this framework is to reconcile MHWs metrics and scales by operating some choices in terms of index definition and requirements. Among various metrics, we are investigating also on how to include the subsurface expression of these phenomena and derive a well-documented and easy to generalize indicator for MHWs to be used in CMEMS or by national/local operational agencies after the completion of the EuroSea project.

The final results for this step have been consolidated in milestone MS10, one publication on Marine Heat Waves in the Copernicus Ocean Status Report 2020 (Dayan et al., 2022) and will be at the core of the deliverable D2.4.

Task 2.2: Observing System Design Experiments with global ocean monitoring systems
Task leader: MOI, Partners: MOI, CLS, ENS

The physical OSSE design was defined in the 1st period report and presented in the report MS1. During the last period, the OSSEs were implemented.

The following tasks were performed during the last period:

- Simulation of the pseudo-observations from the Nature Run. This includes daily SST maps, along-track SLA, Argo floats following the Argo 2030 goal in terms of spatio-temporal coverage, and tropical mooring observations.
- Implementation of the pseudo-observation “loader” in the future version of the forecasting system.

The following simulations were performed:

- A simulation without any data assimilated
- A simulation with only altimetry data
- A simulation with only in situ data
- A simulation with in-situ and altimetry data (REF)
- A simulation with enhanced vertical sampling of tropical moorings
- A simulation with enhanced Argo in Western Boundary Current/Equatorial regions + REF
- A simulation with enhanced Deep Argo in key regions (high latitudes) + REF

The comparison to the true ocean state, i.e. the Nature run, is ongoing with a focus on the 3D estimation of temperature and salinity fields. The role of altimetry in constraining those 3D T and S fields is also carefully evaluated when assimilated alone or together with the in-situ profile observations to better understand their complementarity. The impact of doubling Argo in WBC and tropics is currently under assessment.

The task on the BGC Argo design using operational CMEMS BGC analysis was finished during the 1st report period. Undersampled regions by BGC Argo floats and regions with large forecast error were identified. Those results were discussed with Hervé Claustre, co-chair of the BGC Argo mission team, to serve as input from an operational system to define the extension of the BGC Argo network.

Task 2.3: Observing System Simulation Experiments: impact of multi-platform observations for the validation of satellite observations
Task leader: CSIC, Partner: CLS, IMT, OceanNext, SOCIB

Following the design planned and published in the deliverable D2.1[11], work on the following subtasks has been carried out:

Subtask 2.3.1 (completed): Three different model outputs (CMEMS, WMOP, eNATL60) were used to simulate the observations from different multi-platform sampling strategies in the western Mediterranean Sea and

[11] D2.1 (due on 31 October 2020): Design of the Observing System Simulation Experiments with multi-platform in situ data and impact on fine- scale structures. https://doi.org/10.3289/eurosea_d2.1

North Atlantic. Applying statistical parameters, we have evaluated the different sampling strategy comparing them with the "ocean truth" from the nature run models.

The different steps were conducted as follows:

- Extract and share model outputs: eNATL60, WMOP, CMEMS reanalysis (partners: Ocean-next, SOCIB and CSIC)
- Generate the configurations of the different sampling strategies in the Mediterranean and Atlantic regions (partner: CSIC)
- Simulate observations of CTD, underway CTD, ADCP and gliders (partner: CSIC)
- Simulate observations of SWOT (partner: Ocean-next)
- Simulate observations of nadir altimeters (partner: Ocean-next)
- Simulate drifters (partner: Ocean-next)
- Reconstruct the simulated observations with optimal interpolation (partner: CSIC)
- Statistical evaluation of the best sampling strategies in each region and for each model (partner: CSIC)

Subtask 2.3.2 (in progress): Test different methods to reconstruct the simulated observations: classic optimal interpolation, new temporal optimal interpolation, WMOP data assimilation and machine learning techniques.

This included the following steps:

- Reconstruct the simulated observations with the classic optimal interpolation (partner: CSIC)
- Evaluation of the spatial and temporal correlation scales (partner: CSIC)
- Development of a new method to reconstruct the observations based on an advanced version of the optimal interpolation which includes the temporal variable (partner: CSIC)
- Evaluation of the impact of including the temporal variable and correlation scale in the optimal interpolation (partner: CSIC)
- Reconstruction with WMOP data assimilation (partner: SOCIB)
- Reconstruction with machine learning techniques (partner: IMT)
- Comparison of the reconstructed fields with (i) SWOT pseudo-observations and (ii) the "ocean truth" (partners: CSIC, SOCIB, IMT)

Subtask 2.3.3 (in progress): Simulations of the observations needed for this OSSE were done based on eNATL60 numerical model: drifters, SWOT, nadir altimeters (partner: Ocean-next and CLS).

The first tests of reconstruction with MIOST have been done and have been compared with nature run. This raised an issue concerning the dynamical atmospheric impact on Sea Level Anomalies (SLA) within eNATL60. This signal has large spatial scale and high temporal frequency. The temporal frequency of this signal is too high regarding the altimetric coverage and repetitively: It is thus impossible to reconstruct with our method. We need to remove this signal in the simulated SLA (note that when dealing with real observations of SLA, this signal is removed and called: Dynamical Atmospheric Correction (DAC)). We are currently working on this issue.

Cooperation and interaction with other EuroSea WPs

Co-operator	WP activities
WP3	• Discussion about synergies between T3.9 and T2.3 • Initiated dialogue on observing requirements for sustaining EuroSea indicators
WP4	• Collaborative meeting between T4.4 and T2.3 • Co-construction of indicators for Seasonal Forecasts and requirements
WP5	• Co-construction of indicators for and requirements
WP6	• Co-construction of indicators for Ocean Health and requirements
WP7	• Co-construction of indicators for Climate and requirements

Cooperation and interaction with other projects and initiatives

Co-operator	WP activities
SWOT Science Team	• Participation in the regular meetings organized by the SWOT Science Team Regional Validation and High-resolution ocean modelling working groups
Ocean Predict	• Participation to EuroSea – OceanPredict meeting in order to prepare the Joint Workshop on Ocean Prediction and Observing System Design, planned at the end of June 2022.
Ocean Observing Co-Design programme of the UN Decade of the Ocean Sciences	• Participation as co-chair (S. Speich) and providing input helping shaping the programme
OOPC GOOS & GCOS	• Participation as co-chair (S. Speich) and providing input helping shaping the Implementation Plan of GOOS and GCOS (2.1)

Achieved main results

Milestones		
MS10	Requirements of EOVs and platforms for sustaining indicators for WP4-7	✓

WP3 - Network Integration and Improvement

Lead: HCMR, CO-lead: GEOMAR

Objectives
• Oversee key aspects of integration of European observing technology for its optimal use in an EOOS and global initiatives (e.g. GOOS) and, in parallel, addressing national interests. The integration has two dimensions: observing networks, grouped around technology or platforms (mooring, tide gauges, glider, floats, ships, etc.), and thematic networks, grouped around a certain observing challenge (e.g. metagenomics, data, scientific issues).
• Ensure that most observing networks reach TRL7, defined as: o Network coordinates a community of Best Practice around a specific technology o Network specification and governance structure is articulated (e.g. Terms of Reference) o Network data policy is defined and comply with FAIR principles (findable, accessible, interoperable, re-usable) o Long term (>10 years) sustained observing needs are defined o Networks are open to all operators of the respective observing technology o Best Practices for each network, addressing the EOV specification sheets, are documented and deposited at oceanbestpractices.org
• Improve internal coordination within the observing networks, guided by scientific/engineering expertise and supported by a technical coordinator
• Interact with the observing component in the EuroSea Demonstration activities (WP5,6,7)
• Proof Best Practice documentation
• Enable a dialogue between observing requirements and the underlying scientific approach and the technology framework that is coordinated by the observing networks
• Ensure data delivery according to standards including communication pathways between platform operators, observing networks and data centres.

Summary of progress towards WP objectives

During the reporting period there has been significant work towards the objectives despite the problems due to the pandemic. In particular, activities focused towards internal integration looking into possible governance structures, the connection with stakeholders, the integration of the networks both with European and global organisations (EOOS, GOOS, GLOSS etc.), the formulation and update of Best Practices and on data issues with specific emphasis to the connection with the existing data integrators.

Moreover, three notable deliverables have been achieved: D3.3 New Tide Gauge Data Flow Strategy, D3.4 on HF-Radar Governance, which besides the specific network can be used as a pilot for the other networks, and D3.5 on a ASV Network structure roadmap.

The Argo network activities focused on several issues during this period including the correction of systematic bias in high pressure salinity measurements, discussions on BP and on deep sensors in the framework of the BGC-Argo & Deep-Argo workshop, while cross-network interactions were also strengthened. The underwater gliders network focused on the development of best practices and data format harmonisation together with the EuroGOOS Glider Task Team and H2020 GROOM II glider research infrastructure project. For Vessels a metadata format for ship-of-opportunity platforms including FerryBoxes has been finalised and implemented by OceanOPS while a similar approach has been launched for research vessels. With the support from

International Research Ship Operators (IRSO), interaction with users is in progress while discussions with key shipping companies have permitted to set up new data streams with instruments and telecommunication systems owned and operated by the ship operators themselves. Remarkable is that these observations are motivated by the ship operator's own requirements, but are transferred for public use and global benefit by making the data open access. The fixed platform network worked mainly through the workshop on updating BP considering the global and European consortia as well as on metadata aspects following the recommendations from the global, open ocean time series coordination network OceanSITES. The European Sea Level network focused on the integration aspects with the global community with a dedicated workshop. Moreover, significant work was done on the data issues with a New Tide Gauge Data Flow Strategy (Deliverable 3.3), a first version of a metadata inventory for European tide gauges (EUTGN) being developed and active contribution to the Permanent Service for Mean Sea Level (PSMSL, NOC) portal. Finally, a detailed review of coastal sea level monitoring in the Mediterranean and Black Sea is under preparation. Regarding the HF Radar network, a workshop organised together with the FerryBox Vessel community has been particularly successful with wide participation, showing the growth of capacity and the advancements in terms of technology and science. Parallel to this the community has developed a Governance document in order to enhance the current potential of the European HFR systems and plan the future (Deliverable 3.4). Moreover, efforts also focused on data issues and on communications while two community papers have been completed. Considering that the Autonomous Surface Vehicles is a starting community, efforts were concentrated on the organisation of the first workshop and which brought together ASV operators, manufacturers, users, and wider stakeholder groups to discuss a range of issues (see D3.5 "ASV network structure and roadmap"). Several dissemination and communication activities were performed during events with large attendance, such as the Ocean Science Meeting 2022 etc.

Regarding Omics, activities focused on the development and testing of Standard Operating procedures in collaboration with EMOBON EMBRC observing network, a significant step towards harmonisation and integration. Activities towards Integrating science focused on Developing a Strategic European Vision of Ocean Integration with the publication of a position paper entitled “Ocean Integration: the needs and challenges of effective coordination within the ocean observing system” in line with the WP objectives a) improving integration and coordination of the various components of the European and Global observing systems and b) increasing data sharing and integration. The task 3.10 Interface with in situ data integrators improves connecting the observational networks with European data integrators, Copernicus Marine Service, EMODnet-Physics and Chemistry. T3.10 partners continued to support WP3 networks in their harmonisation activities to facilitate the dataflows to integrators – participation to meetings, contribution to documents etc. Finally, WP3.10 partners are developing a deliverable on Network Harmonisation recommendation, that will provide guidelines on the implementation of FAIR Principles by the different WP3 networks but also at EuroGOOS level with the Data Management, Exchange, and Quality Working Group (DATAMEQ WG).

Detailed progress per task (or subtasks)

Task 3.1: Argo

Task leader: Euro-Argo Eric, Partners: Ifremer, SU

In task 3.1 progress has been achieved on several aspects of the development of the Deep and BGC Argo components during this second period.

A procedure was set-up by an ad-hoc working group involving Eurosea partners to correct systematic fresh bias in high pressure salinity measurements of Deep-Argo floats. The procedure was endorsed by the Argo Data Management Team and implemented in the Argo data system, which will facilitate the use of Deep-Argo data by the community. In collaboration with the H2020 Euro-Argo-RISE project, new methods for BGC data QC were developed by European partners and agreed at international level. A proposition for the organisation of BGC Argo data management in Europe was shared with Euro-Argo Management Board. Different scenarios are presently being discussed: (i) Each team implement the recommended procedures and do DMQC on their own floats, (ii) a centralised entity perform DMQC for all floats and is funded by the EU Members, (iii) Intermediate situation where some institutes commit to perform DMQC for their national fleet plus some of the other European floats deployed in the same areas.

Euro-Argo partners were also involved in the OceanGliders best practice activities, including participation in the workshop held in May 2021 (see task 3.2) and to the writing of various documents, more particularly the Oxygen Standard Operating Procedures one. This involvement allowed cross-network discussions which benefited both networks and aim to be continued in the future.

Interviews for the OceanOps BGC-Argo project office position (2-year at first) to be hosted at SU (LOV-IMEV, Villefranche sur Mer) were conducted in 2021 and hosting agreements between IOC/UNESCO and Sorbonne Université are now in progress for the successful candidate to start in 2022.

One main achievement of this task 3.1 consisted in a Deep-Argo & a BGC-Argo workshops that were successfully organised in September/October 2021, as a virtual unique event, including a common session. The objectives of the BGC-Argo workshop were to review progress done in implementing best practices in the area of floats preparation, float deployment and data management; exchange with user community (e.g. biogeochemical modelers, ocean colour) to better understand their needs, develop synergies and to foster interaction with other components of the ocean observing system, including Deep-Argo. The objectives of the Deep-Argo workshop were to assess progress of the Deep-Argo mission (from scientific use of Deep-Argo data to technological ability of floats and sensors); to review end-users' needs and finalize the implementation plan of the global Deep-Argo array of 1250 floats. The implementation of oxygen sensors on Deep-Argo floats was also addressed: scientific motivation, required accuracy and stability, and oxygen sensor readiness and cost. This last question was addressed during the joint BGC/Deep-Argo session, also dedicated to interactions between Argo (Deep and BGC) and other networks and observing programs (DOOS, GO-SHIP, Oceansites, Gliders). The workshop attracted a large international community, with up to more than 150 participants in some of the 5 sessions. Workshops material and a report can be found on the Euro-Argo website[12].

Task 3.2: Underwater Gliders

Task leader: CNRS, Partners: WMO

The European and global glider community achieved major accomplishments in this reporting period related to the development of best practices and data format harmonisation as a joint effort of EuroSea WP3.2 together with the EuroGOOS Glider Task Team and H2020 GROOM II. The first OceanGliders best practice workshop held in May 2021 in a global context. It has been very effective and also sparked many activities on delayed mode data management within the OceanGliders Community. Initially this expert workshop was planned to occur in person with maximum 30 experts but due to COVID has been organised in virtual mode

[12] https://www.euro-argo.eu/News-Meetings/Meetings/Others/BGC-Deep-Argo-Workshop

over a period of 14 days with 150 participants. Overall this kick-off workshop was a big success and had much more concrete written outcome compared to a typical 1-2 day synchronous in-person workshop. The overall feedback by the participants was very positive and many new connections have been made.

After the workshop participants continued to write various documents i.e. one overview paper entitled: “Towards OceanGliders Best Practices” led by P. Testor and various Standard Operating Procedures (Salinity, Oxygen, Nitrate and Depth Average Currents). The overview paper is planned to be submitted to Frontiers throughout mid 2022.

In September 2021 OceanGliders moved to GitHub[13]. The online community attracted 107 members. Various GitHub training sessions have been provided to the OceanGliders Community members to support the new asynchronous working mode on GitHub, which reduces the requirement for synchronous meetings. Four SOPs have been moved online now for community review. The Oxygen SOP[14] is most advanced and in preparation of version 1.0 to be submitted to the OBPS repository. All SOPs will be submitted to the OBPS after an open community on GitHub. The new OceanGliders Format 1.0 has been agreed on and can be accessed here[15].

A data management workshop is planned and being organized for the end of June-early July 2022 to further improve the data management within Europe. This workshop will be co-organised between EuroSea, GROOM II and EuroGOOS Glider TT.

Task 3.3: Vessels

Task leader: NIVA, Partners: WMO

A metadata format for ship-of-opportunity platforms, fit for purpose for e.g. weather stations, XBT launchers, Continuous Plankton Recorder (CPR), underway/flow-through devices for S/T/pCO2 and more complex FerryBox-like systems has been finalised and implemented by OceanOPS (former JCOMMOPS); weather station metadata from the older WMO Pub47 are mapped into this new format and the full fleet of Voluntary Observing Ships has been migrated. Basic metadata for all known operational XBT systems is regularly updated in OceanOPS, metadata submission and monitoring for other underway systems has started with a first set of thermosalinograph systems. All ship-of-opportunity platforms are allocated with a truly unique identifier (SOT-ID) when they enter the system and operators have started to use this ID in data submissions and phase out former identifier schemes (including mask scheme), which now enables facilitated end-to-end data tracking from data producers to data users. The FerryBox community has joined the broader ship-of-opportunity Implementation Panel (SOOPIP) and the FerryBox Task Team chair reported about task-team activities at the last SOOPIP meeting, harmonization between the groups is thus underway.

A similar approach has been launched for research cruises, where a data flow analysis (attempt) showed the difficulties to track and find data. Producers, different data centres and data users have no appropriate FAIR protocols in place and a working group has thus started to develop a protocol with a truly unique identifier (allocated by OceanOPS, similar to floats and drifters in the earliest planning stages) that should follow a research cruise and its emerging data over the full lifecycle.

[13] https://github.com/OceanGlidersCommunity
[14] https://oceangliderscommunity.github.io/Oxygen_SOP/README.html
[15] https://github.com/OceanGlidersCommunity/OG-format-user-manual

With support from the International Research Ship Operators (IRSO), a pilot project with the developers and users of the “Marine Facility Planning (MFP)” tool now allows to exchange cruise metadata between ship operators who use this now broadly implemented software and the OceanOPS system. After a successful pilot it is planned to roll this out broader and thus allow for machine-to-machine exchange of cruise metadata. Management of common vocabularies and integration of the new proposed identifier for RV cruises will be next targets.

Discussions with key shipping companies like Maersk, CMA-CGM or Brittany Ferries have permitted to set up new data streams with instruments and telecommunication systems owned and operated by the ship operators themselves, for their own requirements. Data from 300 “third party ships” now flow to the German weather service DWD in a pilot project, and from the DWD is further transmitted to the Global Telecommunication system (GTS). A SWOT analysis along data coverage, quantity, quality, availability etc will follow to find out if such data streams are of value and for which applications before the pilot could be rolled out broader and potentially multiply the number of contributing ships. The new SOT ID scheme and metadata format are also already implemented for these stations. The activity is linked with the UN Ocean Decade project Odyssey.

Partners in Task 3.3 held a joint FerryBox-HF Radar workshop together with Task 3.6 (HF Radars) and a follow-up EuroSea Task 3.3-focused workshop in March 2021. The FerryBox workshop was attended by over 100 participants across Europe and elsewhere. The FerryBox workshop consisted of 21 oral presentations related to new observing technologies, research findings, and data/modelling-related activities. The EuroSea Task 3.3-focused workshop included ten participants from partners from EuroSea WP1 and WP3, as well as EuroGOOS FerryBox Task Team participants. The workshop was focused on harmonization and integration of vessel-based observing within the EuroSea framework. Further work will be carried out through follow-up workshops and meetings.

The workshop brought together the FerryBox and HF Radar EuroSea and wider European communities together and in parallel, and also included SME and policy organizations together with the research community. The next steps will be to progress with development and harmonization activities at a follow up FerryBox Task Team/EuroSea workshop in late 2022 and also a WP3 workshop event within the framework of an upcoming EuroSea General Assembly.

Task 3.4: Eulerian Observations

Task leader: SU, Partners: EMSO-Eric, WMO

The Eulerian observations community (comprising the OceanSites, EMSO ERIC, DBCP and WMO communities) held the first virtual meeting on March 8-9, 2021. Its purpose was to assess the need and status of best practices (BP) for ocean operations related to Eulerian observatories coordinated by global and European consortia (OceanSITES, DBCP, ERIC EMSO). The meeting also addressed metadata aspects for these observatories, such as minimum metadata requirements, vocabularies, and adoption of metadata. At the end of the meeting an internal milestone report was produced. The discussions revealed that a possible approach would be BP based on «variables», and thus following successful approaches from other networks and global observational programs (e.g. task 3.2 Underwater Glider). The variables-oriented BP would also include recommendations on the use of metadata vocabularies relevant for the variable and its processing, and the aspects of data dissemination. Best Practices will detail the approaches to determine uncertainties as a consequence on how the data conversion was done and what measures have been taken to calibrate the equipment. For the metadata catalogue, multidisciplinary observational networks have to serve data of great complexity and eventually a very large volume of data. For EMSO ERIC there was an agreement to use the same metadata adopted by OceanSITES (namely the CF Standard) but with some additional metadata based on the various SeaVOX vocabularies (SeaDataNet and BODC). The meeting also mentioned the importance of using OceanOPS to retrieve metadata from the global observational networks in order to provide an integrated and global overview of observational activities. A second meeting to progress on common Best Practices and metadata catalogue upgrade is planned at the end of March 2022.

As part of T3.4, a new pH sensor was acquired by SU in the summer of 2021 and tested in the lab in the fall of 2021. A sensor already approved by the Argo community was chosen that could/should equip several sites interested in monitoring the carbonate system and acidification (SEAPHOX from Seabird). It combines a SeaFet and a SBE37-ODO sensor to measure P, T, S and O2 simultaneously with pH. After 2 weeks of testing and validation in the Villefranche laboratory, the SEAPHOX sensor was deployed on the DYFAMED site at 3m depth (Ligurian Sea). Due to the delay in the delivery of the sensor, it was decided to postpone the D3.6 to April 2022 in order to acquire sufficient data and to make an inter-comparison with the samples obtained during the monthly ship visits at the DYFAMED site.

Finally, a large part of this community joined the new Fixed Platforms task team from EUROGOOS led by G.Magnifico (CNR), Paolo Favali (EMSO) and A.Berry (IE). In 2021, two virtual meetings of this new group have taken place.

Task 3.5: European Sea Level Network

Task leader: EPPE, Partners: NOC, CNRS, MI

During this reporting period the European Sea Level Network has progressed on the following actions, related to the proposal milestones and deliverables for this task:

- The First EuroSea Tide Gauge Network workshop was held virtually on 12-14 January 2021. This first workshop aimed to bring together the global tide gauge community to share experiences, exchange information on recent activities and discuss ways to overcome the challenges across different geographical regions, while ensuring an effective coordination and communication with the Global Sea Level Observing System (GLOSS). The following topics were covered: national experiences from Europe and beyond, new sea level technologies, data flow, GNSS co-location of tide gauges, influence of waves, infragravity waves and meteotsunamis on extreme sea level records, and impact of COVID-19 on the sea level network.
- Deliverable 3.3: A New Tide Gauge Data Flow Strategy[16] report was produced, led by EPPE, with contributions from the sea level community (EuroGOOS Tide Gauge Task Team and GLOSS) and representatives of different data aggregators dealing with tide gauge data (e.g.: GLOSS data portals, EMODnet, Copernicus Marine Service, SeaDataNet and Tsunami Warning Systems). These data are distributed with different time samplings, formats, latency or quality control, targeting different applications. The review showed a preliminary analysis of up to 13 data portals or catalogues, and allowed to identify several shortcomings to be addressed by the global community, such as the lack of an agreement on minimum mandatory metadata with common vocabulary and definition; and ii) the lack of unique and persistent identifiers. This report also provides some recommendations and short-term action lines for the European network.

[16] https://eurosea.eu/download/eurosea_d3-3_new_tide_gauge_data_flow_strategy_revised/?wpdmdl=4176&refresh=62383c104f98d1647852560

- The Irish Marine Institute produced the first version of a metadata inventory for European tide gauges (EUTGN) during the fall of 2021, available at: Tide gauge metadata inventory[17].
- The Permanent Service for Mean Sea Level (PSMSL, NOC) have launched a portal of sea level data obtained using the novel measurement technique of Global Navigation Satellite System-Interferometric Reflectometry (GNSS-IR) (New GNSS-IR data portal[18]), where sea level height can be inferred from the signal-to-noise ratio of conventional GNSS receivers installed to monitor land motion. The portal (still under active development[19]), includes up to 245 sites and is developed as part of Deliverable 3.3. Documentation for the site is still being written, including information on how site metadata can be harvested. PSMSL will continue to work with EuroGOOS, GLOSS, the International GNSS Service (IGS), and sites that aggregate GNSS data to improve the interoperability of the portal.
- SONEL (CNRS) has continued to explore the status of existing data portals with tide gauge data. For that, it has developed an automatic code to compare the contents for the main data portals in terms of gaps and duplicates. Preliminary results were presented during the last meeting of the EuroGOOS Tide Gauge Task Team in July 2021, showing interesting issues and the importance of this exercise and cooperation. In order to make this tool available for the Tide Gauge community a web version has been developed in 2022 and will be released online soon. This online tool allows the user to inter-compare the content of the main data or metadata portals, which will help to identify gaps in portals or to find geographical coordinates errors and should help to unify the station names. These tools should be useful in the process of unifying the portals in terms of metadata and go towards a new unique ID.

In addition to the abovementioned activities, 44 authors representing the sea level community in the Mediterranean and Black Seas have been working on a review paper[20] of coastal sea level monitoring in these two basins (under review). A detailed inventory of existing in-situ sea level measurements mainly based on tide gauges, and data availability in existing data portals is presented, together with a fit-for-purpose status of the existing network, composed at this moment by at least 236 operational stations.

The sea level community has also contributed to Copernicus Marine Service OSR#6 through the following publication: "Western Mediterranean record-breaking storm Gloria: an integrated assessment based on models and observations" (Section 3.1), where tide gauge data with different time sampling intervals are analysed and compared with operational models during this extreme event.

Task 3.6: HF Radar

Task leader: AZTI, Partners: CNR, SOCIB, EPPE

As planned as an internal milestone (iMS9), the first EuroGOOS HF Radar Workshop has been held. This online event, jointly organised with the Ferrybox (FB) community, took place on 17-18 March 2021. FB and HFR communities joined the welcome and closing sessions (with almost 145 attendees), while specific sessions for each platform were carried out in parallel. During the first day of the HFR session, pre-recorded 3-min presentations showed: i) the enlarging of some HFR networks (e.g. Malta, Tuscany region); ii) new

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[17] http://eutgn.marine.ie/geonetwork/srv/spa/catalog.search#/home
[18] https://eurosea.eu/new/a-global-sea-level-data-portal-using-global-navigation-satellite-system-interferometric-reflectometry/
[19] https://psmsl.org/data/gnssir/index.php
[20] https://os.copernicus.org/preprints/os-2021-125/

installations (HFR in the NW of the Iberian Peninsula; an X-Band radar in the Bay of Biscay, a LERA HFR in the South-West of France) and re-installations (Vigo, Cíes Islands); iii) new research outcomes (use of DIVAnd for HFR gap-filling, HFR waves and currents characterization under extreme events); emerging products (waves mapping, upwelling index) and promising projects (i-waveNet); iv) latest upgrades in technology (e.g new software upgrades for direction finding and phase array). During the second day, the progress on the different actions of the EuroGOOS HFR Task Team were presented by the task leaders:

1) Management and community building: TEAMS environment for meetings, sharing documentation and monitoring the workplan, projects mapping and roadmap development, biannual newsletter (#1[21], #2[22]), quarterly progress meetings.
2) Sustainability: stakeholders engagement strategy (> 140 stakeholders identified[23]), endorsement for supporting HFR operators; new opportunities for joint proposals (common competence matrix[24]).
3) Products & services: HFR data gap filling and waves data – need of consensus on the methodology, on the QC tests to be applied and on the definition of the common data & metadata standard model.
4) Research & development: creation of a community-built inventory in Zotero (ZOTERO Community Library[25]) with more than 200 items on HFR and ongoing joint contributions.

Additionally, the main actions of the European HF Radar node were presented: in terms of NRT and REP data management and the next steps to harmonise HFR sites outage reporting. Finally, an interactive session was proposed to all the participants allowing to receive feedback on the ongoing actions and initiatives of the HFR Task Team.

A second main achievement obtained during the current period deals with the governance of the European HF Radar community. A robust and sustained European HFR network governance structure has been designed, considering the global, European and regional landscape of ocean observational networks, built from elements that are already and partially in place and based on the requirements of the HFR community. The proposed governance will enhance the current potential of the European HFR systems and plan the future by: i) enabling broad international collaboration (OceanOPS, GOOS, Global HFR network); ii) fostering the integration with the different marine data aggregators; iii) promoting the development, sharing and usage of best practices from the Ocean Best Practices repository; iv) achieving more impact and gain visibility; v) boosting stakeholder engagement enhancing the current potential of the European systems and planning the future. The full results are described in Deliverable 3.4 - HFR Governance[26].

In order to support the improvement of centralised delayed-mode products coordinated by the European HFR Node, new tools have been developed for improving processing capacities and generating semi-automatic reporting outputs which integrate the interaction between the Node and the local operators responsible for the Data Quality of their systems.

[21] https://us19.campaign-archive.com/?e=%5bUNIQID%5d&u=e5fd08d8d94228eecb45183f9&id=be9a4c36a1
[22] https://us19.campaign-archive.com/?e=__test_email__&u=e5fd08d8d94228eecb45183f9&id=6732a36464
[23] https://docs.google.com/spreadsheets/d/1jos285znDsBVNSwvO6S6cOnwi2bFgqb0QWLXvmkY4fc/edit#gid=375481219
[24] https://docs.google.com/forms/d/e/1FAIpQLScRXHZUi0QoE8nnvJuhyX2p0qgi5bzV-BUrqdwbfJOT16zXuA/viewform
[25] https://www.zotero.org/groups/2601948/eurogoos_hfradar_taskteam
[26] https://doi.org/10.3289/eurosea_d3.4

In order to support the improvement of centralised near real time data production coordinated by the European HFR Node, the node's software and hardware architecture for NRT data processing has been renewed and optimised.

Efforts on communication have been continued with 3 new EuroGOOS HF radar community newsletters "Taking the pulse of the coastal ocean": February 2021[27], July 2021[28], February 2022[29].

A contribution has been achieved in OSR#6 (section 3.1 "Western Mediterranean record-breaking storm Gloria: an integrated assessment based on models and observations"), and a work started for achieving another one in OSR#7 (section 2.9, "Monitoring coastal upwelling in the NW Iberian Peninsula with HF radar-derived observations") to describe the validation and implementation of the newly developed coastal upwelling index based on HFR observations in different pilot areas.

Two joint community papers have also been promoted in November 2021 from the Mediterranean community involving 42 co-authors from 7 countries of the Mediterranean HFR network (Part 1[30] [submitted], Part 2[31] [under review]). The Part 1 showcases the current status of the Mediterranean HFR network, providing a detailed overview of: i) the main achievements and ongoing activities; ii) the alignment with diverse multi-institutional initiatives and alliances at regional, European and global level; iii) the roadmap towards an integrated and mature HFR network operated permanently in the Mediterranean Sea. In addition, future prospects addressing economic, technical and scientific aspects are defined. The Part 2 reviews the existing advanced and emerging scientific and societal applications using HFR data, developed to address the major challenges identified in the Mediterranean coastal waters, organized around three main topics: i) maritime safety; ii) extreme hazards and iii) environmental transport processes. It also includes the discussion and a preliminary assessment of the capabilities of the existing HFR applications and provides a set of recommendations towards setting out future prospects.

Task 3.7: Autonomous Surface Vehicles

Task leader: PLOCAN, Partners: UBREMEN, UPORTO, NOC

PLOCAN, together with its partners in task 3.7 "Autonomous Surface Vehicles", held (virtual) the workshop on the Autonomous Surface Vehicle (ASV). This workshop was organised in non-face-to-face format on October 5th and 6th, 2021. This event was joined by around 100 participants, including the main ASV manufacturers, renowned operators, users and stakeholders from different marine and maritime sectors. The first day focused on state-of-the art technology and applications. The second day, the sessions were addressed to the regulatory framework and use-protocols harmonisation (i.e., mission planning, piloting, best practices and data management). During The workshop, there was also time for open discussions where questions about the benefits to EOOS of creating an ASV network, as well as questions addressed to the implementation of good practices in the use of these vehicles through the establishment of Standard Operating Procedures (SOP).

Deliverable 3.5 entitled "ASV network structure and roadmap" was finally delivered in November 2021. The delay in the delivering was caused by the impediment of holding the workshop in person because of the

[27] https://us19.campaign-archive.com/?e=__test_email__&u=e5fd08d8d94228eecb45183f9&id=6732a36464
[28] https://us19.campaign-archive.com/?e=__test_email__&u=e5fd08d8d94228eecb45183f9&id=1de066b71f
[29] https://us19.campaign-archive.com/?e=%5bUNIQID%5d&u=e5fd08d8d94228eecb45183f9&id=337d9857fd
[30] https://os.copernicus.org/preprints/os-2021-119/
[31] https://os.copernicus.org/preprints/os-2021-115/

existing pandemic situation. Finally, the workshop had to be held in a non-face-to-face format, relatively limiting the presence of some important actors in these technologies. The deliverable contains the main aspects of why it is important to include these new ASV technologies as contributors to EOOS strategy, why it is important to organise the ASV community members as a Network and what is the roadmap to achieve it. The deliverable also analyses the outcomes of ASV workshop and details the future specific actions to carry out during the remaining time of the project in what refers to task 3.7.

Recently PLOCAN, in partnership with the Center for Marine Environmental Sciences (MARUM[32]) of the University of Bremen, the National Oceanic and Atmospheric Administration (NOAA[33]) of the United States, the Laboratory of Technology and Underwater Systems (LSTS/FEUP[34]) of Porto University, the SCRIPPS Research Institute[35] and the National Oceanography Center (NOC[36]) in United Kingdom, has conducted the coordination leadership of a scientific-technical session on uncrewed surface vehicles (USV) technology. The session has been conducted in support to the Ocean Decade[37] within the framework of the Ocean Sciences Meeting 2022[38], which took place in virtual format from 24th February to 4th March 2022, under coordination and support by the American Geophysical Union (AGU[39]), the Association for the Sciences of Limnology and Oceanography (ASLO[40]), The Oceanography Society (TOS[41]) and the Oceanic Engineering Society (OES[42]). The session was labelled as OT05 "Uncrewed Surface Vehicles (USVs). Technology Trends and Improvements on Observing Applications for the Ocean Decade", and with the main goal to engage leading actors representing developers, industry, research, end-users and regulatory bodies to provide an overview on current trends in USV technology, while seeking a baseline understanding of the sector from lessons learned at technical, operational, data management and policy/regulatory levels.

In addition to coordination, PLOCAN's contribution to OT05 session with the oral presentation "Uncrewed Surface Vehicles (USV) Network Initiative in support to EOOS", that attempts to establish the bases for a recognized international network of developers and users related to USV technologies in support of the Global Ocean Observing System (GOOS[43]) strategy and hence, its European component, the European Ocean Observing System (EOOS[44]). This action is framed as part of the EU-project EuroSea activities, where PLOCAN, MARUM, LSTS/FEUP and NOC are joining as consortium members.

Another dissemination activity of task 3.7 has been the oral presentation "Unmanned Surface Vehicles Technology in support to EOOS" conducted at Oceanology International 2022 in London on March 15th, at the thematic session on ASV Technology Developments. Currently, partners are working on the settings for

32 https://www.marum.de/index.html
33 https://www.noaa.gov/
34 https://lsts.fe.up.pt/
35 https://www.scripps.edu/
36 https://noc.ac.uk/
37 https://www.oceandecade.org/
38 https://www.aslo.org/osm2022/
39 https://www.agu.org/
40 https://www.aslo.org/
41 https://tos.org/
42 https://ieeeoes.org/
43 https://www.goosocean.org/
44 https://www.eoos-ocean.eu/

the second WS event, based on the outcomes from previous activities conducted, where an on-site demonstration from a leading ASV technology is being considered as part of the agenda activities.

Task 3.8: Augmented Observatories
Task leader: SZN, Partner: AWI

Regarding the development and testing of omics standard operating procedures (SOPs) at a LTER, a first implementation has been completed at the NEREA Augmented Observatory[45] in the Gulf of Naples. The SOPs procedures have also been added to the Observatory website for favouring their dissemination. The 12-month sampling has been completed and samples are currently at the sequencing centre for the extraction, sequencing and for bioinformatic analyses. Data will be publicly disseminated when ready. The work has been done in coordination with the EMOBON EMBRC observing network. An application for an endorsement by the UN decade of Ocean Sciences has been submitted and it is currently in revision. The observatory is already one of the showcase activities of the OBON UN Decade working group.

Task 3.9: Integrating science
Task leader: SOCIB, Partners: CSIC, AZTI

During this reporting period, we focused on Developing a Strategic European Vision of Ocean Integration (subtask 3.9.1). A major result has been achieved, with the publication in Frontiers in Marine Science of the position paper entitled "Ocean Integration: the needs and challenges of effective coordination within the ocean observing system"[46]. The paper was submitted for publication on 7 July 2021, and was accepted on 13 December 2021 and published on 25 January 2022. The article is a collective reflection on how to reach a truly integrated ocean observing system by 2030. 40 co-authors support the initiative, including WP3 task leaders and other EuroSea members, as well as key GOOS players.

Following an extensive investigation of the issue, it appears that ocean integration is a very complex challenge that goes far beyond the traditional scientific and technological perspective. Reaching high-level integration requires transcending the well-established silos of expertise, which is not a simple task, since it implies a new way of doing business, with major shifts in the organisation, the management and the culture of ocean science. As stated in the paper, "To advance toward a more integrated approach in ocean science, we may (...) need to change the status quo and rethink some parts of our ocean science system". This position paper suggests nine approaches for breaking down the silos and promoting better coordination and sharing. This paper is a first step aimed at opening the way toward further dialogue between all parties involved in the concrete actions to undertake. The objectives are now to 1) present the work in key meetings/workshops (such as the EuroSea General Assembly) in order to disseminate the vision, explain the process that led to our conclusions, receive feedback and new ideas, and discuss the concrete actions to undertake, and 2) identify and reach out to key players that could implement a change through specific actions.

This work directly contributes to several key EuroSea objectives, in particular 1) improving integration and coordination of the various components of the European and Global observing systems, and 2) increasing data sharing and integration. It also contributes to foster innovation, with the development of a new vision of ocean integration, more really focused on the organisational, cultural, and management levels.

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[45] www.nerea-observatory.org
[46] https://www.frontiersin.org/articles/10.3389/fmars.2021.737671/full

Task 3.10: Interface with In Situ data integrators

Task leader: IFREMER, Partners: ETT, OGS

The goal of task 3.10 is to connect the WP3 networks with the existing in situ data integrators that are Copernicus Marine Service, EMODnet-Physics and Chemistry. Based on the Data Management Plan (deliverable D3.1) that was issued in the first reporting period, WP3.10 partners continued to support WP3 networks in their harmonisation activities to facilitate the dataflows to the Copernicus Marine and EMODnet services by participating to the task meetings or contributing to the document elaborated by those groups when FAIR principles implementation aspects were addressed. Following the work done in the first period, in partnership with the Sea Level task (WP3.5) and EuroGOOS Sea Level Task Team a work plan has been developed with Copernicus Marine to integrate in the 2022-2024 In Situ Thematic Centre contract the development of a reprocessed Sea Level product targeted for Ocean Monitoring validation in close link with EuroGOOS Task Team and GLOSS that will also enhance the products available through EMODnet-Physics portal. Similarly, improvement in the HF RADAR data flow and processing has been identified with Task 3.6 partners and are now included in the new Copernicus Marine to integrate in the 2022-2024 In Situ Thematic Centre contract. Integration of European Eulerian data managed by EMSO-ERIC as well as carbon data managed by ICOS-ERIC will be facilitated thanks to the activity carried on within the ENVRI-FAIR H2020 project where a data broker, using common SeaDataNet NVS vocabulary service allows to query the 3 data system and provide the data to Copernicus Marine and EMODnet service.

WP3.10 partners have been working with the WP3.9 partners contributing to the “Strategic European Vision of Ocean Integration“ for the Data Management and Delivery aspects and to the publication in Frontiers in Marine Science of the position paper entitled “Ocean Integration: the needs and challenges of effective coordination within the ocean observing system”.

Finally, WP3.10 partners are developing a deliverable on Network Harmonisation recommendation, that will provide guidelines on the implementation of FAIR Principles by the different WP3 networks but also at EuroGOOS level with the DATAMEQ working group. The development of such deliverables will also benefit from the outcome of the Ocean Data Conference[47] that was held in February 2022 in SOPOT where the European strategy for "Enhancing Fair in situ Data delivery"[48] was presented by S Pouliquen. This deliverable will be developed in collaboration with WP1 (Task 1.5 Gap analysis of European Ocean Observing System) for the gaps related to data management activities. This deliverable is delayed to July 2022 due to a lack of skilled manpower available in the different institutes that is presently solved with new persons involved.

Cooperation and interaction with other EuroSea WPs

Co-operator	WP activities
WP1	• Co-organisation of OceanGliders Best Practice Workshop in May 2021
WP4	• Joint workshop with CMCC, SOCIB, Task 4.2, Task 4.3, Task 4.4 partners on sharing best practices on how to use novel sensors (glider, floats) data for assimilation and validation in the CMEMS (global and MED) and SOCIB operational systems (physical and biogeochemical), 24. June 2021 (virtual)

[47] https://oceandataconference.org/programme/
[48] https://www.youtube.com/watch?v=OnaKsxgc0bM

Cooperation and interaction with other projects and initiatives

Co-operator	WP activities
OceanGliders, EuroGOOS Glider TT, and H2020 GROOM II	• Co-organisation of OceanGliders Best Practice Workshop in May 2021 • Co-organisation of a European Glider data management meeting in June-July 2022 together with EuroGOOS Glider Task Team, H2020 GROOM II, OceanOPS
JERICO-RI, EMODnet	• Co-organisation of the 2021 FerryBox and High-Frequency Radar online workshops, 17-18 March 2021
EuroGOOS HFR TT	• Publication of the EuroGOOS HFR Task Team newsletters "Taking the pulse to the coastal ocean"
Copernicus Marine Service	• Contribution to the Ocean State Reports using HFR data products from In Situ TAC • Provision of HFR NRT data for Near real time in-situ observations of surface ocean currents (drifters and HFR) for the Global Ocean[49] • Provision of HFR REP data for the Delayed Mode in-situ Observations of surface (drifters and HFR) and sub-surface (vessel-mounted ADCPs) ocean currents for the Global Ocean[50] • Development of a plan for a Reprocessed Sea Level product in support to reanalysis activities
EuroGOOS Fixed Platform TT	• Two meetings organised by the Fixed Platforms Task Team from EUROGOOS in 2021
EuroGOOS DATAMEQ WG	• Meeting planned on the 28th March 2022
EuroGOOS FerryBox Task Team	• Workshop organised in March 2021
EuroGOOS Tide Gauge Task Team	• One meeting held by the EuroGOOS Tide Gauge Task Team on June 30th, 2021. Election of new co-chairs (Elizabeth Bradshwaw and Angela Hibert from NOC, and Claire Fraboul from SHOM).
H2020 JERICO-S3	• Workshop organised in March 2021
H2020 NAUTILOS	• Workshop organised in September 2021
ENVRI-FAIR	• Collaboration of FAIR principles implementation. Benefit from the development made in ENVRI-FAIR Marine domain WP that were presented of the Ocean Data Conference
OceanGliders, DOOS, OceanSITES, GOSHIP	• Session in the Deep & BGC Argo workshops organised in September/October 2021 dedicated to discussions on ways to better collaborate between networks.

[49] https://resources.marine.copernicus.eu/product-detail/INSITU_GLO_UV_NRT_OBSERVATIONS_013_048/INFORMATION
[50] https://resources.marine.copernicus.eu/product-detail/INSITU_GLO_UV_L2_REP_OBSERVATIONS_013_044/INFORMATION

Achieved main results

Deliverables		
D3.3	New tide gauge data flow strategy	✓
D3.4	HF-Radar Governance	✓
D3.5	ASV-Network structure and roadmap	✓
D3.6	Sensor implementation on Eulerian Obs.	✓
Internal Milestones		
iMS9	HF-Radar 1stWorkshop	✓
iMS13	Omics Augmentation 1st Workshop	✓
iMS14	Gliders workshop on “best practices”	✓
iMS15	FerryBox workshop	✓
iMS16	Eulerian 1stWorkshop	✓
iMS17	Tide Gauge 1stWorkshop	✓
iMS19	ASV 1st workshop	✓
iMS27	Euro-Argo BGC workshop	✓
iMS33	Euro-Argo DEEP workshop	✓
iMS34	Workshop on “delayed mode data management”	✓

WP4 - Data integration, Assimilation, and Forecasting

Lead: MOI, CO-lead: UNIBO

Objectives
• Ensure that new or consolidated *in situ* observation data sets from the different networks (WP3) and from the WP5, 6, 7 demonstrator activities are integrated in the European modelling and forecasting systems at different space and time scales, from the Copernicus Marine Service global to the regional North East Atlantic and Mediterranean Sea systems
• Implement ensemble forecasting at regional level to extract Extreme Forecast Indices (EFI) to connect with WP5 and WP6
• Assess the skill of ocean variables from the Copernicus Climate Change seasonal forecasting systems using observable ECVs to develop and provide user-relevant indicators in WP2 and WP7
• Integrate all new products, observational and model data, in the Copernicus Marine Environment Monitoring Service and the Copernicus Climate Change System (C3S) thus reaching TRL7 and 8

Summary of progress towards WP objectives

WP4 will improve the integration of in situ observation data sets from the different WP3 networks and from the WP5, 6, 7 demonstrator activities in the Copernicus Marine Service modelling and forecasting systems (tasks 4.1 and 4.2). New ensemble forecasting capabilities are developed and tested at regional level (task 4.3). In situ observations are also used to improve satellite Cal/Val activities (task 4.4) and to develop ship-based time series pilot products and produce new carbon synthesis products (task 4.5). Finally, the skill of ocean variables from the Copernicus Climate Change seasonal forecasting systems has been assessed from observations (task 4.6). All tasks are on track as detailed in the next sections.

Detailed progress per task (or subtasks)

Task 4.1: Assimilation in the global and North East Atlantic (IBI) Copernicus Marine modelling system and analysis/forecast quality assessment

Task leader: MOI, Partners: EPPE

During the last period, we compared the Copernicus Marine global 1/12° system analyses to mooring observations to refine the assimilation efficiency in the tropical oceans. A wide range of processes with signature at different frequency are seen in the mooring observations, including high frequency signals not represented in the model equations. In addition, the spatial resolution of the mooring array makes part of the observed signal between the mooring location uncorrelated, preventing finding a model correction for those scale. A strategy will be to filter the high frequency of the mooring observations prior to their assimilation. A spectral analysis was done between mooring observations and the long-term reanalysis simulation done with the 1/12° global physical system. It highlighted the benefit of the assimilation compared to a free simulation. It also shows the difference in spectral content at high frequency between the mooring and system analysis. This will help to define the observation filtering characteristics and the model covariance error in the tropics.

On the shelf regions, the impact assessment of physical observing systems will focus on gliders. Gliders are the only platforms providing high resolution observations of the water column on coastal and shelf environment. Those platforms can also be used to regularly monitor key region/frontal zone in an operational context. The glider data available in the CMEMS Coriolis database on the IBI domain were documented. Common experiment in the Western Mediterranean was also discussed with members of task 4.2. This will allow us to analyse how different systems ingest and benefit from the assimilation of glider data. The regional IBI system at 1/36° that will be used for the experiments is currently implemented. The impact of glider data assimilation will be studied also in the Atlantic part of the domain.

To improve the Copernicus Marine BGC global system, BGC Argo observations were used to optimize the PISCES model parameters in its 1D-version. This was done using observations along the trajectory of a specific float in the North Atlantic and an ensemble-based approach. The optimized 1D model gives better results than the actual 3D model compared to NO3 observations along the float trajectory (Figure 1). This procedure will be generalized to other regions using different Argo floats to estimate model parameters in different ocean regions and apply them to the full 3D PISCES model. (Gasparin et al. 2020, Mignot et al. 2022)

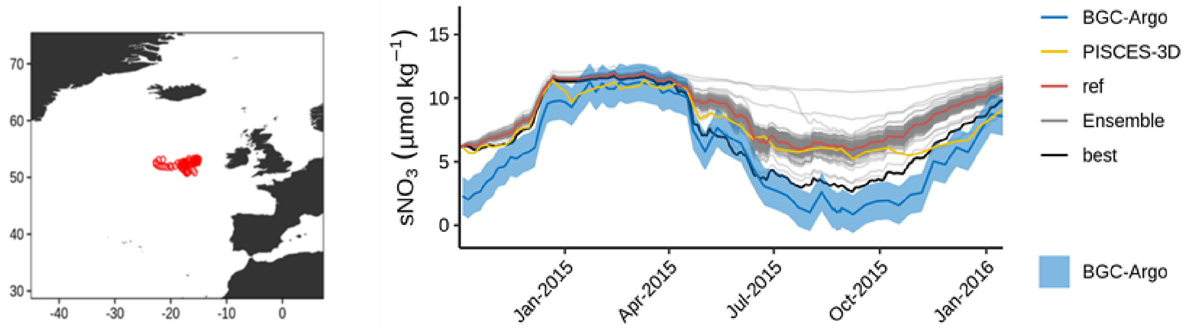


Figure 1. NO3, derived from the BGC-Argo floats observations (blue) and from PISCES-3D (yellow), PISCES-1D (red) and the ensemble (grey).

Task 4.2: Assimilation in the Mediterranean Sea Copernicus Marine modelling system and analysis/forecast quality assessment

Task leader: CMCC, Partners: OGS, SOCIB

The task 4.2 team proceeded to design and perform the experiments to assess the direct impact of the assimilation of the glider profiles in the Copernicus Marine MED-MFC PHY and SOCIB WMOP systems and impact on the Copernicus Marine MED-MFC BIO system due to the ocean physical forcing. Following the workshop organised in June 2021 as IMS28 to address the data gaps in the Copernicus Marine repositories for the glider observations and the investigation in Deliverable 4.2, the historical monthly dataset provided by the Copernicus Marine INS-TAC is frozen in a separate data space and shared among the partners. This dataset will be assimilated in both MED-PHY and WMOP systems for the intercomparison addressing the deliverable 4.9 for the intercomparison. Figure 2 shows the distribution of the measurement between the 200-400 m depth in March (left) and April (right) 2017.

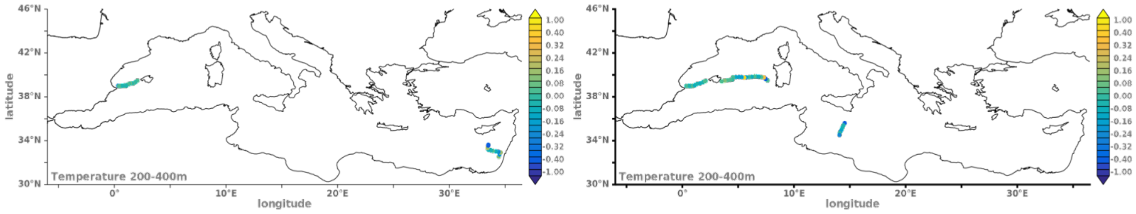


Figure 2. Distribution of the glider observations in March (left) and April (right) 2017.

The MED-PHY system is experimenting to investigate different subsampling strategies, the best of which will eventually provide the physical forcing to the MED-BIO system (Table 1). In, a list of experiments performed is given and the time evolution of the errors are shown in Figure 3. A control experiment (ALL_MED_CTL_00; black in Figure 3) without the assimilation of glider observations is performed (we refer to the D4.2 for the status of the Task 4.2 systems). In ALL_MED_GLD_00 (red in Figure 3), only the last ascending profile of the assimilation cycle is assimilated. Finally, in ALL_MED_GLD_04 (blue in Figure 3). The RMS of the misfits and number of observations assimilated are shown in Figure WP4/3 for the 45-135 m layer (left) and 200-400m (right).

Table 1. List of experiments performed to compare the impact of the glider assimilation in the entire Mediterranean Sea for the CMEMS MED-MFC PHY system.

Experiment	Glider assimilation	Subsamling
ALL_MED_CTL_00	X	-
ALL_MED_GLD_01	✓	last ascending profile of the day for each mission
ALL_MED_GLD_04	✓	all good quality ascending profiles

The increased number of observations are evident when assimilating all the ascending profiles in the assimilation cycle. In relatively deeper layers (e.g., 200-400 m), there is an improvement in terms of RMS of temperature misfits, while there are layers in which the skill does not change significantly (e.g., 45-135 m). Further investigations and experiments are ongoing to better understand the losses and gains due to the chosen subsampling strategy. The best solution identified will provide the ocean forcing for the MED-BIO system to further assess the impact of glider assimilation but on biogeochemistry (D4.10).

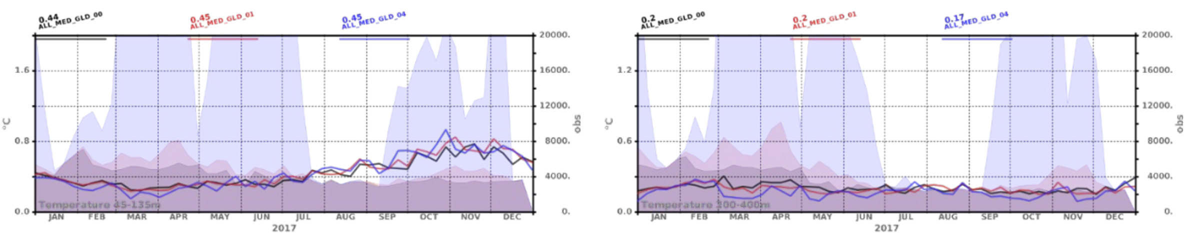


Figure 3. Time series of the RMS of temperature misfits for the layers 45-135 m (left) and 200-400 m (right). The black, red and blue curves show the experiments ALL_MED_CTL_00, ALL_MED_GLD_01 and ALL_MED_GLD_04 respectively (see Table 1 for further details).

For the assessment of the impact of glider assimilation in the western Mediterranean (hereafter, WMED) on the different analysis/forecasting systems, Tasks 4.1 and T4.2 decided to act together in which IBI-MFC PHY will be included in the intercomparison. All the systems will start from a frozen dataset in 2017 and assimilate them in the WMED. Given the different practices of each system on the assimilation (e.g., assimilation window, observation error covariances etc.) and quality control procedures, it is difficult to compare the systems directly. One way to assess the impact without creating further complication is to compare the relative impact (e.g., in percent) on each system. Another approach in the same direction is to put aside some glider missions only for validation purposes. A final way to compare the system is to give more weight on some specific physical structures, for example the formation of an eddy between August-December 2017 in the Balearic Sea (Aguiar et al., 2019). This is a good testbed to assess the gain from glider observations which are prone to generate eddy-like structures in the analysis (Pasmans et al., 2019).

Task 4.3: Model development and validation for improved forecasting
Task leader: UNIBO, Partners: SOCIB, CMCC

The task 4.3 team is developing a foundation for the 10-day lead time ensemble forecasting in the Mediterranean Sea. Currently, multiple methodologies for producing ensembles forecasting are being implemented in a “research-and-development” version (hereafter EAS1-RD) of the current software used from the Copernicus Marine Mediterranean Sea operational ocean forecasting system (CMEMS MED-MFC PHY). With respect to the operational CMEMS MED-MFC PHY code, this “research-and-development” version has a lower spatial resolution (1/16 vs 1/24 of MED-MFC PHY) and a slightly older version for the DATA assimilation scheme. After a successful testing and validation phases, we have produced a first suite of initial-condition ensemble forecasting experiments. In these experiments, the initial condition (IC) used for the forecast, which is normally the best estimate available (i.e., analysis state), is perturbed by using analysis fields from the preceding 10-days. We will refer to this an IC-shifted ensemble scheme (Figure 4).

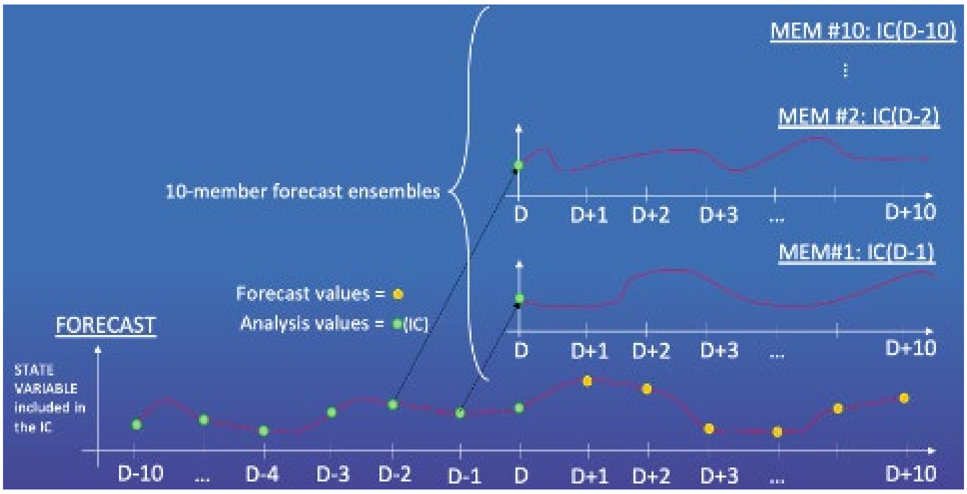


Figure 4. IC-Shifted ensemble forecasting scheme. Each ensemble member (i.e., MEM#) has been obtained using analysis estimates from previous days.

The IC-shifted ensemble scheme is used not only to produce ensemble forecasts but also to explore the forecast dependency from IC versus the atmospheric forcing. Specifically, the relative importance of IC and surface forcing is assessed. When the initial condition dominates the forecast uncertainty, the inter-member spread increases with time (EMed subplot of Figure 5). Conversely, the inter-member spread decreases when the surface forcing dominates the time evolution (GoL subplot of Figure 5).

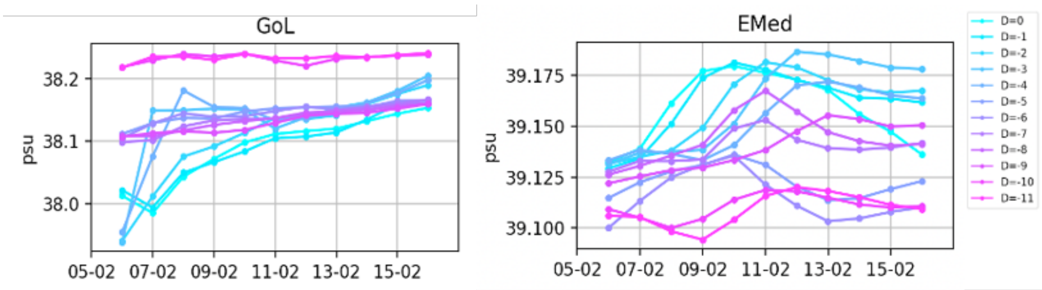


Figure 5. 10-day time series of daily mean surface salinity values for a grid point in the Eastern Mediterranean Sea (Emed) and a grid point in the Gulf of Lion (GoL)

While a perturbed IC-ensemble is needed to explore the initial conditions' errors, experiments with perturbed atmospheric forcing are needed to sample the errors associated with the forcing. Based on the work of Pinardi et al. (2011) and Lima et al. (2019), we are developing a novel perturbation methodology for the generation of the ensemble members. These methodologies require a characterization in terms of analytical probability distribution function (PDF) for wind components and amplitudes, but also for turbulent (i.e., latent and sensible) and radiative (shortwave and longwave) heat fluxes. An example of such characterization can be seen in Figure 6 which shows ECMWF latent heat fluxes as derived using bulk formulae over the period 2011-2020. After identifying an optimal theoretical distribution function, which for the latent heat fluxes is the Weibull PDF, "data" moments are compared with Weibull-derived moments to assess the goodness of the fit, which is also done with a formal chi-square test (not shown here). Perturbed atmospheric forcing will be generated by randomly sampling the studied PDF adding members to the IC-ensemble thus producing a large but realistic spread in the forecast.

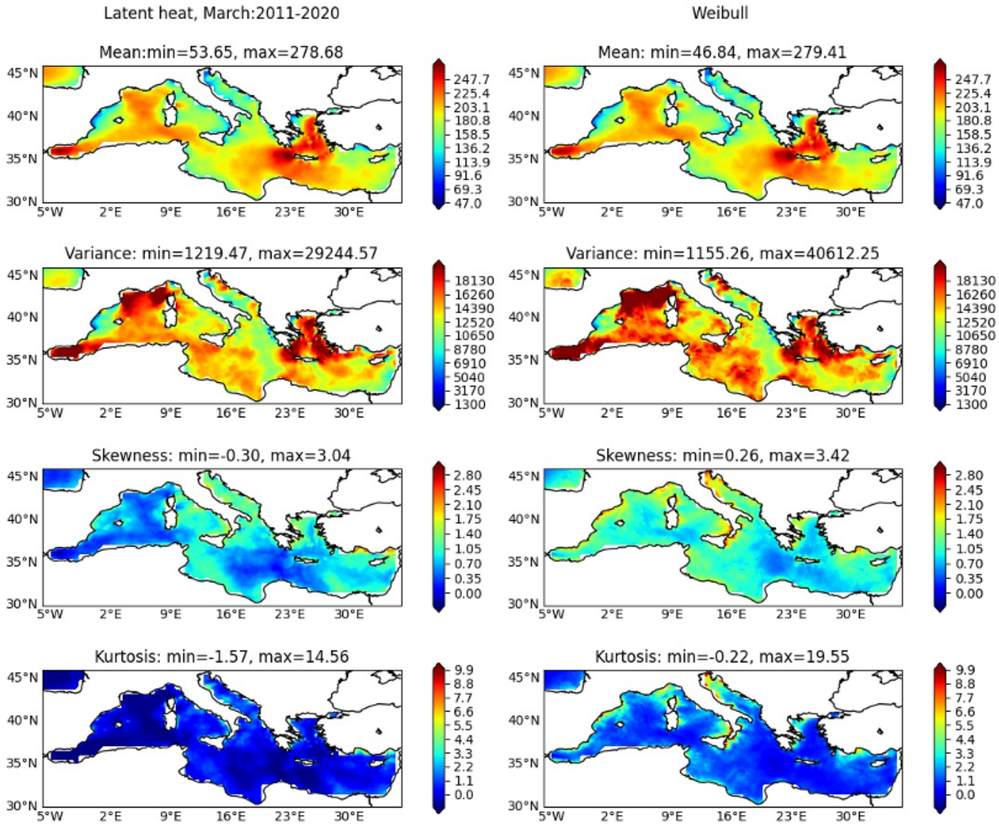


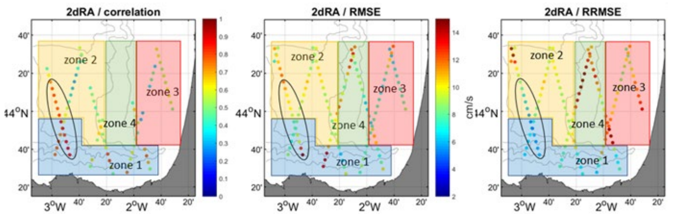
Figure 6. The first four statistical moments for latent heat fluxes over the Mediterranean Sea. The modes computed directly from the data (left column) are compared with the modes derived from fitting the data with an analytical Weibull distribution function. The theoretical distribution approximates well the first two modes (i.e., mean and variance) while it presents some deficiencies for the 3rd and 4th modes (i.e., skewness and Kurtosis).

Task 4.4: Improving the use of in-situ observations for the long-term validation of satellite observations

Task leader: CLS, Partners: AZTI, ACRI, CSIC

Comparison between Sentinel 3B (S3B) altimetry-derived across-track geostrophic currents and HF radar have been performed (Figure 7). Results show a marked sensitivity to the dynamics of the area; the persistence of the currents and the strength of the geostrophic component provide better results:

- Zone 1 (affected by the slope current): High correlations and relatively low RRMSDs
- Zone 2 (open ocean): Medium correlations and RRMSDs. For the track 257 of S3B high correlations and low RRMSDs are observed (points inside the black circle) where persistent currents were observed (high RMS values in the previous slide)
- Zone 3 (area of low geostrophic signal): low correlations and high RRMSDs
- Zone 4 (area potentially affected by the slope current): very low correlations and very high RRMSDs (surprising result)



	RMSE (cm/s)	RRMSD	Correlation
Zone 1	8.99	0.70	0.68
Zone 2	9.28	1.04	0.46
Zone 3	7.96	1.29	0.37
Zone 4	9.79	1.61	0.17
General	8.91	0.95	0.51

Figure 7. Results of the comparison between altimetry-derived across-track geostrophic currents and HF radar currents.

We have also colocalized 3 independent dataset and applied a triple collocation method to quantify the consistency of these 3 datasets: 1) Dynamic heights from Argo profiles; 2) S3B along track SLA (without correction, raw, filtered) and 3) Mapped sea level anomaly from altimetry from J3 and S3A. Among the different results we looked at the drift of S3B. We clearly see that drift correction and along-track filtering improve the consistency of S3B SLA with independent observations.

The following tasks for the validation of ocean colour satellite missions (S3A&B) for Chl-a, particulate backscattering coefficient and diffuse attenuation coefficient using BGC Argo data have been performed:

- Validation of satellite chlorophyll products using different quality level of BGC-Argo Delayed Mode QC (A, C and D), globally and at the Mediterranean scale
- Application of the triple collocation techniques
- Definition of criterion allowing to flag bad data (significant discrepancies between satellite and BGC-Argo observations) based on triple collocation technique
- Development of a visual tool to retrieve spatial and environmental context of data, and try identify source of discrepancies between satellite and BGC-Argo floats (e.g., wind, cloud cover, etc..).

Task 4.5: Synthesis product development based on ship-based in situ biogeochemical data

Task leader: UIB, Partners: GEOMAR

Task 4.5 was divided in 4 subtasks. Within the second year of the project partners continued to focused on the subtasks 4.5.1, 4.5.2 and 4.5.4. The “original” subtask 2 has been successfully completed with a workshop held in November 2020. However, the outcomes of the workshop lead to ongoing work. To accommodate for the needs of the participating time-series sites, the initial time-series product time plan had to be extended, hence subtask 4.5.3 will be implemented when finalized.

Subtask 4.5.1 Develop quality control procedures for data from certain platforms e.g. ship-based time series stations

With the collected time-series data, partner GEOMAR continued to refine its Matlab quality-control (QC) routines. Eventually, some participating sites rejected the proposed “interconsistency checks”, i.e. crossover-based comparisons. Hence, the QC development focused on the refinement of the enhanced outlier detection technique. By testing the routine to multiple sites with different characteristics, it has become clear that the proposed QC is limited to time-series sites with long-term data and with station visits throughout all seasons.

To counter the above-described QC-problematic, additional metadata checks will extend the developed routine. To this end a biogeochemical time-series metadata template has been developed and send to all sites. This template combines several purposes:

- Store "high-level" information, such as PI', data submitters, etc.
- Map between different ontologies
- Obtain detailed information on sampling and analysing techniques
- Check the implementation of the time-series Bermuda workshop recommendation (Lorenzoni et al., 2012)

Eventually, partner GEOMAR aims at introducing a tier-based system, indicating 1) metadata-availability, 2) compliance with the Bermuda-workshop recommendation and 3) the level of applied QC-routines. This is in line with a more flexible QC approach, warranted by the community. Presently, partner GEOMAR is still waiting on the filled-out templates.

The related envisioned data-flow connecting all ties, including the newly developed tier system, is shown in Figure 8.

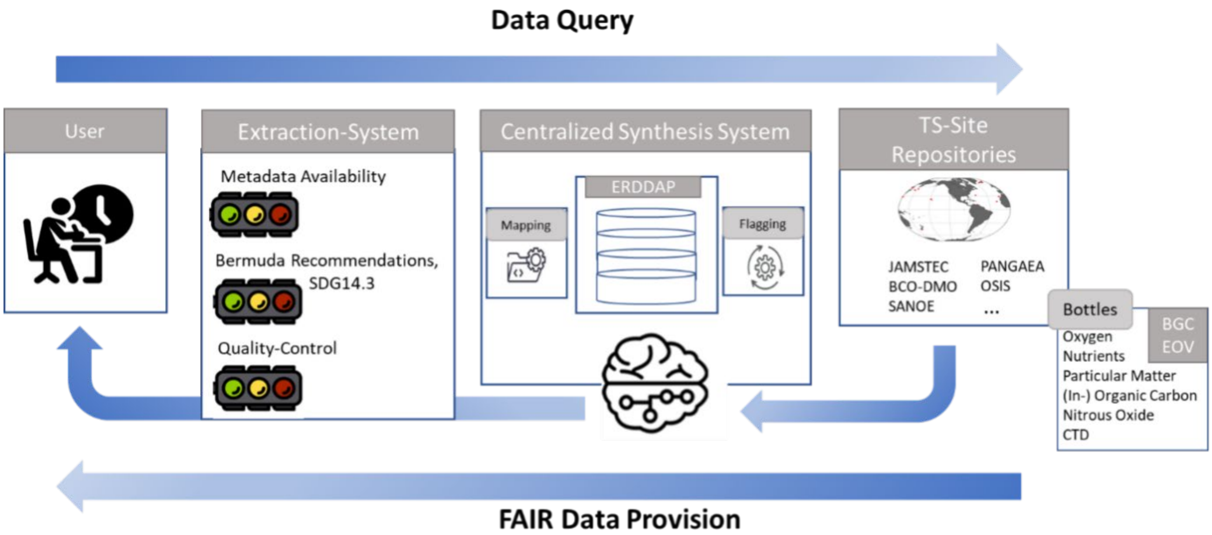


Figure 8. Envisioned biogeochemical time-series product data flow, including the newly developed tier system.

Subtask 4.5.2 Plan and perform a workshop with PIs from international ship-based and open-ocean BGC time-series sites on data routines

A main outcome of the workshop has been the formation of 4 working groups; Concept, Data Policy, Data QC and Metadata. The work of the latter two contributed to the results described in subtask 4.5.1. The concept group led by GEOMAR has successfully written a community-agreed concept note on the envisioned biogeochemical time-series data product. In that note, consensus could be reached on the exact vision and mission and the benefits of the product for all stakeholders are clearly outlined. Further, the concept group established a strong and ongoing cooperation with the RCN-METS program.

Subtask 4.5.3 Integration of those quality-controlled data with the Global Ocean Data Analysis Project (GLODAP).

(To be implemented when finalized.)

Subtask 4.5.4 Operationalize European SOCAT and GLODAP quality control efforts and test the implementation of the quality control routines for ship-based time-series

GLODAPv2.2021 has been finalized in August 2021, with the two major updates being the addition of 43 new cruises and the inclusion of DOIs for each cruise. We helped with the collection of new and updated data, performed the 1st and 2nd quality control of the new cruises, discussed the results at the reference group meeting, merged the data for the final product, generated updated statistics for the accompanying paper (Lauvset et al. 2021, Tanhua et al. 2021). Partner UiB provided the data and needed documentation to Copernicus Marine in-Situ TAC.

SOCATv2021 was released in June 2021. UiB assisted in uploading, assembling and coordination of SOCATv2021. Ongoing discussions with US colleagues about the automation of metadata entries and interoperability of these were discussed in November 2020 and an initial version will be available in May 2022 which will follow and be aligned with the methodology for SDG 14.3.1 metadata reporting. Partner UiB provided the data and needed documentation to CMEMS in-Situ TAC.

Task 4.6: Quality assessment of ocean variables from the C3S seasonal forecasts

Task leader: ECMWF, Partners: CMCC

The skill of seasonal forecasts of SST, OHC and SSH has been assessed and intercompared, following best practices used for the verification of atmospheric variables. The verification has been completed for spatial maps, and currently being done for the EuroSea Indicators. A distinctive feature of ocean variables is that the impact of trends is much more noticeable and prominent than in the atmospheric counterpart and needs to be taken into account in the calibration process.

We have performed the first extensive verification and skill assessment, at global scale, of ocean variables from 2 seasonal forecasting systems contributing to C3S. The ocean variables are sea level anomaly (SLA), ocean heat content (0-300m, OHC) and sea surface temperature (SST). Seasonal re-forecasts from 1993 to the present day have been compared to long-term (~30 years) and high-resolution observational records: satellite-derived surface variables from ESA CCI (SST and SLA), and the CMEMS Global Ocean Reanalysis Ensemble Product (GREP) for OHC. The variables have been assessed with a range of skill scores. A subset of these results has been published (McAdam et al 2022).

A set of observable ocean indicators for monitoring and forecasting has been defined. These indicators target five sectorial applications: i) seasonal forecasts of weather statistics (SF); ii) Climate Variability and Change (CVC); ii) Coastal Sea Level Rise (CSL); iv) Marine Health (MH) and v) Marine Productivity (MP).

The indicators are area-averaged timeseries of monthly means over 43 different regions. An example of the timeseries of these indicators from the reference datasets is provided in the left column of Figure 9, which shows the monthly mean anomalies of SST (top), OHC (middle) and SLA (bottom) over the Canary upwelling area, as represented by the CANARYC indicator (area average over the box limited by longitudes 330E-350E and latitudes 11N-31N). The OHC indicator shows the individual GREP products as well as the ensemble mean in black. All of them show coherent interannual variability, which is more visible in SST. Superimposed on this variability are decadal modulations in the OHC, and a clear upward trend in the SLA.

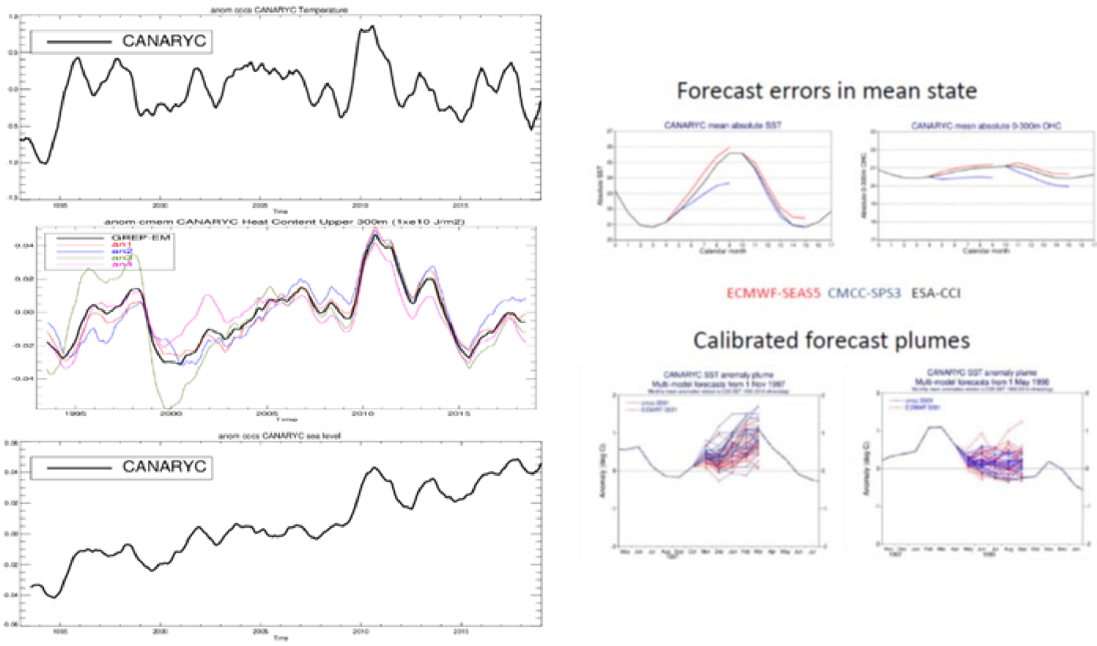


Figure 9. Left column: Timeseries of SST (top), OHC (middle) and SLA (bottom) anomalies over the CANARYC region from the verifying ECVs. The OHC indicator shows the four individual GREP products as well as the ensemble mean in black. All of them show coherent interannual variability, which is more visible in SST. Superimposed on this variability are decadal modulations in the OHC, and a clear upward trend in the SLA. The anomalies are with respect the 1993-2016 climate and are smoothed with a 12-month running mean. Right columns top) Mean seasonal cycle of SST (left) and OHC (right) over the CANARYC. The red and blue lines are for the each of the seasonal forecasting systems, showing the mean evolution of forecasts initialized in May and November. The dashed black line shows the verification. The differences in OHC are visible in the first month, and remain relatively stable after that. This is a clear indication of discrepancies already in the initial conditions. In contrast, the forecast drift is SST evolves slowly over time. Right column bottom) Forecast plumes of SST anomaly of the CANARYC indicator. Shown are the ensemble seasonal forecasts from ECMWF (red) and CMCC (blue) initialized in November 1997 (left) and May 1998 (right).

The same area-averaged indices have been derived from the ECMWF and CMCC seasonal forecasts, which provide probabilistic forecast of indicators up to 6 months ahead. For each variable, there are 48 seasonal reforecasts, initialized over the period 1993-2016 (24 years), twice a year (starts in May and November). For each initial date during this period there is a 25-member ensemble forecast of the following 6 months. The reforecasts have been used to estimate the mean model climate as a function of lead time and initial date (as illustrated in Figure 9 top right panels), which allows the calibration of the forecast anomalies (Figure 9 bottom right panels). The reforecasts are also used for skill assessment, a necessary step for the usability of forecast information.

The calibration of the indicators includes correction of mean bias and linear trend. Preliminary results show that in most instances the seasonal forecasts of SST beat the persistence forecasts, and that uncertainty in OHC initial conditions in the upwelling region limits the assessment of forecast skill. Results also highlight the importance of representing the decadal variability and trends in ocean heat content and sea level in the initial conditions. This is a non-negligible challenge for the ocean data assimilation systems used in the production of ocean initial conditions. The representation of decadal variability and trends is essential for decadal forecasts and climate projections. Therefore, the results from the seasonal forecasts are also very relevant for the efforts on decadal variability and climate projections.

This preliminary analysis of the seasonal forecasts indicators points to the need of probabilistic scores to evaluate the ability of seasonal forecasts to represent short lived extreme events, such as the extreme warm event in the Western Mediterranean during the summer 2003. We have also shown that there is need to better understand and characterize the variability of the upwelling areas, specifically, the long-lasting cold period over the Canary Upwelling region during 1993-1994 with cold anomalies that have not been seen since then. It is also important to gain understanding, in relation to the forecast performance among the different ocean variables.

Cooperation and interaction with other EuroSea WPs

Co-operator	WP activities
WP2	• Direct link to T2.3 - simulated observations will be used in T2.3 to test methods to be implemented in T4.4 • Exchange information on indicators to evaluate observational needs
WP3	• Joint impact assessment of WP3 networks on CMEMS system (T4.1, T4.2)
WP7	• Close communication and exchange about the common goal of improving seasonal forecasting systems for user-relevant applications, as well as by the co-involvement of CMCC and ECMWF: new validation efforts in task 4.6 have identified the capabilities of the forecast systems, while discussions with external stakeholders in task 7.2 have determined how to best communicate and display the validation work (T4.6) • Definition of user-relevant indicators and forecast visualization
WP8	• Participation in the "Stakeholder engagement strategy development" webinars • Presentation in Policy Feedback meeting
WP2, WP6, WP7	• Partnership in the EuroSea Marine Heat Wave task team to discuss methodology and agree on a common approach.

Cooperation and interaction with other projects and initiatives

Co-operator	WP activities
Copernicus Marine Service (CMEMS)	• Sharing of deep Argo and glider assimilation results with the large data assimilation community of CMEMS (T4.1, T4.2) • Recommendation of selected verification datasets for sea level and ocean heat content for the verification of ocean variables now publicly available in Sub-seasonal to Seasonal data bases (S2S) (T4.6)
Argo steering team, OSE-Val Team of OceanPredict	• Sharing of deep Argo and glider assimilation results (T4.1, T4.2) • Discussion on impact of Argo data assimilation in regional and global simulations within the OSE-val Task Team of OceanPredict (T4.1)
Copernicus Climate Change Service (C3S)	• Continuous dialogue about T4.6 activities which are of high relevance for the C3S plans to deliver seasonal forecasts of ocean variables in the near future
NOAA	• Verification of seasonal forecasts of sea level
WCRP	• The verification datasets for sea level and ocean heat content selected by EuroSea task 4.6 have been recommended for the verification of ocean variables now publicly available in Sub-seasonal to Seasonal (S2S) data base, in support for the activities for the WCRP S2S activities.

Co-operator	WP activities
CEAZA-Chile	• Promote the use of extended and seasonal forecasts of ocean variables in research projects for coastal applications
IPSL-CNRS-France	• Promote the use of extended and seasonal forecast products for research projects focused on MHW prediction over French Indo-Pacific territories

Achieved main results

Deliverables		
D4.1	Design of experiments (global/IBI)	✓
D4.3	Derive observable ocean climate indicators from seasonal forecast	✓
Milestones		
MS11	User driven indicators defined and selected EOV/ECV from ensemble of seasonal forecasts verified	✓

WP5 - Coastal Resilience and Operational Services Demonstrator

Lead: NOC, CO-lead: EPPE

Objectives
• To demonstrate the end-to-end connection from observations - including a new generation of multi-parametric monitoring station - to their wider availability and use by a wide variety of stakeholders by combining and incorporating existing CMEMS and satellite products into novel decision-making tools for policy and planning
• To develop new coastal management products including the downscaling of ocean analyses and forecasts for port and adjacent cities' operations aiming to: o Provide an end-to-end demonstrator for climate quality sea level measurement to sea level services with a focus on the Mediterranean, but linked with Africa o Development and demonstration of integrated observations and models supplying oceanographic services for ports and cities.

Summary of progress towards WP objectives

Progress towards the majority of WP objectives is on schedule. Our first deliverable, D5.1, in respect of task 5.1.3 (the prototype sea level planning and scenario visualization tool) was successfully met on time in April 2021 and was demonstrated to key stakeholders, meeting milestone MS23. The tool was showcased at a satellite event of the UN Ocean Decade Laboratory for 'A Predicted Ocean' in September 2021 and to the UK Parliamentary and Scientific Committee meeting in February 2022.

The study period for D5.2 (Mediterranean Sea-level reconstruction spanning 1950-2017) was adjusted to cover the period 1960-2018 due to the sparsity of available tide gauge data prior to 1960. Deliverable D5.2 was met on time, the sea level reconstruction dataset was produced and an associated report completed. The sea level estimates were produced ahead of time and included within D5.2 so the remaining deliverable for this piece of work (D5.8 - a final report) is on schedule and is being prepared in the form of a scientific paper.

Work on D5.6 (Documentation associated to the capacity building) relates to subtask 5.1.1 (Low cost and maintenance free tide gauges) and was delayed due to travel restrictions associated with the COVID-19 pandemic. Consequently, MS14 (Prototype low maintenance multiparametric monitoring at 2 sites) has also been postponed to May 2022, but a lack of engagement from local partners in Taranto means that only 1 tide gauge (at Barcelona) is likely to be in place by that time. Difficulty in obtaining site permissions has led to a change in the 3rd choice of site from Alexandria, Egypt to Buenaventura, Colombia. It is anticipated that it will still be possible to meet D5.9 if stakeholders in Taranto co-operate. Exploitation plans have been developed in conjunction with Laser Consulting and WP8. MS24 is on schedule.

Work on D5.3 (CMEMS downscaled circulation operational forecast system), and D5.4 (CMEMS downscaled wave operational forecast system), both related to subtask 5.2.1 was completed and submitted in time (end of October 2021, PM24) for two of the pilot sites (Barcelona and Taranto). It has not been possible to progress on the work for the third site (Alexandria), for the problems explained above for the installation of the pilot tide gauge station. On-going actions are now in place for implementation of new downscaled circulation and wave models at the new site in Buenaventura (Colombia).

Since the previous report, the LIM-UPC team has been working on developing two 3D hydrodynamic operational tools for the Barcelona site. The first one, called OSPAC V1, is now operational using the ocean circulation model, ROMS. The second, called OSPAC V2, although ready to be implemented operationally, is currently running offline using the circulation and wave coupling models (ROMS and SWAN Models). The LIM-UPC team has also participated in the first contact meetings with Colombian colleagues where, as an example for the future development of the Buenaventura modelling case, the advances in the development of the high-resolution prediction system in Barcelona have been shown. In addition, the available data necessary for future simulations, such as atmospheric forcing, different observations, or freshwater data, have started to be collected. Likewise, the generation of domains and bathymetric grids for the models have also been initiated. All the progress is tracked through monthly meetings between both teams.

In respect to the previous reporting period the downscaled modelling for Taranto, developed by CMCC, has been advanced in: (i) improving the validation of SHYFEM circulation model (e.g. with drifters, ADCP and CTD profiles in the harbour zone); (ii) setting the WW3 wave model component and validating with coastal buoy.

Linked to subtask 5.2.3 (OSPAC software development), deliverable 5.5 (Final version of the software running operationally for the demonstration) was also successfully met on time at the end of October 2021 (M24). The Oceanographic Services at the service of Ports And Cities (OSPAC) software encloses a one-stop shop of met-ocean indicators and tools for the management and decision support at Ports and coastal Cities. It features a modular implementation that allows highly-customizable applications providing visualisation of met-ocean parameters, both real-time instrumental measurements and model forecasts, model simulations such as oil-spill, or warning systems to detect risks during ocean-related activities. All these applications can be managed by a common infrastructure, in which each pilot-site may have several administrators and users, each one having different access roles which allow the customization of the OSPAC software for each user. The demonstrator software is active for the Port and City of Barcelona, providing information from measuring instruments and downscaled ocean model forecasts which are fully operational, under restricted access.

Exploitation plans have been developed for key exploitable results (KERs) in conjunction with Laser Consulting and WP8.

Detailed progress per task (or subtasks)

Task 5.1 Sea Level Advice Demonstrator (SLADE)

Subtask 5.1.1 Low cost and maintenance free tide gauges

Task leader: NOC, Partner: EPPE

Task 5.1.1 aims to deliver a new standard of low-cost and largely maintenance-free tide-gauge system, powered by renewable energy, to monitor both land motion and sea level, using novel techniques. There is potential to advance these technological solutions via the GLOSS community as a global standard. The new gauges will employ solar powered technology, low-cost/free telecommunications systems and surface-mounted sea level radar sensors to eliminate costly underwater maintenance. They will meet the specifications of the Intergovernmental Oceanographic Commission's GLOSS (Global Sea Level Observing System) in order to guarantee scientific quality measurements. In addition, fast transmission of high-frequency samples will be implemented for tsunami monitoring purposes.

Progress since Action Progress Report 1: The tide gauges were originally intended for installation in Barcelona, Taranto and Alexandria, but difficulty in obtaining site permissions at Alexandria led to a change in the third intended installation site, which is now Buenaventura, Colombia. The capacity-building element of this task remains unchanged, however, as a Colombian counterpart (Yosamy Garcia Sanmiguel) of the Direccion General Maritima (Dimar) will attend the Barcelona tide gauge installation in place of Egyptian stakeholders and will be trained to install the third tide gauge in Buenaventura. Work on D5.6 (Documentation associated to the capacity building) relates specifically to the third tide gauge installation and was therefore postponed to allow for an alternative site to be identified.

Travel restrictions associated with the COVID-19 pandemic have unavoidably delayed MS14 (Prototype low maintenance multiparametric monitoring at 2 sites) beyond the target date of 21/10/21. Nevertheless, significant progress has been made towards this milestone. Ordinarily, NOC tide gauge engineers would survey tide gauge locations in person to develop tide gauge designs with dimensions to precisely fit the installation site. As an alternative, we created local organising teams for each of the target locations, to gather the necessary information remotely. Using virtual meetings with the Barcelona local organising team, we agreed the instrument configuration and installation site shown in Figure 10. This location was revised from that shown in periodic report 1, due to concerns about potential overtopping by large waves.

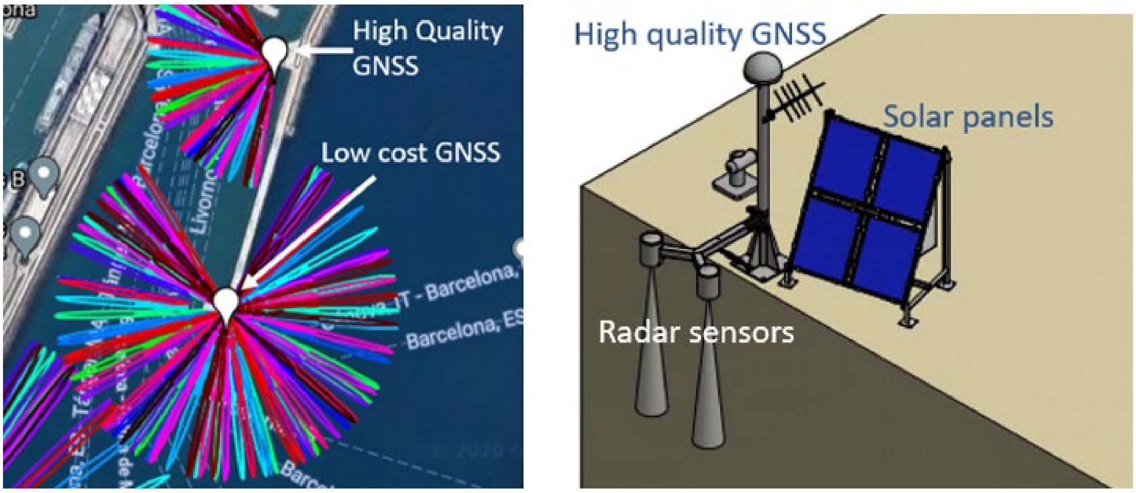


Figure 10. (a). Location for installation of the Barcelona tide gauge, with coloured radial lines showing a Fresnel zone (footprint for GNSS-IR) for the chosen locations of GNSS receivers (b) Proposed design of tide gauge framework and sea level instruments showing downward-projecting radar sensors and GNSS receiver.

Here, we will install dual sea level radar sensors with a high quality GNSS receiver on the inner edge of the quayside. The GNSS will be used to simultaneous track sea level via interferometric reflectometry (IR) as well as monitoring land motion, which will eliminate the need for regular manual levelling exercises. In addition, a low cost GNSS will be mounted upon the lighthouse to monitor significant wave height in the area. The location of the GNSS sensors was chosen to maximise the sea areas that can be 'viewed' - these areas (known as Fresnel zones) are depicted by the coloured lines radiating from the locations shown in Figure 10(a). All components of the Barcelona tide gauge have been procured, constructed and tested at NOC's laboratory. Shipping of the equipment to Barcelona is currently being arranged with an estimated installation date of the week commencing 25/04/22. An INGESCO lightning detector has already been installed within the port's energy centre to provide advance warning of lightning strikes, so that oil transfer operations can be shut down for safety purposes. A press release detailing this case study has been jointly prepared by the Eurosea partners and INGESCO and has been distributed via the INGESCO and EuroSea websites.

For the Port of Taranto, virtual meetings have allowed the choice of location to be narrowed down to one pier (Figure 11(a)), but the precise location of the instruments has yet to be agreed. Site plans, measurements and permissions are currently awaited from the port, having been requested several times since February 2021. Given these delays MS14 should be considered at risk of being further delayed if local stakeholders do not engage. Nevertheless, progress has been made, by developing preliminary tide gauge designs and by procuring and testing some major electronics components. This includes the procurement of a specialist radar sensor (a MIROS Rangefinder) which will allow for the measurement of significant wave height (SWH) at the fixed point of the tide gauge, complementing the use of GNSS-IR over a wider sea area. At this stage it is anticipated that it will still be possible to meet D5.9 if stakeholders in Taranto co-operate.

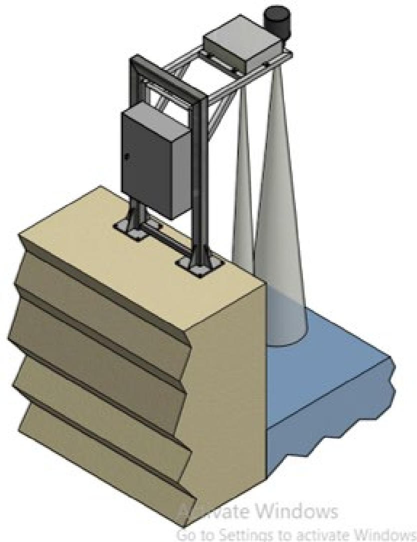


Figure 11. (a). Preferred jetty for installation of the Taranto tide gauge, showing a Fresnel zone (footprint for GNSS-IR) for one possible location (b) Proposed design of tide gauge framework and sea level instruments showing downward-projecting radar sensors

For Buenaventura, NOC will construct and ship an identical tide gauge to that at Barcelona. Yosamy Garcia Sanmiguel of Dimar will then supervise installation of this instrument based upon the training that he will receive during the Barcelona tide gauge installation (planned for the week commencing 25/04/22).

MS24 is on schedule. Exploitation plans have been developed for this KER in association with WP8 and Laser Consulting.

Subtask 5.1.2 Optimization of combined tide gauge data and satellite altimetry

Task leader: NOC

The objective of task 5.1.2 is the optimisation of combined tide gauge data and satellite altimetry. Sea level changes in the Mediterranean Sea show large spatial variation and can deviate significantly both from the global average sea-level rise and from changes in the nearby Atlantic. Characterizing such spatial structure is crucial to improved coastal planning for climate change adaptation, but this is complicated by the sparseness of the observational record in time and space. Our main source of information on long-term sea-level changes comes from tide gauge records, but those are spatially sparse, often temporally inhomogeneous, and only located on the coast. In the case of the Mediterranean, nearly all tide gauges are situated in the northern coasts with almost no stations along the African coasts. Satellite altimetry provides a much better spatial coverage but only since 1992. To address the limitations due to data sparseness in the Mediterranean region, this task combines, in a statistically rigorous way, the tide-gauge observations with satellite altimetry data to yield reconstructed sea-level fields with complete spatial coverage and spanning the same period as the tide-gauge record.

In designing the reconstruction strategy, it is important to recognize that while tide-gauges measure sea level relative to the land on which they reside (what is termed relative sea level), satellite altimetry measures geocentric sea level. This means that the sea level observed by tide gauges is affected by changes both in sea surface height (SSH) and in the underlying solid Earth (i.e., vertical land movements - VLMs) and so it is not directly comparable to the altimetry measurements. Therefore, combining tide gauge data with altimetry observations requires a physically consistent framework that distinguishes between the contributions from SSH and VLM. Here, we achieve this by using a Bayesian hierarchical model that links the tide gauge and altimetry observations together and solves simultaneously for the contribution from four processes: short-term variability, ocean dynamics, contemporary land-mass changes, and glacial isostatic adjustment (GIA).

Progress since Action Progress Report no 1 - The study period for D5.2 (Mediterranean Sea-level reconstruction spanning 1950-2017) was adjusted to cover the period 1960-2018 due to the sparsity of available tide gauge data prior to 1960. The sea level reconstruction dataset was produced and the associated deliverable report (D5.2) was met on schedule. The spatiotemporal Bayesian Hierarchical Model (BHM) was built and used to model sea level as the sum of four contributions, namely short-term variability (interannual to decadal), sterodynamic changes (ocean dynamics and thermal expansion), GRD (changes in Earth gravity, Earth rotation, and solid-earth deformation due to land-mass changes), and GIA. Estimates of the basin average rate of sea-level change are shown in Figure 12. Gridded estimates of relative sea-level changes (i.e., all contributions, including short-term variability) have been produced as well as gridded estimates of the yearly rate of sea-level change associated with all the contributions for the period 1960-2018. This work was completed ahead of schedule and was therefore included with D5.2. Since these estimates were originally intended to be included within the second report for this piece of work (D5.8), that deliverable report is instead being prepared in the form of a scientific paper.

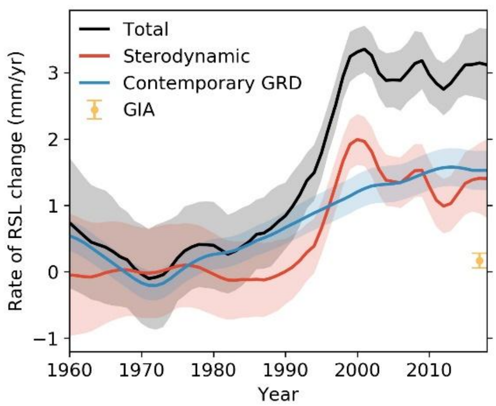


Figure 12. Rate of relative sea-level change and its individual contributions averaged over the Mediterranean basin for the period 1960-2018. Here, the terms sterodynamic and contemporary GRD refer to the contributions from ocean dynamics and contemporary land-mass changes, respectively.

The Bayesian estimates of Mediterranean Sea-level changes and contributions for 1960-2018 have been made publicly available via Zenodo[51]. Additionally, these estimates were presented at the EGU General Assembly 2021[52].

Subtask 5.1.3 Data-driven modelling and visualization for sea level guidance

Task leader: ARUP, Partner: UCAM

The aim of task 5.1.3 is to improve decision making in the coastal zone under uncertainty; the uncertainty is present in the range of possible future sea Level Rise projections. Decision makers in cities and other locations on the coast need to make informed decisions on risk and resilience in relation to coastal flood risk, now and into the future. The risk assessment process is complex, and it is difficult to bring through all the climate science and sea level rise projections to the decision making, and presently, decisions are made without real understanding of the uncertainty.

The task has used a case study location, the city of Hull, on the River Humber, on the east coast of the UK. Hull has significant risks from tidal flooding. This task is split into 2 elements:

Climate science and Physical Modelling of the Impacts

This element, led by University of Cambridge, has taken detailed sea level rise projection data, available around the UK as calculated by UKCP18. As projections get further from the present, the uncertainty around the prediction increases (Figure 13). Typically, flood risk assessment for future scenarios are based on 50th percentile of a sea level rise projection, which ignores this sea level rise uncertainty.

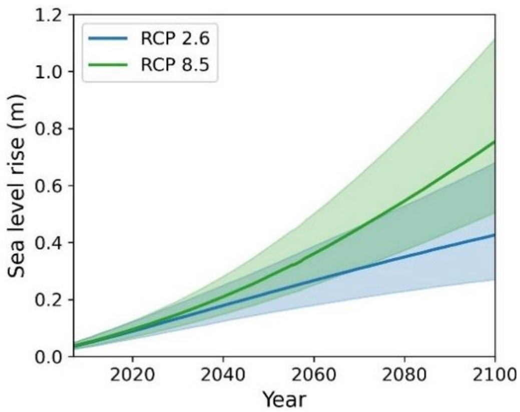


Figure 13. Sea level rise projections for the River Humber for a low (RCP2.6) and high emission scenario (RCP 8.5), showing 5th, 50th and 95th percentiles

Progress since Action Progress Report 1 - To incorporate this sea level rise projection uncertainty into coastal flood risk assessment, UCAM has set up a modelling framework that allows the uncertainty to be propagated through to the calculation of risk. To calculate the flood hazard, reduced complexity models have been used to allow a large number of scenarios to be run and all potential pathways of flooding to be considered. Model input data has been derived from already existing sources including wave data from (joint probability analysis), extreme water level and future sea level rise projections. The input hydrodynamics have been used to calculate overtopping discharge at representative transects on the coastal defences of the Humber using

[51] https://doi.org/10.5281/zenodo.5562985
[52] https://doi.org/10.5194/egusphere-egu21-15087

the EurOtop[53] empirical equations. The overtopping discharge time-series has then been used to drive a LISFLOOD-FP flood spreading model (Bates at el. 2000). A selection methodology has been developed for input parameters based on probability of occurrence from available hydrodynamic data. Full framework testing, troubleshooting and optimisation of the framework to reduce model run time is complete. A total of 21,350 model runs have been completed, comprising 122 sea level rise increments, 7 extreme water level return periods, and 25 wave conditions. Additional scenarios with adaptations to coastal defence height have been tested. This work element is now complete.

Risk Model and Visual Interface

Arup and CADA consulting have led this element, which receives and processes the UCAM modelling.

Progress since action progress report 1 - In order to generate economic impacts from the flood modelling outputs, a simple risk model has been produced, including depth-damages. This model takes receptor data (houses, businesses etc) and depth damage data (receptor types, damages per type for varying depth) and combines them with flood depths to calculate economic damages. The annual chance of each flood depth is then used to produce an annualised economic risk which is converted into a present value equivalent over the duration of the analysis. The calculation is deliberately simplistic, only considering direct economic damages such as building fabric, possessions and machinery and clean-up costs. A visualisation prototype was produced to promote discussion with stakeholders. It has two main methods of display and interrogation:

1. Single scenario: this allows the user to look at one scenario and provides detailed metrics associated with that scenario. The user can easily change the scenario and see how the metrics are updated. (Figure 14)
2. Two-scenario comparison: this allows the user to directly compare two scenarios for the same dataset or compare two different datasets. Again, the user can rapidly switch between scenarios to get a feel for the sensitivities. (Figure 15)

Each page provides a set of plots and images which are intended to be useful to a decision maker or interested stakeholder. They demonstrate a selection of potential presentational techniques to promote further discussion for any future implementation. The key challenge is in communicating the uncertainty to a range of stakeholders; we might end up with multiple visualisations depending on their background and need. The interface has been demonstrated to a key stakeholder, the Environment Agency.

The key deliverable for Task 5.1.3 (D5.1) was successfully met on schedule in April 2021 and was demonstrated to key stakeholders as required by MS23. Additionally, the tool was showcased at a satellite event of the UN Ocean Decade Laboratory for 'A Predicted Ocean' in September 2021 and to the UK Parliamentary and Scientific Committee meeting in February 2022. Discussions are ongoing with Cambridge University's Office of External Affairs and Communications Office on using outputs from Task 5.1.3. for showcasing the University's impact and outreach activities. Exploitation plans have been developed in conjunction with Laser Consulting.

[53] EurOtop (2016) Manual on wave overtopping of sea defences and related structures. An overtopping manual largely based on European research, but for worldwide application. Van der Meer, J.W., Allsop, N.W.H., Bruce, T., De Rouck, J., Kortenhaus, A., Pullen, T., Schüttrumpf, H., Troch, P. and Zanuttigh, B., www.overtopping-manual.com.

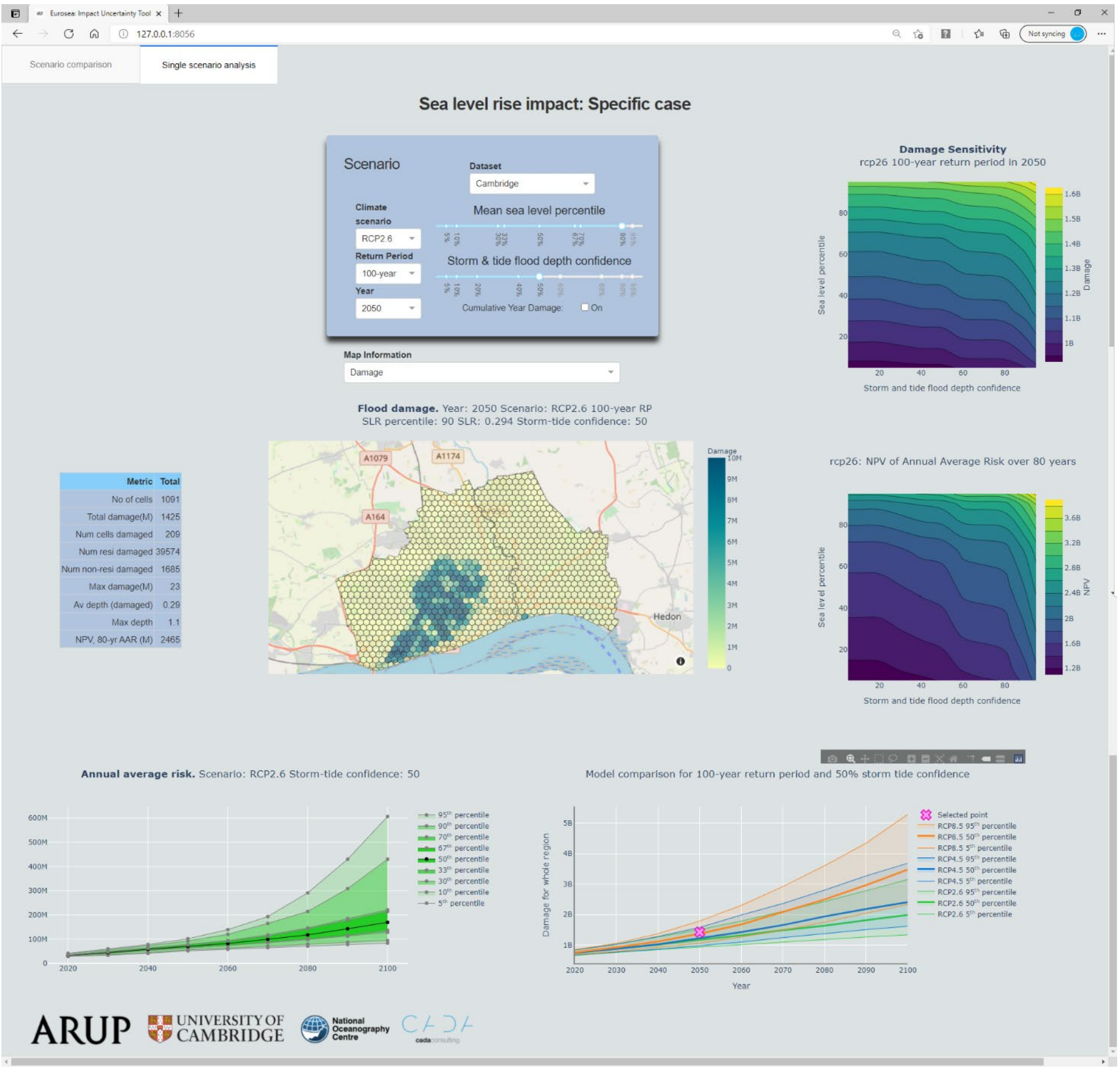


Figure 14. A screenshot of the visualisation prototype for a single scenario, in this case sea level model RCP4.5 at the 90th percentile with the best estimate (50%) storm & tide flood depth confidence at a 100-year return period in 2050.

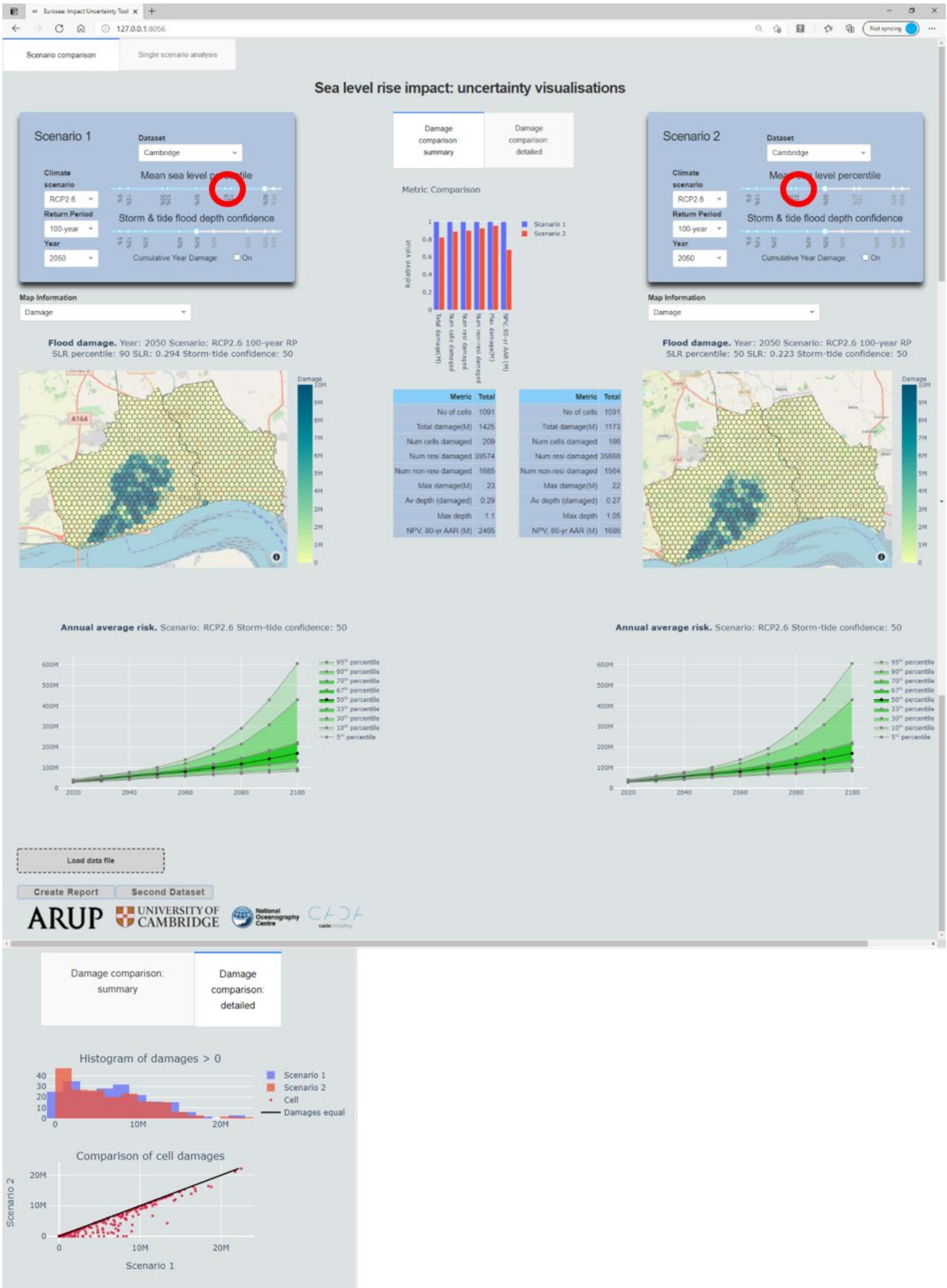


Figure 15. A screenshot of the visualisation prototype comparing two scenarios, in this case sea level model RCP2.6 at the 90th percentile on the left with the 50th percentile on the right (highlighted as a red ring).

Task 5.2 Oceanographic services at the service of ports and cities (OSPAC)
This task aims to develop a demonstrator based on an integrated set of tools and measuring instruments that will provide an operational service to the city and the adjacent port, in order to minimize risks and improve environmental management. This demonstrator was planned to be implemented in three pilot sites. Since the last report, different states of progress in its implementation are described below for Barcelona (Spain) and Taranto (Italy). Difficulty in obtaining site permissions for Alexandria have forced the choice of the third pilot site to be Buenaventura (Colombia).

Subtask 5.2.1 Model downscaling
Task leader: UPC, Partners: CMCC

High-resolution operational forecast systems have been developed for wave, sea level, sea surface temperature, and circulation at the test sites, with a resolution in the order of meters, open boundary conditions provided by CMEMS systems, and atmospheric forcing coming from national Met-Offices. Results of the models will be made available every day in an OPeNDAP system, so further third-party applications could be developed in the future. The models will be validated with already existing instrumentation at the test sites, and with the instruments to be deployed in task 5.2.2. The systems will run on a daily basis at Puertos del Estado and CMCC facilities, and the results will be exploited by the OSPAC software system (subtask 5.2.3). This subtask connects to the data integration for multi-hazards forecasting in WP4.

High-resolution models for Barcelona
In the framework of the EuroSea initiative, the LIM-UPC team is developing a 3D hydrodynamic tool with enough resolution to solve the inner dynamics of local domains such as Barcelona's coastal waters, harbour, and beaches. COAWST relies on the ocean model ROMS (Regional Ocean Modelling System) and SWAN (Simulating WAves Nearshore) wave model. The simulations are based on a two-way coupling between ROMS and SWAN running on the same computational grids. The atmospheric forcing was uncoupled, and CMEMS products provided fields (Figure 16).

The COAWST model utilises the model-coupling toolkit (MCT) to achieve communication among the submodels via the message passing interface (MPI). In the coupling process, ROMS receives the surface and bottom wave direction, height, length, period, percentage breaking, energy dissipation, and bottom orbital velocity from SWAN, while it provides bathymetry, bottom elevation, sea-surface height, and depth-averaged currents to SWAN.

We used the latest version of the COAWST modelling system (version 3.7), which includes the ROMS model (version 3.9) and SWAN model (version 41.31) at the date of publication of this Report. However, for future checks and improvements, numerical details and complete model descriptions, user documentation, and source codes are available at the COAWST website[54], the ROMS website[55] and the SWAN website[56].

Bathymetries are built using a combination of bathymetric data from EMODnet[57] and specific high-resolution sources provided by local Port Authorities (see Figure 16: Bathymetry panel). An updated and higher resolution bathymetry is also applied to adjust the open boundary to the coastal bathymetries in the port

[54] https://www.usgs.gov/software/coupled-ocean-atmosphere-wave-sediment-transport-coawst-modeling-system
[55] http://www.myroms.org/
[56] https://swanmodel.sourceforge.io/
[57] https://emodnet.ec.europa.eu

domains. Finally, the bathymetry information interpolated is smoothed using a Shapiro filter with an r-factor criterion below 0.25.

The bottom boundary layer was parameterized with a logarithmic profile using a characteristic bottom roughness height of 0.002 m. The turbulence closure scheme for the vertical mixing is the generic length scale (GLS) tuned to behave as k-epsilon. Horizontal harmonic mixing of momentum is defined with constant values of 5 m2 s−1. The model configuration is nested into the daily updated regional ocean forecast products delivered by CMEMS- IBI.

The numerical simulations are performed on two-nested grids configurations (see Figure 16: Downscaling panel). The model is performed on two-nested grids configurations with two-way ocean refinement and one-way wave refinement with coupled exchanges between two grids for the fields of currents, bathymetry from the ocean to the wave, and wave dissipation, height, length, and direction, surface and bottom periods, and bottom orbital velocities from the wave to the ocean model.

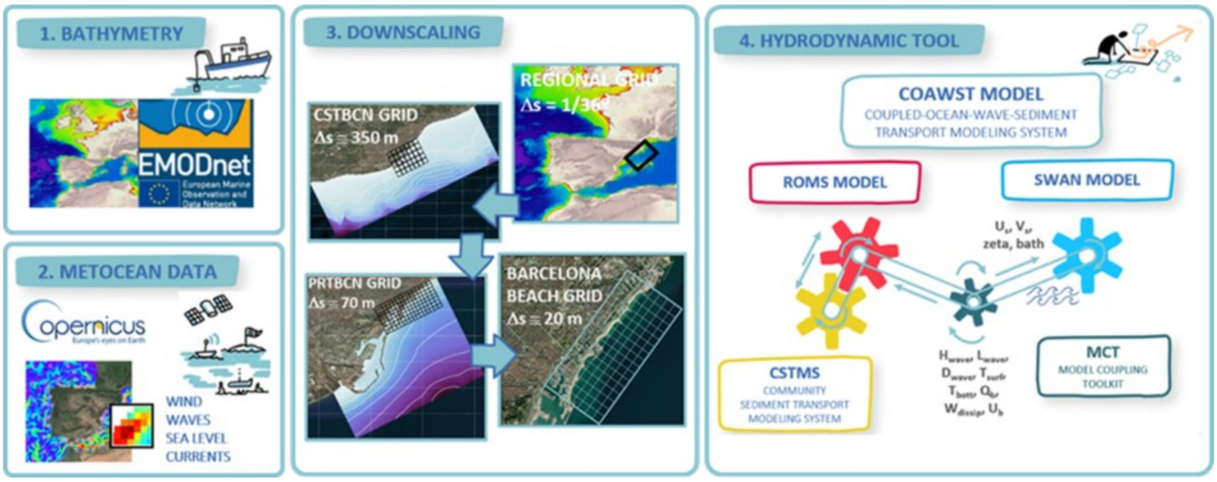


Figure 16. Hydrodynamic tool and setup overview scheme

The model simulation generates three-day forecasts of three-dimensional waves heights fields and other oceanographic variables, such as wave direction, wave period, current fields, temperature, salinity, and sea level (see Figure 17: Model Results panel). Product quality assessment is a crucial issue for operational forecast systems. For that reason, the model outputs are being validated with in-situ observations from field campaign data; preliminary validations display good agreements and correlations between them, allowing us to better understand the quality and accuracy of the model products (Figure 17: Model Results panel). However, there is still necessary work in the wave model operational implementation to generate forecast model products.

Throughout the Barcelona port campaign, two main patterns were identified: the water entered through the port's mouth from the outside to the interior of the port (entry episode) and another where the water left through the port's mouth into local coastal waters (exit episode). Figure 17: Validation panel, show some oceanographic variables modelled from these episodes: the surface speed, temperature, and sea-level correlations between modelled variables and Barcelona's port campaign measurements.

Regarding the correlations, the model predicts well the Sea-level. The correlation is 0.82. Respecting the surface temperature, the correlation between predictions and observations is 0.95. And finally, concerning current surface speed and direction, the model underpredicts the observations, and the correlations between modelled values and measurements are 0.27-0.35.

The new improvements in future coupled model versions will try to improve the correlations between the model predictions and the observations.

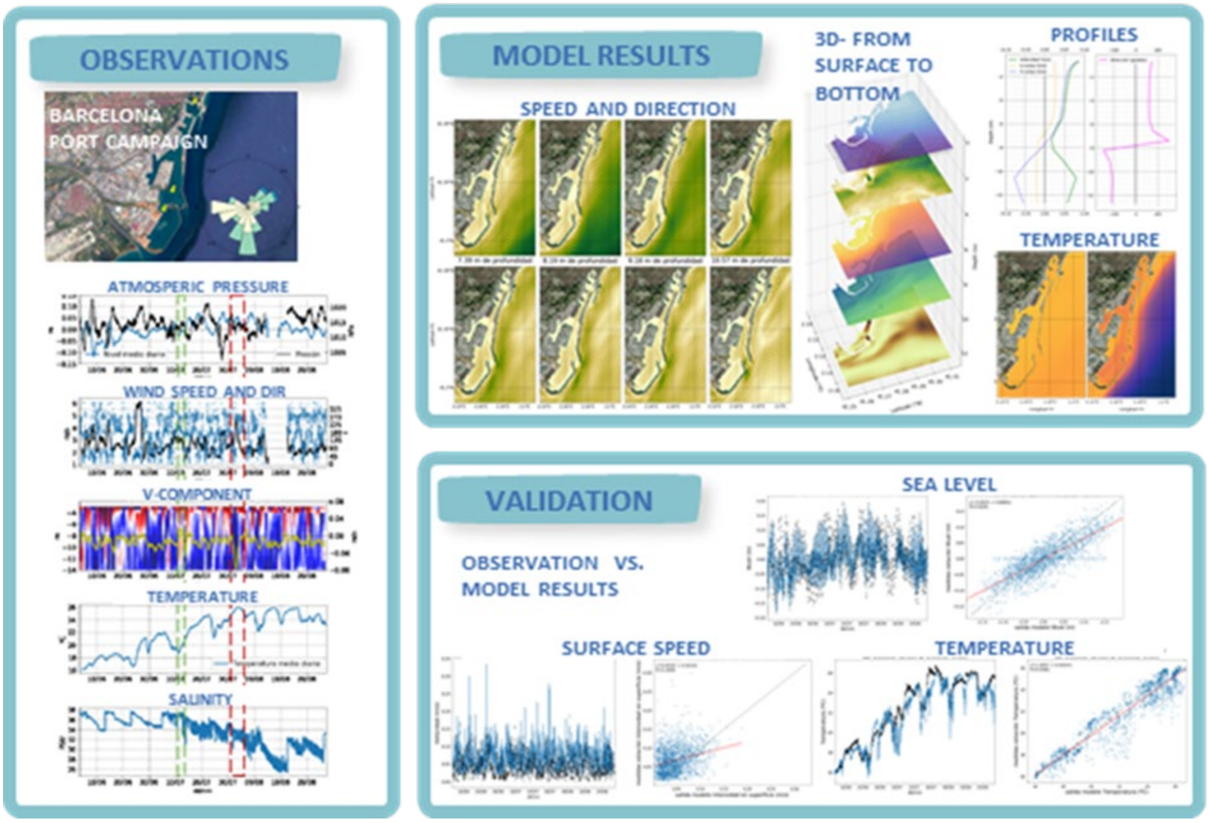


Figure 17. Overview of the observations (left panel), Model results (upper right panel), and Validation (lower right panel) at the Barcelona local coastal waters and port.

High-resolution models for Taranto

The hydrodynamic coastal model of the Gulf of Taranto system (hereafter named GT model) is based on the SHYFEM model and it was set, calibrated and validated in the previous reporting period. We have now advanced in further validation, especially at the coastal and harbour scale. In particular, the velocity fields have been compared with the observed ADCP data recorded in the Taranto harbour and with the CMEMS-Med model in Figure 18. The comparison shows a remarkable similarity between the GT model fields and the observations, demonstrating that the GT model is capable of propagating the tidal sea level from the lateral open boundary condition to inshore.

Figure 19 shows the mean trajectories of two groups of drifters released in the Taranto harbour. The observed trajectory is shown in black and is compared to those simulated by the Lagrangian model using the GT model and CMEMS model data. For the eastern group of drifters, the GT model trajectory shows a significant improvement, while for the western group the GT model and CMEMS drifts are equivalent.

Figure 20 shows the model comparison between GT model and CMEMS and the temperature CTD data. The spatial distribution of the CTD profiles is very dense (spacing between the stations is less than 1 km overall the Taranto Seas), due to the need to sample the coastal and local scale features. The 31 CTD temperature casts have been averaged to produce a representative profile of the Taranto Sea, as reported in the left panel of Fig 14, together with the modelled profiles. The GT model is close to the observed temperature profile, showing a significant improvement in terms of the coarse resolution CMEMS analyses. The improvement is evident in the BIAS profile (Fig. 14, centre panel), which is 0.13 C for the coastal model and 0.3 C for CMEMS. For the RMSE profile (Fig. 14, right panel) values of 0.15 C and 0.32 C are obtained for coastal model and CMEMS, respectively.

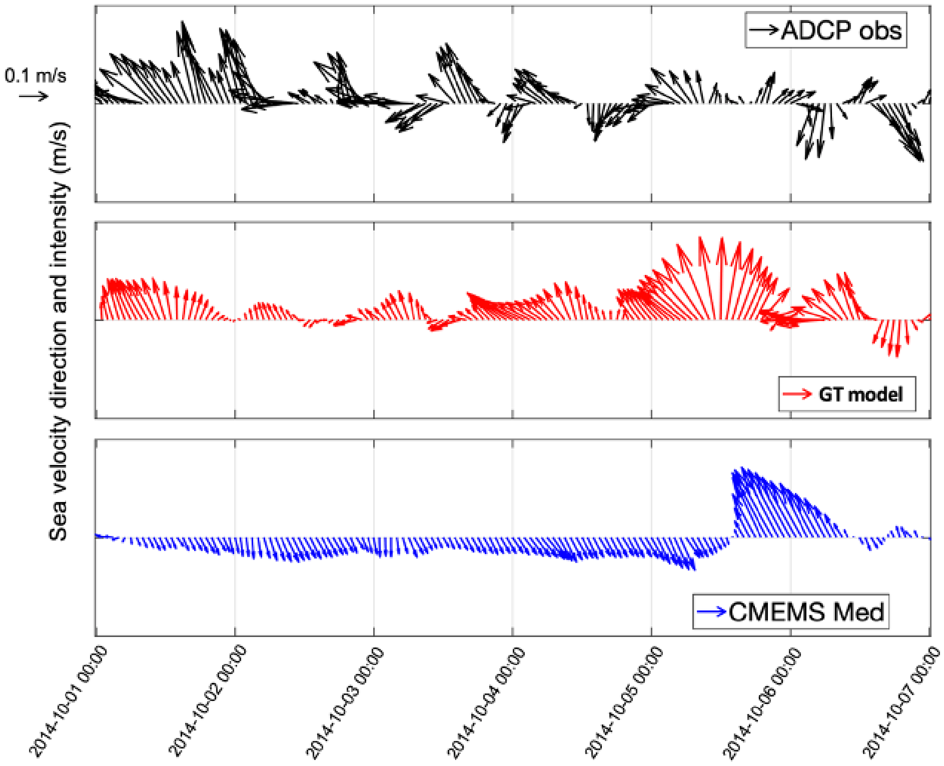


Figure 18. Time series of sea velocity direction and intensity, as measured by ADCP (black rows) and modelled by GT model (red rows) and by CMEMS Med (blue rows) (bottom panel) are given.

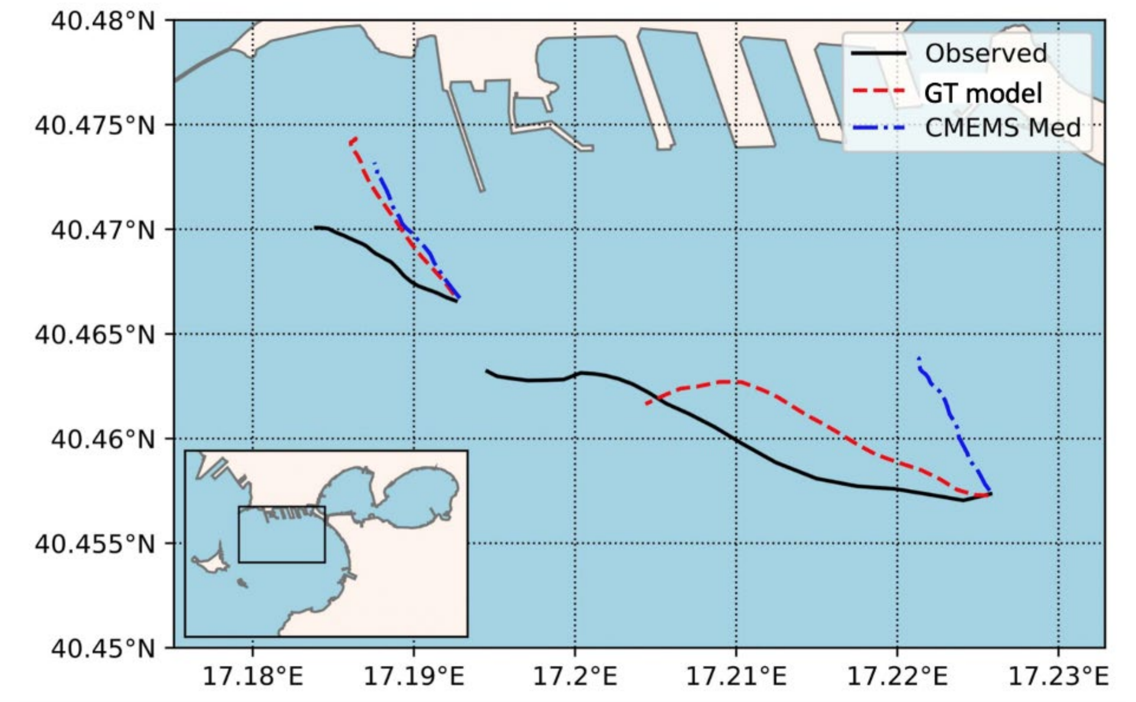


Figure 19. Mean drifter trajectories of the two drifter groups released in the Taranto Sea (black), and simulated drifter trajectories using the GT model(red) and CMEMS Med (blue).

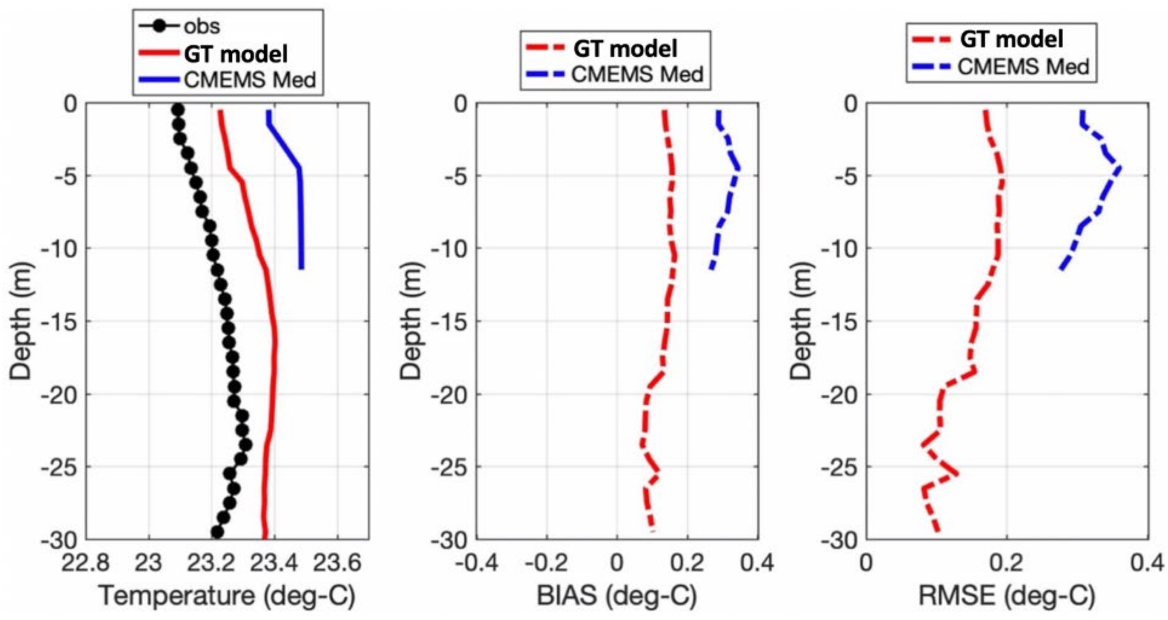


Figure 20. Comparisons between modelled (SURF-U and CMEMS Med) and observed CTD temperature profiles (left panel), with BIAS (middle panel) and RMSE (right panel). The observed temperature (black dotted line) is an average profile over the 31 CTD stations collected during the MREA14 survey in the Taranto Sea.

The wave model for Taranto has been set, calibrated and validated in this reporting period. In particular, the modelling system is based on WAVEWATCH-III (WW3), a community wave modelling framework that includes the latest scientific advancements in the field of wind-wave modelling and dynamics. We have developed a specific and hyper-resolution configuration for Taranto Seas, hereafter GT-WAVE or uWW3. The new system covers the GT with a horizontal resolution from 3 km in open-sea to 100 m in the coastal waters to 20 m in the port of Taranto. Figure 21 shows the grid and bathymetry in GT and Taranto Seas. The spatial grid is the same adopted for the circulation configuration.

Results in the coastal and harbour scale of Taranto and a quantitative analysis comparing the modelling results with observations are reported here. We performed sensitivity tests on different upwind/downwind conditions and on shallow-water source terms in WW3 (reported in Deliverable 5.4.). The optimal configuration has been used to simulate extreme wave events. Here we highlight the event that occurred in 2014, on 4-6 October. In Figure 22 we report the significant wave map at the highest peak of the event and the timeseries of Hs and Tm during the event. Two peaks of Hs (1.8m and 1.6m) are present, with a mean direction at the boundary from southeast. Both the peaks were better represented by GT-WAVE (uWW3 in legend)) with respect to the CMEMS parent model. For the first peak it is evident an underestimation by both the models, while the second one is very well described by GT-WAVE while CMEMS underestimates it. Considering the wave period, CMEMS showed a significant underestimation. GT-WAVE performs better, reducing the underestimation of 50%.

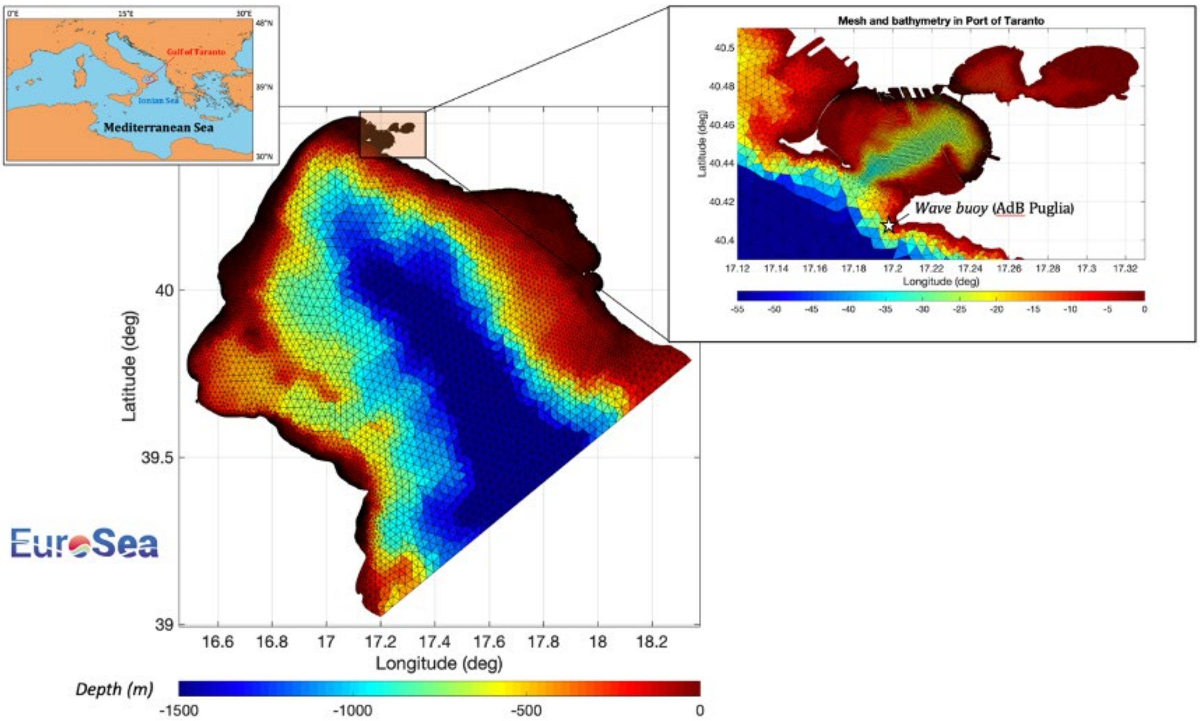


Figure 21. Horizontal grid with bathymetry overlapped for the Gulf of Taranto system and for MG-MP. Star symbol indicates the wave buoy location (property of Autoritá di Bacino, Apulia region) used for validation.

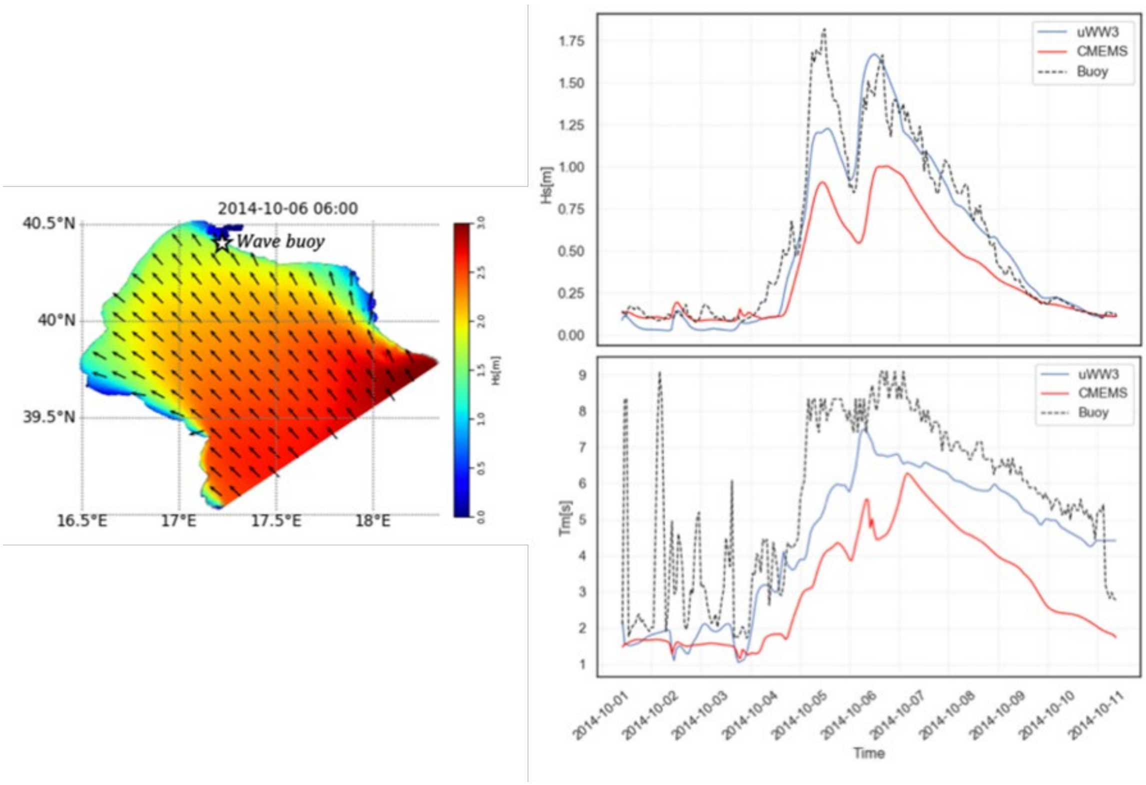


Figure 22. Map of Hs at the peak of the event of October 2014. Models (GT-WAVE/uWW3 and Med-Waves-CMEMS) timeseries of Hs and Tm compared with wave buoy observations.

Subtask 5.2.2 Instrumentation deployment at test sites

Task leader: NOC, Partners: EPPE, CMCC

The novel multi-parametric equipment developed in task 5.1.1 will be implemented at the three test sites, with final configuration dependent on site requirements. For example, at Barcelona, meteorological, visibility sensors and lightning detectors (to support safety during flammable liquid operations) will be implemented, while at Taranto complementary significant wave height (SWH) at the fixed point of the tide gauge will be provided by a MIROS Range Finder. In both cases, GNSS sensors will be used for simultaneous tracking of land motion and for providing sea level via interferometry (IR).

During this reporting period the design of the stations has been completed (see subtask 5.1.1), and the initial test site of Alexandria (Egypt) has been changed to Buenaventura (Colombia). Local organising teams have been established for each of the locations, and relevant information was gathered remotely so far by NOC engineers. Installation plans and other advances in the deployment vary from site to site:

- Barcelona: an INGESCO lightning detector has already been installed within the port's energy centre to provide advance warning of lightning strikes. Installation of the rest of equipment (dual radar sensors with a high quality GNSS receiver on the inner edge of the quayside, and a low cost GNSS upon the lighthouse to monitor SWH) is planned for the week starting April 25th 2022. The station will be installed in a quay at the north mouth of the harbour.
- Taranto: the tide gauge design has been completed (MIROS Range Finder and GNSS). However, the only progress on the installation schedule was the choice of a specific pier, while the precise location

remains to be decided. Delay in answers from the local team at the harbour has prevented progressing on the installation plans since the last reporting period.

- Buenaventura: several meetings have been held with the Colombian team in Dimar, since election for this third pilot site, during this reporting period. NOC will construct and ship an identical tide gauge to that at Barcelona. An invitation letter will be sent to Yosamy García Sanmiguel of Dimar, who will supervise the installation in Barcelona and receive the corresponding training for the installation in Buenaventura.

Subtask 5.2.3 OSPAC software development

Task leader: Nologin, Partners: EPPE, CMCC

The Oceanographic Services at the service of Ports And Cities (OSPAC) software encloses a one-stop shop of met-ocean indicators and tools for the management and decision support at Ports and coastal Cities. It features a modular implementation that allows highly-customizable applications (Figure 23). These applications include (i) visualisation of met-ocean parameters, both real-time in-situ measurements and model forecasts, (ii) model simulations such as oil-spill, and (iii) warning systems to detect risks during ocean-related activities. All these applications can be managed by a common infrastructure, in which each pilot-site may have several administrators and users, each one having different access roles which allow the customization of the OSPAC software for each user.

The development of OSPAC has been completed during this reporting period. This development includes the backbone code of OSPAC, which allows integrating different modules in a plug and play approach. The following capabilities have been included:

- Visualise real-time met-ocean parameters (e.g. waves, sea level, wind, currents, temperature and salinity) coming from different in-situ stations (buoys, tidal stations, meteorological stations, etc.).
- Visualise met-ocean forecasts (3 days ahead) coming from high-resolution models developed within the framework of the EuroSea Project.
- Create highly customizable alerts for any of the above-mentioned parameters, be it from real-time parameters or met-ocean forecasts. These alerts can be timely received by e-mail or SMS.
- Include a REST-API that simplifies the connection of third-party modules to the OSPAC software.

The pilot site of Barcelona has already been integrated into the OSPAC software, including all the measurement stations available, as well as downstreamed CMEMS wave and circulation models. As a result, two added-value modules have been implemented: (i) an oil spill and (ii) a floating debris lagrangian trajectory simulators (Figure 24). A soft release of OSPAC for Barcelona is expected in May 2022. Proper interaction with the port authority of Barcelona and the city of Barcelona has helped understanding their needs within OSPAC and several forecasting points have been selected for the different activities of the port community and citizens.

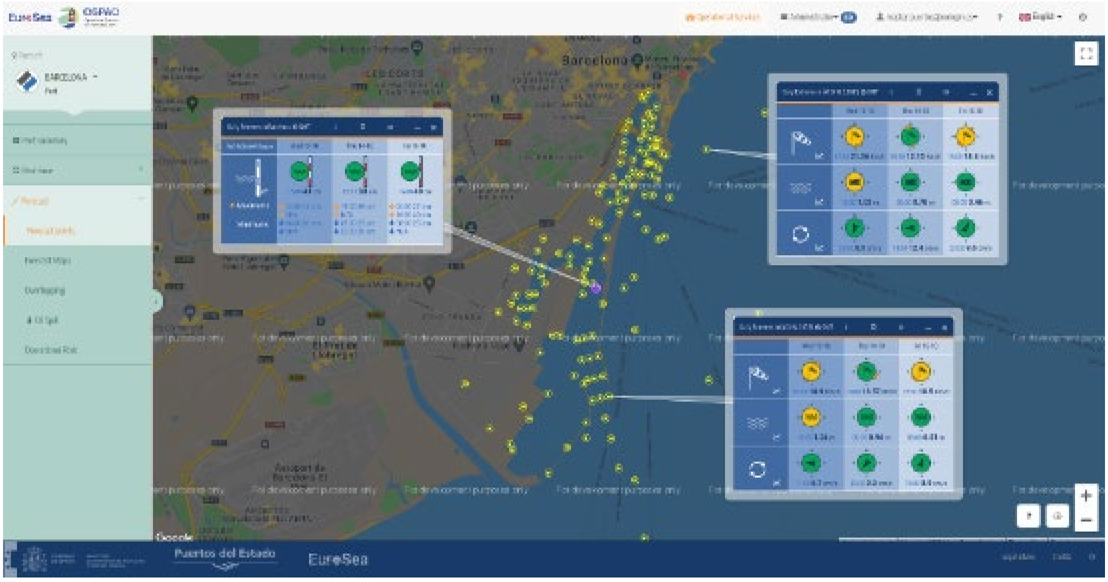


Figure 23. Screenshot of the OSPAC application (Desktop version). Forecast points at several points of the Barcelona harbour for the following met-ocean parameters: sea level (left); wind, waves and currents at the harbour entrance (centre) and wind, waves and currents at the outer part of the harbour (right).

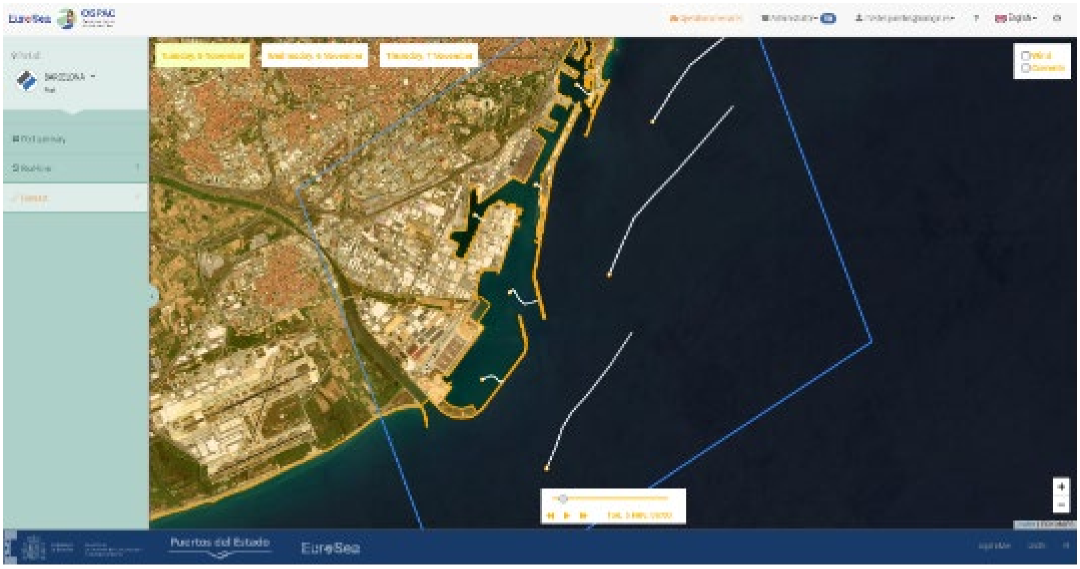


Figure 24. Forecasted floating debris trajectories at the Barcelona harbour, derived from the currents from the downstreamed CMEMS model. The orange dots represent the source origin of the floating debris (defined by the Administrator). The solid white lines are the lagrangian trajectories at different points inside/outside the Barcelona harbour.

One of the key elements implemented in the OSPAC software is the concept of magnitude threshold for met-ocean variables, which allow a specific user to define two threshold values for a certain position or measurement station (Figure 25). These thresholds can be considered as a yellow or red flag, so the user knows that there is a risk associated with their ocean-related activity and the time-frame of that risk. Closely linked to the visualisation of this information, the users can set-up warnings that will send emails with tailor-made information of when and which threshold is triggered.

These thresholds constitute one of the main elements of the OSPAC warning system. This system deals with two information sources: monitoring stations or specific model points. Each alert point can have three types of alerts: (i) Global (i.e. same at all sites), (ii) site-specific (i.e. defined by the site Administrator) and (iii) private (i.e. user-defined) alerts. Also, specific variables may also include filters (e.g. in case of directional variables (wind, currents, waves, etc.), data can be filtered by directional sectors). The system delivers alerts to each user by e-mail or SMS. The update frequency depends on the nature of the data: (i) monitoring data depends on the sensor type (ranging from 5 to 20 minutes), and (ii) forecast data depends on the number of forecasts cycle per day (e.g. wave-forecasts are updated every 12 hours, whereas circulation-forecasts are daily updated). This methodology ensures that the monitoring and forecast data developed within EUROSEA, are promptly communicated to the end-users.

By the use of these warnings, companies or citizens can schedule in advance their ocean or port site-related activities. The joint action of OSPAC software and downstreamed forecasting applications allows one to know the expected time frames in which there is a risk for these activities, thus being able to mitigate the impact of these situations through proactive actions.

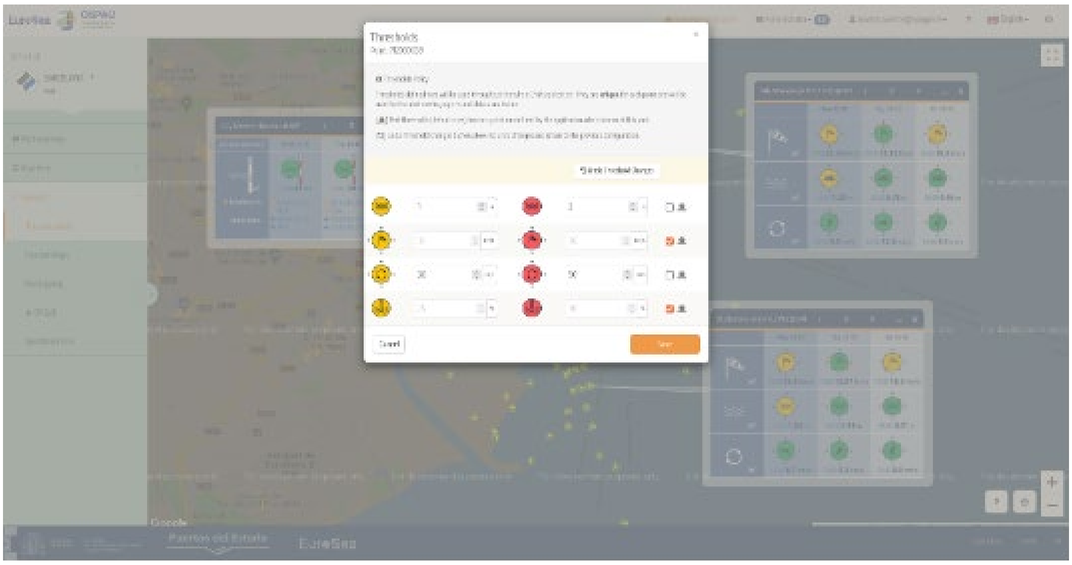


Figure 25. Option menu for changing the thresholds at a specific point

Subtask 5.2.4 Demonstration of the tools at two European sites

Task leader: EPPE, Partners: NOC, CMCC, Nologin

Once the product is implemented and operational, this subtask focuses on the optimization of the system and testing all elements in close cooperation with the users (port and city). Tests to finish bug removal are now being performed at the only operational site in Barcelona. This subtask also includes actions to support dissemination and promotion of OSPAC, expected to reach TRL7 at the end of the project (including real users at all sites). A first demonstration to the EuroSea consortium and the EuroSea advisory board will be done at the next EuroSea Annual Meeting in Cádiz (May 2022).

A meeting with WP8 was held on March 11th, 2022 for planning next dissemination actions. First steps have already been taken in reaching interested stakeholders and demonstrating the OSPAC tool at Barcelona pilot site, including first a soft launch with Barcelona port and city for the end of April 2022 (online technical demo and feedback round), followed by an official launch open to the public in June 2022. Production of an introductory video/pitch video at the European Maritime Day (19 & 20 May 2022 in Italy) was also considered with WP8.

Subtask 5.2.5 Demonstration of the tools at a non-European site

Task leader: EPPE, Partners: NOC, CMCC, Nologin

This task has not started yet.

Cooperation and interaction with other EuroSea WPs

Co-operator	WP activities
WP3	• Task 5.1.1 presented at 1st Eurosea Tide Gauges Workshop (co-ordinated by EuroGOOS Tide Gauge Task Team)
WP8	• Worked with LLC and Task 8.3 to develop an exploitation plan for KER3 – Low maintenance tide gauge • Produced Ingesco press release [58](Task 5.1.1) • Publicised UK Parliamentary and Scientific Committee meeting (Task 5.1.3) via EuroSea website and Twitter • Tasks 5.1.1 and 5.1.3 made video presentations at the EuroSea Anniversary Webinar

Cooperation and interaction with other projects and initiatives

Co-operator	WP activities
Ingesco	• Along with WP8, WP5 produced a news article for Ingesco website about the use of their products in Task 5.1.1
UN Ocean Decade	• Task 5.1.3 Prototype sea level visualization and planning tool was showcased at a satellite event of the UN Ocean Decade Laboratory for 'A Predicted Ocean' in September 2021
UK Environment Agency	• Testing of Task 5.1.3 Prototype sea level visualization and planning tool with key stakeholder
UK Parliamentary and Scientific Committee	• Task 5.1.3 Prototype sea level visualization and planning tool was showcased at UK Parliamentary and Scientific Committee meeting in February 2021
University of Cambridge	• Discussions with University's Office of External Affairs and Communications Office on using outputs from Task 5.1.3. for showcasing University's impact and outreach activities
Permanent Service for Mean Sea Level (PSMSL)	• The dataset relating to Task 5.1.2 optimization of combined tide gauge data and satellite altimetry is to be additionally distributed via the PSMSL website. The associated scientific paper (in development) will also be linked to the website.

[58] https://www.ingesco.com/en/noticias/interview-angela-hibbert-physics-and-ocean-climate-expert

Achieved main results

Deliverables		
D5.1	Prototype sea level planning and scenario visualization tool	✓
D5.2	Mediterranean sea-level reconstruction spanning 1950-2017	✓
D5.3	CMEMS downscaled circulation operational forecast system	✓
D5.4	CMEMS downscaled wave operational forecast system	✓
D5.5	Final version of the software running operationally for the demonstration	✓
Milestones		
MS23	Policy-led and industry-lead stakeholder demonstration of prototypes	✓

WP6 - Ocean Health Demonstrator

Lead: MI, CO-lead: CSIC

Objectives
• Develop a shared understanding of water management among end-users in Aquaculture, Fisheries, Tourism, Environmental Agencies and Scientists by working together to co-create products that help to identify and foresee "Extreme Marine Events" threatening marine ecosystems, resources, and related businesses, and supporting adaptive management decisions
• Demonstrate the value of ocean observing and forecasting of "Extreme Marine Events" at local to regional scales by developing downstream products and services to assess marine ecosystem health, and provide an early warning system to support sustainable Blue Growth industries and food security needs.
• Provide a new perspective for environmental managers and policy makers focused on maintaining healthy marine ecosystems in harmony with human activities supporting stronger local and regional governance by using EuroSea decision support tools to assess ocean health
• Support the sustainable development of ocean observing and forecasting systems to monitor ocean health by stimulating international ocean observing initiatives
• Create new market and management opportunities for the private sector by co-creating new ocean products for aquaculture and fisheries

Summary of progress towards WP objectives

The overall objective is to develop a shared understanding of water management among end-users in Aquaculture, Fisheries, Tourism, Environmental Agencies and Scientists by working together to co-create products that help to identify and foresee "Extreme Marine Events" threatening marine ecosystems, resources, and related businesses, and supporting adaptive management decisions.

In the second reporting period, WP6 has progressed well towards these objectives with two milestones (MS08 and MS16) submitted and the next milestone on track (M22). Two scientific articles were peer reviewed and published and four scientific conference abstracts submitted (3 EGU, 1 ICES ASC). EuroSea co-developers[59] (Task 6.1) agreed on the products and services they want, relating to key EOVs (e.g., temperature, dissolved oxygen, wave height, pH) in the case studies focused on marine ecosystems and aquaculture. Some products are already developed (e.g., Luzza et al 2022) and the two associated deliverables are on track. The EuroSea team participated in the Blue-Cloud Hackathon event in collaboration with a new co-developer (CGG – environmental company) to create a marine heat wave application. For the fisheries task (Task 6.2) connecting CMEMS and fisheries communities, advances were made to link CMEMS environmental data with fisheries stocks and there are plans to present these findings to the WGHANSA in June 2022. In this second reporting period, WP6 (Task 6.3) has made great strides toward ensuring an increased volume of near real time data from ship-based and other ocean observing platforms in the Baltic

[59] EPA, BIM, NPWS, MI Benthic ecologist and fisheries scientists MOWI, and two new co-developers in the Mediterranean that include AVRAMAR - world leading sea bass and sea bream brand and the largest fish producer in the Mediterranean and APROMAR-REMA - the Spanish Aquaculture Business Association and Marine Aquaculture Experimentation Network who is the main actor of aquaculture innovation in Spain keen to help bring EuroSea results/innovation to the aquaculture sector.

Sea are made available to CMEMS (and EMODnet) and advances were made to assimilate data into numerical models aimed at developing suitable products to help improve HELCOM MSFD reporting efforts. Initial discussion with HELCOM member states are promising with a positive response to proposed products now under development. Excellent progress was made to build the data buoy delivery system (Task 6.4) with the first tailor designed data buoy delivered to the Irish aquaculture co-developer (MOWI). The second data buoy system bespoke build for our Spanish co-developer (AVRAMAR) is underway with upcoming onsite staff and technician training planned in April 2022.

While WP6 has not had any deliverables due so far in the project, progress was made towards achieving impact in EuroSea especially in the following areas:

- "Improve integration and coordination of various components of the European observing system and strengthen GOOS": The work carried out in T6.3 on improved and more comprehensive delivery of marine information to policy makers in the Baltic supports the sustainability of the observing and monitoring system.
- "Build capacity, internally in EuroSea and externally with EuroSea users, in a range of EuroSea areas": Conduction of training of EuroSea product end-users during T6.2 workshop on using CMEMS products for fisheries scientists and T6.4 training session for aquaculture operators.
- "Develop innovation, including exploitation of novel ideas or concepts; shorten the time span between research and innovation and foster economic value in the blue economy": In particular, the "New monitoring system with sensors to measure oxygen, heat and pH for aquaculture, including innovative buoy design and modelling to deliver forecasts of extreme marine events", with the Irish buoy already on site and ready to be deployed in April 2022 and the Spanish buoy in production and planned to be sent to Spain in April.

Detailed progress per task (or subtasks)

Task 6.0: Coordination and co-development

Leader: MI & CSIC, Partners: CSIC, SOCIB, DMI, TalTech, Xylem, IOC-UNESCO

In this reporting period, WP6 had two official online team meetings (24 April 2021 & 20 January 2022), with regular monthly WP6 leader meetings (to monitor progress and document actions), EuroSea SC meetings and numerous ad-hoc meetings to address requests from the EuroSea coordination office/other WPs/external stakeholders. One to one meetings and group workshops with relevant stakeholders were organised by WP6 partners to discuss, among other, science-based products and methodologies and gather information needed for the development of data products with end-users providing feedback on an ad-hoc basis. WP6 partners actively cooperated and interacted with other EuroSea WPs, external stakeholders and exchanged information with other relevant projects and communities, details of which can be found below. The EuroSea cloud is used to share project documentation.

Task 6.1: Extreme Marine Events" Ocean Observing & Forecasting

Task leader: MI, Partners: CSIC, SOCIB, IOC-UNESCO, Co-developers: MOWI, EPA Ireland, BIM, NPWS, GlobalHAB, MI Benthic ecologist and fisheries scientists

Progress was made on the analyses of historical "Extreme Marine Events" with frequency, duration, intensity of surface and subsurface temperature (MHWs) and dissolved oxygen, and pH trends examined over short to long time periods. Work is now underway, using a case study approach, to combine results of 3-

dimensional ocean modelled variables with vulnerable habitats (SACs), biological EOVs (e.g. hard coral, seagrass and macroalgal canopy cover and composition) and aquaculture species tolerance thresholds. Biological datasets were collected under the guidance of our expert co-developers and from different sources including EMODnet Seabed Habitats for Essential Ocean Variables (EOVs), Special Areas of Conservation and from licensed aquaculture sites. Great progress was made to develop user-friendly monitoring and visualization tools of Essential Ocean Variables and derived indicators (including marine heat waves) in the Mediterranean Sea providing relevant information to diverse ocean stakeholders at regional, national and local scales. Examples include: (i) The web-based tool "Mediterranean Surface Exploration Tool"[60] (MSET) for exploration and visualisation of oceanography data in the western Mediterranean Sea maintained ensuring system operability. (ii) A "Sub-regional Mediterranean Sea indicators" tool[61] (Juza and Tintoré, 2021) to monitor and visualize multivariate and sub-regional ocean indicators in the Mediterranean Sea and around the Balearic Islands. This operational product provides continuous and timely information on the ocean state and variability at daily (events) to interannual/decadal (climate) time scales. Sub-regional marine heat waves are detected automatically. (iii) The "Sub-regional Mediterranean Marine Heat Waves" tool[62] (Juza et al., 2022) provides continuous and timely information about marine heat waves at sub-regional scale in the Mediterranean Sea, from event detection in real-time to long-term changes in response to global warming (since 1982). These web-based tools are maintained to ensure system operability, and are continuously improved (e.g., addition of extended ocean datasets and diagnostics as they become available).

Task 6.2: Connecting CMEMS and fishery communities to increase uptake, and inform development of products for fishery management

Task leader: CSIC, Partners: MI, Co-developers: IEO-CSIC, ICES WGHANSA, JRC fisheries scientists/modellers

Progress was made on the small pelagic species, Chub Mackerel, a fish stock that has yet to be scientifically assessed for management purposes although the importance of Chub Mackerel has grown significantly in recent years due its commercial value. Chub Mackerel seems to have wide geographic distribution, from Morocco/the Canary Islands fisheries bank, to Galicia in northern Spain. During this reporting period, work on analysing the population dynamics in the Canary Islands fisheries bank off the Moroccan coast began, with initial results showing correlations with environmental variables extracted from CMEMS. This work has advanced to include environmental variable information in the population dynamics models. In June 2022, this topic will be presented to, and reviewed by the ICES WGHANSA. Results/Outcomes will be included in the 2023 ICES WGHANSA annual report. WP6 partners (IEO-CSIC and JRC), invited by the Horizon 2020 FarFish project, taught a short course to participants of the 2021 EuroSea session at the UNESCO GRÓ Fisheries Training Programme Workshop on the use of CMEMS products. A productive interaction with EuroSea ISTAB member, Colm Lordan, was held in February 2022 to discuss task progress. An outcome of this meeting was that an amendment to the EuroSea grant agreement is needed to change the target fish species in this task to ensure the most pressing co-developer and end user needs are addressed.

Task 6.3: Multipurpose integration of BOOS & HELCOM observing networks

Task leader: DMI, Partners: TalTech, Co-developers: HELCOM, BOOS

[60] https://apps.socib.es/MSET/
[61] https://apps.socib.es/subregmed-indicators/
[62] https://apps.socib.es/subregmed-marine-heatwaves/

The aim of this task is to develop and make available two products (a) regular assessment of eutrophication status and (b) regular reports on abnormal or extreme events (e.g., salt water inflows). Both CMEMS products and in situ data from environmental monitoring are incorporated. In this reporting period WP6 partners have greatly advanced the operational delivery of NRT Baltic Sea monitoring data to CMEMS. Near real time (NRT) delivery was agreed by Sweden, Denmark, Estonia and Finland, and discussions are ongoing with Germany and Poland. A productive interaction with the co-developer HELCOM was achieved at the HELCOM STATE meeting in May 2021, with a number of potential EuroSea data requirements and products discussed (this is reflected in the Meeting Outcomes; see MS16 for details). Advances were made in the modelling reanalysis with results expected in August 2022.

In this reporting period progress was made in three key areas: i) Improvement of near real-time delivery of T/S observations; ii) Production of interim reanalysis by assimilating T/S observations collected; iii) Assessment of ocean conditions by using CMEMS and the interim reanalysis:

Improvement of near real-time delivery of T/S observations

Progress was made to improve access to NRT and interim ship CTD data from Baltic countries, with HELCOM and BOOS contributors. Working closely with the BOOS Working Group on near real time ship data delivery and the BOOS Steering Group, efforts have now ensured that Estonian data is delivered in NRT. At the start of the EuroSea project, only Sweden (SMHI) was delivering NRT CTD data. Data was then delivered by TalTech to SMHI, where it was further processed and disseminated to CMEMS and EMODnet. Later in the project, some of the BOOS partners agreed to deliver more in-situ data at the requested interim scale. The status of this initiative is documented in the "Minutes of the BOOS Steering Group meeting, 3 September 2021". An automatic downloading system was developed by DMI to get access to ship CTD data on an interim scale from BOOS members (SMHI, IOW, AU, IOPAN, TalTech, FMI). In addition, NRT delivery of T/S data from 3-4 gliders from NGO VOTO has been organized by DMI. More details on this activity can be found in MS8 report, submitted Sep. 2021.

Data assimilation and interim reanalysis

Efforts were carried out to improve the physical data assimilation scheme PDAF (Parallel Data Assimilation Framework), coupled with a physical-biogeochemical model system NEMO-ERGOM. The SST and T/S assimilation, using a LESTKF scheme in PDAF, was validated and is ready to generate the interim reanalysis. The first interim experiment was designed for the period from October 2019 to December 2021 with T/S observations were collected from ICES, EMODnet and BOOS partners for assimilation. Weather, river and boundary forcing data were prepared. A test run for the period October 2019 to January 2020 using PDAF-NEMO-ERGOM and the interim analysis is expected in August 2022.

Assessment of Baltic eutrophication status

TalTech assessed the possibility of using the model and remote sensing data provided by Copernicus Marine Environment Monitoring Service (CMEMS) to calculate HELCOM eutrophication indicators and influencing hydrographic characteristics or extreme events like marine heatwaves and coastal upwelling events. Reanalysis products BALTICSEA_REANALYSIS_BIO_003_012 and BALTICSEA_REANALYSIS_PHY_003_011 together with remote sensing product SST_BAL_SST_L4_REP_OBSERVATIONS_010_016 were used for state indicators and hydrographic characteristics, respectively. Selected HELCOM eutrophication indicators were calculated following HELCOM methodology as average concentrations in the surface layer (0 – 10 m) for winter (DIN and DIP), summer (Chl-a) and whole year (TN and TP). Indicator calculations show a steady decline in concentrations of all nutrient compounds in recent years for all basins in the north-eastern Baltic Sea that is not confirmed by the measurements. We suggest a way forward for harvesting monitoring data prior to their official submission deadline and producing interim reanalysis products to improve the confidence of assessments based on CMEMS products. For occurrence and intensity of heatwaves, a climatology (1986-2020) of sea surface temperature (SST) and the 90th percentile was calculated for each grid cell in the Baltic Sea. The heatwave was identified when SST exceeded the 90th percentile value for a site and date. For upwelling, the SST data were analysed along transects from coast to coast in either North-South or East-West direction. Every grid point with the local SST value >2 °C colder than the transect average was assigned to a coastal upwelling event. The results based on two selected products (reanalysis and remote sensing) agree well except in years/seasons when the seasonal thermocline was very shallow (e.g. 2018). We demonstrate that CMEMS products covering the surface layer dynamics in the Baltic Sea (e.g. SST) can be used in describing long-term trends and inter-annual variability in hydrographic conditions (also extreme events) and serve as background information for indicator-based eutrophication assessments.

Task 6.4: System Operation

Task leader: Xylem, Partners: CSIC, MI, Co-developers: MOWI, AVRAMAR

Task 6.4 is focused on D6.4: Real-time data to central server with display to stakeholders. During this reporting period, the design and sensor selection was done in collaboration with the partners and co-developers. Each buoy has slightly different sensors based on the challenges of the stakeholder who will receive the buoy. A MOU to align expectations and obligations surrounding the systems is being worked out to ensure the value of the installed demo sites continue after the EuroSea project is completed. One data buoy was delivered to our co-developer, MOWI, in Ireland and is currently at their premises waiting deployment in April 2022. The other buoy is in production with plans to ship to Spain in April 2022. This is in support of MS22: Prototype available for validation. Other work relating to set-up a prediction system has progressed with an in-situ SST test dataset examined using a ML approach as a first step.

Cooperation and interaction with other EuroSea WPs

Co-operator	WP activities
WP1	• Best Practice process • EuroSea Workshop: Towards a Coordinated European Observing System for Marine Macroalgae[63]
WP2	• The "marine heat wave" task team - Close interaction with WP2 to discuss MHW analysis. Strategy to develop a MHW product for the NE Atlantic [common metrics, developed by Hobday et al. 2016, and parameters to calculate MHWs]. Find relevant CMEMS products in the region to test the algorithms and make some maps and investigate downscaled models in the region. Link to biological EOVs. • Discussion and exchange of information on key EOVs and indicators. Highlight any EOVs and indicators in order to connect with the ocean observing governance structure in WP2. Shared information on indicators relating to T6.1 and 5.4 • Discussion about sharing information about AI / Machine Learning approaches - to reconstruct in situ (mainly physical variables) simulated observations. Rationale document developed.

[63] https://eurosea.eu/new/workshop-towards-a-coordinated-european-observing-system-for-marine-macroalgae/

Co-operator	WP activities
WP4	• "Product specification sheets" • Pending buoy deployment in Ireland and Spain - WP4 to advise WP6 on data delivery to EMODnet via the CMEMS data pipeline • Linking products under development in WP4 with needs in WP6 (Tables - product specification sheets). Identification of how useful improved CMEMS products are in the demonstrators.
WP8	• Attendance of internal webinars on Stakeholder engagement • Input into deliverable 8.3 "Lessons learnt on science-policy interfaces" • EC exploitation webinar and several meetings on EuroSea Key exploitable results (KERs) etc. • Meet with Exploitation manager to provide information on Impact • Provided information related to co-developer e.g., YouTube channel with video tutorials about the GADGET model • Innovation & Stakeholder Committee - nominated new members e.g. Juan Fernandez Aldana (APROMAR-REMA) (Spanish aquaculture sector) • Participation in two ISC meetings in 2021 online, third ISC meeting planned to take place in person at the Annual Meeting in May 2022 • Attendance of EuroSea consortium communications training with David Rose (online) • Provision of input for news items for the first public EuroSea newsletter
WP9	• Attendance of all monthly SC meetings, the second EuroSea Anniversary Webinar, EuroSea Annual Meeting and General Assembly 2021 and preparation for the Annual Meeting and GA 2022, EuroSea EC review meeting

Cooperation and interaction with other projects and initiatives

Co-operator	WP activities
Blue-Cloud[64]	• EuroSea / Blue-cloud workshops/meetings • A EuroSea team (CSIC, MI, GEOMAR, and co-developer CGG who are working with Xylem on ML) participated in the Blue-Cloud Hackathon 7-9 February 2022. 17 January 2022 was the official launch of the BlueCloud hackathon. Outputs from the activity included an abstract, a presentation, the developed application (python) and a video pitch all created within a 48-hour period. The team's main goal was to develop a solution for the identification and prediction of Marine Heat Waves. The work carried out will be used for delivering an "Extreme Marine Event" detection system to the stakeholders as described above.
PANDORA[65]	• In this H2020 funded project the MSET tool (partly developed in the framework of EuroSea), was selected for integration into the PANDORA toolbox; a compilation of tools for improving fisheries assessment. The PANDORA toolbox will then progress toward developing an ICES toolbox in the future. [Integration of oceanographic variability into fisheries - developing environmental variability indicators and indicator visualisation in the Mediterranean, specifically linked to tuna fisheries and indicators of marine heat waves].

64 https://www.blue-cloud.org/
65 https://www.pandora-fisheries-project.eu/

Co-operator	WP activities
ICCAT[66]	• Bluefin tuna project - integrate operational oceanography into the sustainability of Bluefin tuna. Working on the ICCAT "ecosystem report cards", which will inform about other, not only species-specific, variables in fisheries, such as by-catch. SOCIB and IEO work with the ICCAT links science and stakeholders, since they are part of ICCAT advisory and compliance working groups.
HELCOM[67]	• EuroSea activities and product development presented to HELCOM community in May 2021
EC policy meeting	• Attendance and discussion on "How are EuroSea activities impacting European policy?" in a dedicated meeting with EC representatives
OceanPredict	• EuroSea/OceanPredict workshop[68] planning meetings
NAUTILOS[69]	• EuroSea-NAUTILOS thematic meeting (synergy building) on Sensors and instruments for aquaculture facilities
TechOceanS[70]	• Exchange meeting between TechOceanS and EuroSea
ICES ASC 2022	• Abstract submitted: "An assessment of extreme marine events on habitats and aquaculture off the SW coast of Ireland"
EGU[71]	• T6.1 SOCIB work on Multivariate sub-regional ocean indicators in the Mediterranean Sea: from event detection to climate change estimations, published in Frontiers in Marine Science, was presented at EGU 2021
EOOS technology forum[72]	• Attendance of the European Ocean Observing System (EOOS) Technology Forum 2022
FarFish[73]	• WP6 partners were invited to provide tutorials on CMEMS products in Fisheries research.

Achieved main results

Milestones		
MS8	Agreed products and planned services Documented	✓
MS16	System for NRT data collection from cooperation of HELCOM and BOOS is developed	✓

66 https://www.iccat.int/en/
67 https://helcom.fi/
68 https://oceanpredict.org/events/eurosea-oceanpredict-workshop-on-ocean-prediction-and-observing-system-design/#event-overview
69 https://www.nautilos-h2020.eu/
70 https://techoceans.eu/
71 https://www.egu.eu/
72 https://www.eoos-ocean.eu/events/2020-technology-forum/
73 https://www.farfish.eu/

WP7 – Ocean Climate Indicators

Lead: MOI, CO-lead: IO PAN

Objectives
• Generate a feedback loop between EuroSea, climate and ocean services, the economy sector, and decision makers by co-examining ocean climate indicators, assessing their uncertainties and quantifying their economic value
• Provide user-relevant products for ocean climate monitoring and deliver ocean forecasting indicators in support of improved ecosystem management, risk management and blue growth
• Carry out AtlantOS (H2020)[74] recommendations for observing system strategies, and demonstrate the improvements though ocean climate indicator developments with decreased uncertainty

Summary of progress towards WP objectives

Task 7.1. aims to evaluate the observing strategies and data products needed to determine the economic value of the variable ocean carbon sink of European relevant deep convections regions. The analysis is based on operational carbon assessments using a combined observing and modelling approach. The assessment of existing air-sea CO2 and interior ocean carbon storage data products, methodological approaches and the data flows are investigated. Regional high-resolution model simulations of partners are used to test different observational network strategies in the Mediterranean Sea and Labrador Sea. Techniques to estimate the time integrated ocean uptake of excess carbon (Cant) using different parameter combinations and observation platforms is further investigated.

With task 7.2, WP7 has successfully published an analysis of societally-relevant predictions of ocean variables and indicators in seasonal forecast systems. Moreover, WP7.2 has achieved major advancements with respect to stakeholder engagement activities. In particular, activities in this task included the planning, development and launch of a stakeholder engagement strategy which will lead to the creation of user-defined ocean monitoring indicators.

In task 7.3, the focus is set on the upscaling spatio-temporal coverage and quality of carbon fluxes over the tropical Atlantic. This will be achieved through a Tropical Atlantic Observing System (TAOS) optimization demonstration following an integrative multi- platform approach, and additionally aiming for closing observational gaps for carbon observations through PIRATA (pCO2 @8N38W), BGC-Argo (pH) and Autonomous Surface Vehicles (ASVs; pCO2) and neural network (CANYON). Progress in this task has been significantly affected by pandemic conditions, but a major part could be balanced through additional efforts (e.g., successful external additional funding secured for an ASV mission following withdrawal of external partner). Consequently, BGC Argo float deployments and ASV missions have been successfully performed during 2021. The extension of Brazilian PIRATA array is however subject to further delay (deployment cruise scheduled for April 2022).

[74] https://www.atlantos-h2020.eu/

Detailed progress per task (or subtasks)

Task 7.1: Carbon audit of the European relevant deep convection regions

Task leader: GEOMAR, IfW, Partners: Euro-Argo Eric, CNRS, Ifremer, DAL, MUN, MOI

One carbon-related variable that describes the integrated effect of the oceans capacity to store carbon dioxide as a result of a disequilibrium between the ocean and the atmosphere is anthropogenic carbon (C_{ant}). While C_{ant} is not directly used in the auditing process, it still is important to detect an increase/decrease in the ocean's ability to take up excess carbon from the atmosphere (Gruber et al. 2019) as this will set important boundary conditions for future atmospheric conditions which in turn impact the audit. In 7.1. advanced observational and analytical methods based on Argo float data are used to estimate C_{ant} in the North Atlantic over the period 2010-2021. The mechanisms that drive the penetration of C_{ant} at depth and its abyssal distribution in the Labrador and Irminger Seas are examined. The concentration of C_{ant} is estimated via Bayesian neural networks applied to the Argo dataset (temperature, salinity and oxygen) and using back-calculation methods. First results reveal that C_{ant} penetration increases through time and that the Labrador Sea Water plays an essential role as a deep advective route for C_{ant}.

The MOOSE-GE 2021 cruise was successfully carried out in June 2021 in the NorthWestern MedSea after delay / cancellation of the 2020 cruise due to COVID (see MS17). The biogeochemical MOOSE data is prepared following the best practice described in Jiang L.Q. (2022) to be submitted to the CARIMED dataproduct, which is the regional product of GLODAP. High-quality data products like GLODAP play a key role for carbon auditing as they can be used to train regional neural networks to increase carbon data coverage (i.e. Fourrier et al. 2020). During the MOOSE-GE 2021 cruise there was a successful collaboration with "The Ocean Race". Task 7.1 scientists supported the analysis of pCO2 measurements carried out by the sailing ship, helped to quality control the data, compare them with available data products (SOCAT) and models (Jena Carbon Scope). During this exercise the whole data flow relevant for carbon auditing was assessed. These activities were noticed by the EU ocean commissioner Virginijus Senkevičius.

To assess regional ocean carbon uptake, we obtained estimates for the country social cost of carbon (CSCC) presented by Ricke et al. (2018, 2019) who present their estimates for different SSP/RCP scenarios, different discounting scenarios, different climate impact scenarios, and different scenarios for estimating the uncertainty of climate change. We obtained for each scenario the median CSCC and applied then a resampling weighted bootstrapping approach to derive a distribution for CSCCs. The weighted bootstrapped ensured that different climate impact functions have the same probability. The obtained CSCCs have been used to assess the wealth contribution and redistribution of coastal carbon uptake. The results have been published ocean-access in Bertram et al. (2021). The publication received considerable media attention and was covered by Carbon Brief (Rickels and Quaas 2021). Currently, we are using the CSCC to assess the wealth contribution of sinks in general (i.e., also accounting for the terrestrial carbon sink) and work on obtaining data on regional marine CO2 uptake within the EEZs of countries. This work will lead to D7.5 (due in month 40).

Task 7.2: Demonstrate societal benefit of physical Ocean Monitoring and Forecasting Systems: Design of user driven products

Task leaders: CMCC, ECMWF, Partner: MOI

In collaboration with Task 4.6, Task 7.2 is developing and validating physical ocean indicators in seasonal forecast systems. Two fully-coupled and operational seasonal forecast systems (CMCC-SPS3/3.5 and ECMWF

SEAS5) are being used; the output of both is made freely available through the Copernicus Climate Change Service. The forecasts are validated against a range of long-term climate records for Essential Ocean Variables such as ocean heat content and sea level, all of which are available through CMEMS.

There are three “stages” of indicators being developed in Task 7.2:

- STAGE 1 climate indicators
- STAGE 2 complex indicators
- STAGE 3 user-defined indicators

Stage 1 indicators are existing and pre-defined indices, already used in certain regions, relevant to climate variability and change monitoring (CVC), coastal sea level (CSL), marine health (MH) and marine productivity (MP). These have been defined and presented in Milestone 11 & Deliverable 4.3 as part of WP4 Task6 (month 24, last quarter 2021). The validation of the seasonal forecast skill of these indicators is ongoing and will be presented in Deliverable 4.6 (month 36, last quarter 2022).

Stage 2 indicators consist of metrics more complex than time series of physical variables. Marine heat waves (MHWs) are an example of a Stage 2 indicator (in particular, metrics such as number of MHW days and intensity). Task 7.2 is studying the capability of seasonal forecast systems to detect MHWs and the conditions which instigate such events. The forecast skill of extreme events and their various metrics is being analysed and interpreted in terms of physical processes and model capabilities (e.g., duration or intensity).

Two studies on Stage 2 indicators have already been accepted for publication in the upcoming Copernicus Ocean State Report 6. First, forecasts of long MHWs in the North Pacific in the past decade have been analysed. Second, in collaboration with other work packages, an inter-comparison of MHW events in various long-term SST products has been performed for the Mediterranean Sea. Improved understanding of MHW detection is a vital scientific task and is also a means of identifying the most informative and clear indicators for potential users.

Meanwhile, the development of Stage 3 user-defined indicators has required a different approach to the previous two. Task 7.2 has developed a stakeholder engagement strategy which is being put into place in the second quarter of 2022. Members of 7.2 have taken part in the EuroSea stakeholder engagement strategy workshop in preparation of this task.

The first step, which is currently being undertaken, is to identify potential users and begin an effective means of communicating with them. Given that the strategy depends on the target and the aim, the focus is currently on one type of user: Marine Protected Areas (MPAs). To raise awareness of EuroSea’s seasonal forecasting work while simultaneously understanding the needs of potential uses, Task 7.2 has prepared a survey entitled “EuroSea Survey for Marine Protected Areas: Marine Seasonal Forecasting for a sustainable ocean”. The survey includes aims to understand users’ appreciation of marine products, extreme events, as well as their interests/concerns. Also included is a clear and brief description of key validation results (see Figure 26). It will be sent out to Mediterranean MPAs via contacts in the MedPan MPA network.

Once responses have been received, we will begin direct discussions with users; these discussions will be tailored to the specific user based on their survey responses. These discussions, it is hoped, will lead to co-development of marine indicators with the users. There is a potential to organise a workshop with MPAs on indicator-definition.

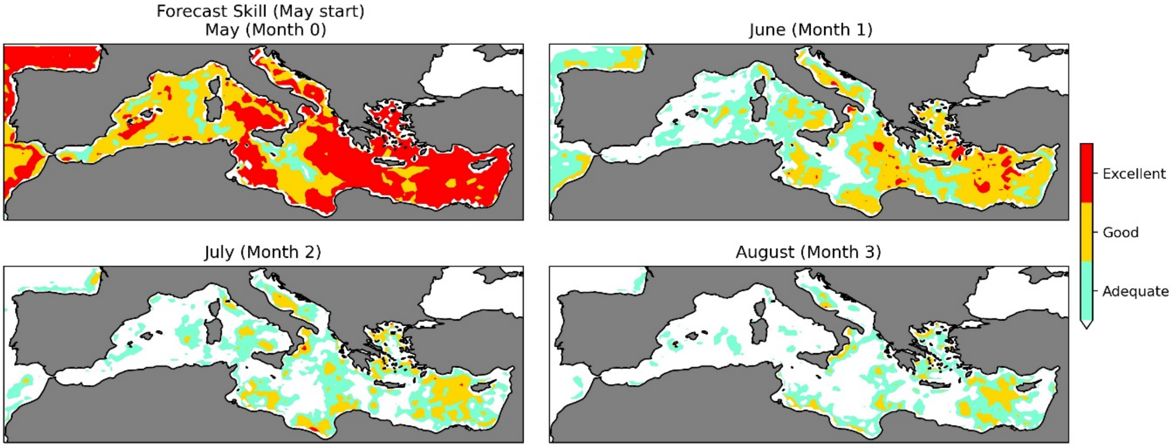


Figure 26. Anomaly Correlation Skill Score of Ocean Heat Content 0-40m in CMCC-SPS3.5 seasonal forecast system, over the period 1993-2016. It is an example of a new ocean variable being validated for Eurosea. It demonstrates the ability to make good predictions up to a season in advance in some parts of the Mediterranean Sea. Correlation score range for labels: adequate (0.4-0.6), good (0.6-0.8) & excellent (>0.8).

Task 7.3: Quality enhancement of tropical carbon fluxes through network optimization of the Tropical Atlantic Observing System

Task leader: GEOMAR, SU, Partners: Euro-Argo Eric, IRD, UERJ, UFPE

Task 7.3 – the so called "tropical Atlantic demonstrator" – will develop indicators for carbon flux at the air-sea interface and for ocean acidification based on an improved Atlantic observing system. These carbon-based indicators are of high political relevance, and are identified as a key parameter under the UN SDG framework (SDG 14), under the EC MSFD framework and for the Intergovernmental Panel on Climate Change (IPCC). Demonstrating improved quality of carbon measurements even at a regional scale would benefit the implementation of the SDG 14.3.1 indicator for ocean acidification (IOC-UNESCO). An improved network design would also benefit stakeholders such as local fishing industries by providing access to near real-time environmental data. Major advancements include:

- Clarification of technical details for CO2 sensor integration on PIRATA-BR platform
- Preparation of PIRATA-BR emergency recovery cruise; unfortunately, the cruise had to be cancelled due to technical vessel issues and loss of mooring spare parts (destroyed during fire); the northern part of the network is now not operational for more than 2 years
- Liaison with stakeholders from race sailing community for joint collection of pCO2 data (Vendée Globe 2020 and The Ocean Race 2022)
- Successful fund-raising (220.000 €) for Saildrone ASV mission to mitigate negative COVID-19 impact on the private industry (Saildrone sponsors)
- Technical integration of a VeGas pCO2 system (incl. reference gas) on a small surface buoy deployed in February 2022 at the Cape Verde Ocean Observatory
- Moorings:
    - CO2 installation at 8N38W
    - Two CO2 sensor installations along 10°W (PIRATA-FR, non-EuroSea)
    - CO2 sensor installation at CVOO (Feb. 2022, non-PIRATA)

- BGC-Argo:
    - 5x BGC Argo (incl. pH) deployed during PIRATA-FR31 (Mar. 2021)
    - 1 BGC Argo (incl. pH) deployment north Cabo Verde (May 2021, EU COMFORT)
- ASV mission (Sept. 21 – Jan. 22):
    - TAOS circumnavigation: Mooring and BGC Argo cross-validations for carbon measurements (pH & pCO2)
    - 4-month mission in the tropical Atlantic, one crossover with PIRATA-CO2 mooring (0N10W) and 4 crossovers with BGC Argo floats.
    - Currently, the saildrone heads back to the US for recovery of full (high resolution) data sets and post-calibration of CO2 data to assure highest possible quality of CO2 data.

The 5 BGC Argo floats as deployed in spring 2021 on PIRATA FR31 cruise have collected 230 profiles (40/50 each float) under a cycling frequency of 10 days, a parking depth at 1000m and performing profiles down to 1000dbar, and down to 2000 dbar once a month. First results for 3 floats show some issues, i.e. no measurements of pH for float #75, and pH measurements for floats #76 and #78 still have to be investigated for potential drifts. There had been also a successful appointment achieved between a saildrone and floats #76/77 on 16/11/2021 at ~1N18W (Figure 27), where 30 Argo profiles had been taken in vicinity of the saildrone. These new data allow for an in-depth Argo data quality assessment through the intercomparison of the independent BGC measurements. An additional expert had been hired (start March 2022) in support of this analysis, particularly to recover and process full data sets from ASV platforms and to validate the Argo data. Another appointment between a saildrone and an BGC Argo float is planned during the upcoming PIRATA FR32 cruise in spring 2022. An additional expert (hired in February 2022) will further support the analyses CO2 fluxes while applying a neural network approach (Canyon-B).

According to the challenging pandemic situation, the three deliverables for task 7.3 are on delay, i.e.: D7.1 (Report on demo mission and dissemination pathways of obtained data), D7.2 (Development of BGCArgo data quality validation based on an integrative multiplatform approach), D7.6 (Integration of in situ and satellite multi-platform data [estimation of carbon flux for trop. Atlantic])

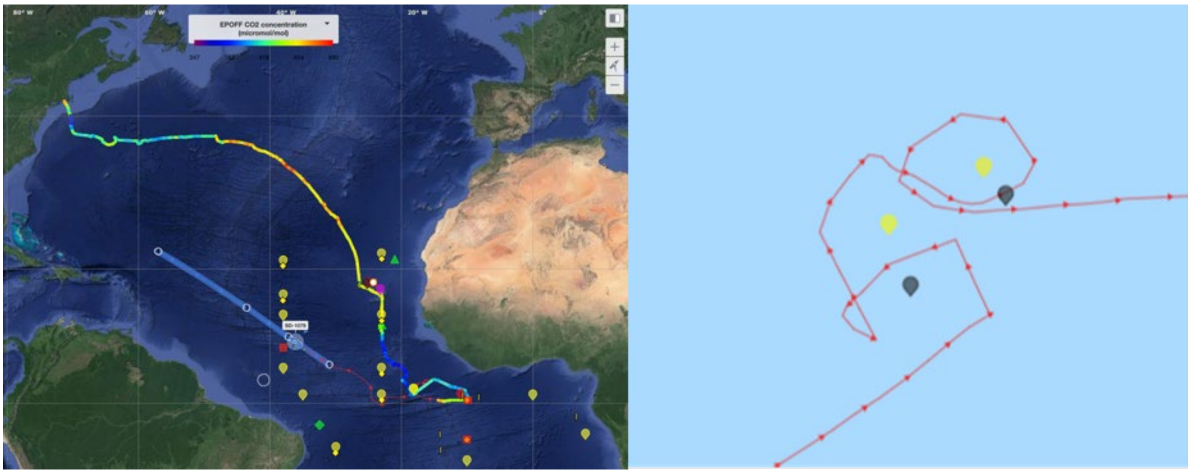


Figure 27. Left: Overview map illustrating the pCO2 measurements conducted during the multi-month EuroSea Saildrone mission across the tropical Atlantic. Right: Appointment between the saildrone and BGC floats #76/77 on 16/11/2021 at ~1N18W.

Cooperation and interaction with other EuroSea WPs

Co-operator	WP activities
WP2	• Collaboration for Marine seasonal forecasting for aquaculture, collaboration
WP3	• Interaction on OceanGliders Best Practices • Interaction with Autonomous Surface Vehicle community • Valorisation of Deep-Argo and BGC-Argo data
WP2, WP4, WP6	• Partnership in the EuroSea Marine Heat Wave task team to discuss methodology and agree on a common approach.
WP6	• Topical exchange: Marine heat waves in the Atlantic
WP1, WP3	• Best Practice documents for Salinity, Oxygen, Nitrate and Depth Average Currents covering the whole deployment cycle

Cooperation and interaction with other projects and initiatives

Co-operator	WP activities
CMEMS	• Engagement in discussions, particularly in the light of future use within the Copernicus Marine Service Ocean Monitoring Indicator framework[75]
Obs. Villefrance[76]	• Exploration of the potential of innovative neural network approaches for improved carbon auditing in the Mediterranean Sea (T7.1)
MIO[77]	• Collaborative assessment of biogeochemical glider and Argo measurements in the Mediterranean Sea to understand their potential to carbon auditing (T7.1)
Laboratoire d'Aérologie	• Collaboration in analysis of regional high-resolution BGC model simulations to make suggestions for an improved observation network for the Mediterranean Sea for carbon auditing (T7.1)
The Ocean Race	• Collaboration on pCO2 measurements on board of Sailing ship, data quality control, analysis and submission to SOCAT (T7.1, T7.3), THE OCEAN RACE - Science Report
Argo	• Collaboration with the Argo program and the Euro-Argo RISE project for the qualification of the Argo data (salinity and oxygen)
H2020 project COMFORT	• Collaboration with COMFORT project to share and QC BGC Argo Float data
Stakeholder engagement in Cabo Verde	• Collaboration with Cabo Verdean NGO "Biosfera-1" and national institute for fisheries research (IMar) regarding data sharing from the EuroSea Saildrone mission (e.g. providing data to local students for M.Sc. theses).
IIM Vigo (Spain), LOPS (France), OVIDE/BOCATS project	• Collaboration in analysis and interpretation of C_{ant} data collected in the subpolar gyre of the North-Atlantic along the OVIDE line since 2002 and more specifically during the OVIDE-BOCATS cruise conducted in 2018.

[75] https://marine.copernicus.eu/science-learning/ocean-monitoring-indicators/
[76] Observatoire Océanologique de Villefranche-sur-Mer, http://oov.obs-vlfr.fr/
[77] Mediterranean Institute of Oceanography, https://www.mio.osupytheas.fr/en

Co-operator	WP activities
Capo Carbonara and Torre Guaceto Marine Protected Areas	• Marine Protected Areas (T7.2)

Achieved main results

Others (optional)		
	Subpolar North Atlantic cruise	✓
	Analysis of approaches to conduct the carbon uptake variability	✓
	Strategy development for Exclusive Economic Zone (EEZ) assessments	✓
	Secured co-funding for Saildrone mission	✓
	EuroSea Saildrone mission in tropical Atlantic accomplished	✓

WP8 - Communication: Engagement, Dissemination, Exploitation, and Legacy

Lead: EuroGOOS, CO-lead: GEOMAR

Objectives
• Deliver professional communications, stakeholder engagement and business exploitation support to the project and its demonstrators
• Enhance collaborative, inclusive, and strategic stakeholder dialogue that moves beyond stakeholder consultation towards co-design
• Enable exploitation of the project's results and products in business sector, sustainable strategic partnerships and governance, as well as strategic foresight
• Provide tangible support and guidelines on intellectual property rights and business development along the Responsible Research and Innovation principles and best practice in knowledge and technology transfer
• Support capacity building to empower strategic partnerships, support business development and communicate achievements effectively
• Ensure the project's legacy is sustained with consolidated contributions to short, medium and long-term project's goals

Summary of progress towards WP objectives

Engagement activities (task 8.1) foster interfaces and partnerships with the project's stakeholders and users: During the reporting period, stakeholder engagement was conducted via online workshops and events, most notable of those are: the EuroSea policy meeting in September 2021 and the EOOS Technology Forum foresight workshop in March 2022 (The EuroSea Anniversary Webinar is mentioned under Task 8.4). WP8 supported these events, organised respectively by WP9 and WP1, through promotion and participation. Planning is well underway during the time of this report for a science-policy dialogue at the European Maritime Day stakeholder conference, through a workshop co-organized by EuroSea, EMODnet, and Blue Cloud, titled 'Ocean observing, marine data and services for the European Green Deal'. A related deliverable on "Lessons learnt on Science-Policy interfaces" (D8.3) is currently in preparation and will be submitted in May 2022. Planning and conduction of activities related to the report on "Lessons learnt from the EuroSea public engagement activities" (D8.5) have advanced.

Various dissemination activities have been conducted to date to promote the project and its demos to policy makers, industry and scientific users, and the general public (task 8.2). During the reporting period, WP8 produced a EuroSea Communication Kit with all EuroSea dissemination resources in one place. As of 29 March 2022, 43 news articles have been published on the EuroSea website. The EuroSea Twitter account has 1.140 followers. The EuroSea YouTube channel has 4 new videos with 943 new views.

Furthermore, the exploitation of both the project and the demonstrations' results have advanced substantially by supporting the production of exploitation plans within each of the demonstrator work packages and the production of business plans for commercially exploitable products and services (task 8.3). As part of the used Horizon Results Booster service an EuroSea exploitation strategy with focus on three key exploitable results having commercial potential was developed. Workshops were held with demo WPs to develop activities towards commercialisation. Feedback on these developments was obtained from the EuroSea Innovation and Stakeholder Committee (ISC) during two dedicated meetings.

In order to distil and sustain the legacy of the project (task 8.4), provide advice on the guiding principles for Responsible Research and Innovation (RRI) and best practices for knowledge and technology transfer, and ensure that the project's findings and legacy are incorporated into relevant policy agendas, various efforts were also made during this reporting period: The 2nd Anniversary Webinar took place with the objective to take stock of the EuroSea progress towards sustained legacy and discuss this with stakeholders. Besides, the impact protocol was implemented through the impact monitoring table, which will be fed into a new impact web page.

Detailed progress per task (or subtasks)

Task 8.0 Coordination

The WP8 coordination led the WP across its objectives and the four main tasks. In the reporting period, all EuroSea Steering Committee meetings were attended by WP8 co-leaders with relevant reports presented as required. Six WP8 team meetings took place. A communications training was conducted for the consortium in February 2022 and received very positive feedback. The training addressed how to make clear and impactful presentations (including, structuring, messaging, timing, voice, interactivity) and to produce recorded presentations which can then be widely shared. Connections were strengthened with other related EU projects as well as with the European Commission. The task has also supported a successful re-allocation of funds among WP8 partners due to the departure of one WP8 member and a substantial reduction of contributions from another one.

Task 8.1: Engagement

Task leader: EuroGOOS, GEOMAR, Partners: SciencEthics, MI, RBINS, ISPRA, SOCIB

This task helped promote engagements and co-organised events with other WPs. Most notable events include: the EuroSea policy meeting by WP9 (September 2021), the UN Ocean Decade Laboratory workshop by WP5 (January 2022), the EOOS Technology Forum foresight workshop by WP1 (March 2022). Furthermore, engagement with the next generation of stakeholders (towards WP8 D8.11) has started. Students of the European SEA-EU inter-university initiative have been invited to participate in the EuroSea Annual Meeting 2022 (May 2022) and act as co-rapporteurs and participants in various thematic workshops. Planning is underway for a science-policy dialogue at the European Maritime Day stakeholder conference (19-20 May 2022), through a workshop co-organized by EuroSea, EMODnet, and Blue Cloud, titled 'Ocean observing, marine data and services for the European Green Deal'. Deliverable 8.3 Lessons learnt on Science-Policy interface is underway; planning for Deliverable 8.7 Lessons learnt from Public-Private interface has started.

Task 8.2: Dissemination

Task leader: SOCIB, RBINS, Partners: EuroGOOS, GEOMAR

A EuroSea Communication Kit[78] was developed in June 2021 to bring together all the dissemination and communication tools and promotion materials of the project in one place. This kit collects all EuroSea dissemination resources from links to videos & presentations, roll-up or a virtual meeting background. This document also includes a short introduction to EuroSea to help consortium partners communicate about the project. Contact details for media requests are also included, as well as the EuroSea project accounts on social media.

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[78] https://eurosea.eu/download/outputs_and_reports/EuroSea_Communications_Kit_June2021.pdf

The EuroSea website[79] continues to represent a key instrument in the EuroSea dissemination activities. A total of 43 news articles have been published on the EuroSea website between January 2021 and March 2022. Another communication instrument is the EuroSea Twitter account[80]. The account has reached 1.140 followers (as of 29 March 2022). The activity on the EuroSea YouTube channel[81] in the reporting period has included 4 new videos, representing 943 new views and 14 new subscribers. The first public newsletter was released during the reporting period.

In order to enrich the EuroSea communication channels and streamline the flow of information from the consortium to WP8, the EuroSea call for content form[82] has been created, through which all the consortium members inform WP8 about their content proposals, such as scientific discoveries, events, case studies, etc. for dissemination of their work through the EuroSea website, newsletter and social media.

In relation to the project's dissemination activities, a EuroSea Dissemination activities form[83] has been created to track all dissemination activities directly linked to the project.

WP8 has met with other WPs to jointly plan or execute the promotion of new EuroSea tools. For example, an outreach plan for the OSPAC system or the sea-level-rise prediction tool.

Task 8.3: Exploitation
Task leader: MI, Partners: ISPRA, SciencEthics

During the period from January 2021 to March 2022 (time of the submission of this report), exploitation task partners used services provided through the Horizon Results Booster platform to assist with the development of the EuroSea exploitation strategy. This service focussed on the commercial exploitation of EuroSea results and helped to improve the exploitation strategy. Three key exploitable results from the demonstration work packages were identified as having commercialisation potential and these were the focus for the HRB services. These were:

- Oceanographic Services for Ports And Cities (OSPAC software) – real time alert to provide forecast of sea conditions (WP5);
- Solution for marine sensors to measure and forecast oxygen, heat and pH related Extreme Marine Events onsite for aquaculture – monitoring system for extreme marine events at aquaculture sites (WP6);
- Low maintenance tide gauges (WP5).

For each of these key exploitable results, information tables were prepared on characterisation of the result, risk assessment and priority mapping, exploitation roadmap and use options. Exploitation strategy workshops were organised to further analyse options for exploitation. For the OSPAC software and the solution to measure extreme marine events for aquaculture workshops were held on 18 and 19 February 2021 respectively; for the tide gauges the workshop was held on 11 June 2021. This helped the demo WPs to better understand the various exploitation and dissemination needs and prepare exploitation and risk

79 https://eurosea.eu/
80 https://twitter.com/Euro_Sea
81 https://www.youtube.com/channel/UCS4yuekKpYA8QVtr7vrl50Q
82 https://docs.google.com/forms/d/e/1FAIpQLSeFf-j-ebtHLf-mTocb2mHxIuPqkCspDbmicOYqlnn_Q1fHfA/viewform
83 https://docs.google.com/forms/d/e/1FAIpQLSdFc1rkZwIMPvHehS-cZTUYwwR6y8hKbX0cqjWFsgLPUeXU8g/viewform

mapping. During the webinars feedback was provided by the experts to the relevant partners and several areas of importance were discussed.

In addition to the three key exploitable results outlined above, the exploitation was also analysed for the prototype sea level planning and scenario visualisation tool (WP5). This is another EuroSea result that has significant potential for commercialisation.

Over the period from January 2021 to March 2022, the Innovation and Stakeholder Committee had two virtual meetings (26 February 2021 and 2 November 2021). In advance of both of these meetings an updated draft of the exploitation strategy was sent to the ISC members to review and provide comments. The exploitation strategy was discussed at these meetings and useful feedback was provided on it.

The output from this work formed the basis for Deliverable 8.3 on the EuroSea Exploitation Strategy, submitted in October 2021. For the subtask on the economic value of ocean observations, a concept note was developed describing the structure of the deliverable report and an outline of the content.

Task 8.4: Sustaining legacy

Task leader: SciencEthics to EuroGOOS, Partners: ISPRA, SOCIB, RBINS, MI, EuroGOOS, GEOMAR

The main activities of this task in the reporting period include the 2nd Anniversary Webinar and the Impact monitoring.

The 2nd Anniversary Webinar took place on 25 November 2021 as a two-hour event. The main objective of the anniversary webinars scheme is to annually, in the month when EuroSea began its work, take stock of the progress and pathway towards impact. These webinars are designed to plan the EuroSea legacy from the start and discuss the ways to achieve it with the EuroSea stakeholders and targets (as defined in the communications plan).

The 2nd Anniversary Webinar[84] was broadly disseminated on the website. The Twitter posts had a significant reach and the outreach campaign of the webinar brought numerous new followers.

The programme[85] was introduced with a keynote from OECD on the impact valuation of the ocean observing enterprise. Two sessions titled 'Planning the Legacy' followed featuring talks and panel discussions from the EuroSea partners. The last session concluded the event discussing the EuroSea role in the European and global ocean observing and forecasting landscape.

Some statistics from the webinar include:

- Webinar announcement flyer was downloaded from the website 646 times
- The programme was downloaded 457 times
- Twitter impressions on the day were close to 3K; retweets and engagements were from notable EuroSea stakeholders including the European Commission and various EU and global projects and initiatives

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[84] https://eurosea.eu/new/recording-of-the-eurosea-2nd-anniversary-webinar-planning-the-legacy-for-european-and-global-ocean-observing-system-improvements/

[85] https://eurosea.eu/new/registration-open-for-the-2nd-anniversary-webinar-of-eurosea-on-25-november/

- The webinar was attended by 90 participants, spanning the EuroSea community, related other projects and organisations, the European Commission, and members of the EuroSea external boards. The webinar was re-watched on YouTube 33 times.

The EuroSea impact protocol was further improved. The methodology for the development of the protocol was documented and presented previously to ISTAB and the Commission. The Commission review highlighted the impact protocol among the most noteworthy achievements of the project in the interim evaluation.

In the reporting period, the protocol was discussed with the EuroSea general assembly and subsequently implemented by all WPs, via an impact table. Once the table was completed, the leader of WP8 and the EuroSea exploitation manager distilled the inputs to arrive at a solid list of measurable impacts. During this work the impact areas were also slightly re-organized to arrive at a smaller and better formulated number of areas. The next version of the impact table and the list of areas (now, 8) were validated with the consortium and completed. The impact areas include:

1. Improve integration and coordination of various components of the European observing system and strengthen GOOS
2. Increase data sharing and integration
3. Deliver improved climate change predictions
4. Build capacity, internally in EuroSea and externally with EuroSea users, in a range of EuroSea areas
5. Develop innovation, including exploitation of novel ideas or concepts; shorten the time span between research and innovation and foster economic value in the blue economy
6. Facilitate methodologies, best practices, and knowledge transfer in ocean observing and forecasting
7. Contribute to policy making in research, innovation, and technology
8. Raise awareness of the need for a fit for purpose, sustained, observing and forecasting system in Europe

In each area at least one measurable impact (but in most cases more than one) has been validated for monitoring. Work continues on monitoring the progress in this list of impacts.

The impact areas have been included in the EuroSea deliverable template and the periodic reports. In Spring 2022, the table will be transferred to a web interface. The interface will have a front end visible to the visitors of the EuroSea website and a back end which the consortium will be updating as new measures of impact become available (e.g. statistics). A workshop titled EuroSea Impact and Legacy is being prepared as part of the EuroSea Annual Meeting week in May 2022.

D8.9 EuroSea recommendations on RRI in Ocean Observing is underway and a questionnaire is prepared for the EuroSea Annual Meeting in May 2022.

Cooperation and interaction with other EuroSea WPs

The WP8 is intrinsically based on cooperation with all consortium partners. Interactions are often fast and efficient thanks to the personal knowledge of each other in the consortium, despite it being a very big partnership. Not all interactions are listed below, since they are not all monitored and sometimes happen quickly and informally.

Co-operator	WP activities
WP1	• Preparation and dissemination of EuroSea news articles, among others, on Workshop for European marine microalgae observing system (Sept. 2021), EOOS governance (Sept. 2021), UN Ocean Decade Laboratory event on Integrated Marine Debris Observing System (Oct. 2021), EOOS/GOOS national focal points report (May 2021), EOOS Technology Forum (Dec. 2021 -March 2022), EuroSea/OceanPredict workshop (February 2022)
WP2	• Preparation and dissemination of EuroSea news article on In situ observations for new satellite altimetry mission (Sept. 2021)
WP3	• Preparation and dissemination of EuroSea news articles, among others,on EuroSea Tide Gauge Workshop (Jan. 2021), High Frequency Radar and FerryBox joint workshop (Feb. 2021), EuroSea Eulerian Workshop (Feb. 2021), OceanGliders Best Practices Workshop (March 2021), Autonomous Surface Vehicles workshop (Aug. 2021), Biogeochemical Argo workshop (Aug. 2021), OceanGliders Oxygen Standard Operating Procedure consultation (Oct. 2021), Global sea level data portal (Nov. 2021), OceanGliders Salinity Standard Operating Procedure consultation (Dec. 2021), Sea-level rise insights tool (Jan. 2022), Paper on science integration / Task 3.9 (Feb. 2022)
WP5	• Preparation & dissemination of EuroSea news articles, among others, on UN Ocean Decade Laboratory EuroSea event on Predicting Sea Level Rise (Sept. 2021), Presentation of EuroSea sea level tool at UK Parliamentary committee (Feb. 2022), Interview with WP5 leader Angela Hibbert (Feb. 2022) • Communication and dissemination actions of the video on Sea level rise insights tool • Outreach support towards the OSPAC tool (Oceanographic Services at the service of Ports and Cities) • Joint dissemination of news about the presentation of WP5 sea level insights tool at the UK Parliamentary Committee • Organisation of exploitation strategy seminars for the OSPAC software and the low maintenance tide gauges • Support for the exploitation of the prototype sea level planning and scenario visualisation tool
WP6	• Preparation and dissemination of EuroSea news article on Services to prepare for extreme marine events (June 2021) • Organisation of an exploitation strategy seminar on the monitoring system for extreme marine events at aquaculture sites.
WP7	• Preparation and dissemination of EuroSea news article on Ocean carbon measurements as part of Ocean Race (Dec. 2021) • Exploitation support for the user-driven calibrated seasonal forecast ocean indicators for reliable decision making
WP9	• Preparation and dissemination of EuroSea news article Horizon Results Booster policy brief[86] led by EuroSea (Oct. 2021); all major EuroSea events, e.g. Annual Meeting and Anniversary Webinar.

[86] https://doi.org/10.5281/zenodo.5576120

Cooperation and interaction with other projects and initiatives

Co-operator	WP activities
Projects in Horizon Results Booster: ATLAS, iAtlantic, NAUTILOS, EUROFLEETS AtlantECO, Blue-Cloud, Odyssea	• Policy brief[87] and preparatory work for the EMD2022 workshop
NAUTILOS	• Meeting on joint communication and stakeholder engagement activities
EMODnet and Blue Cloud	• Joint workshop at EMD2022
TechOceans	• Meeting on joint priorities
The Ocean Race	• Communication for the press release on observations and reports. Preparation & dissemination of a EuroSea news article.
Federal Ministry of Education and Research, Germany	• Video about EuroSea as joint project in the European Research area

Achieved main results

Deliverables		
D8.4	Project exploitation strategy	✓

[87] https://doi.org/10.5281/zenodo.5576120

WP9 - Project Coordination, Management and strategic ocean observing alliance

Lead: GEOMAR

Objectives
• Provide top level management of the project to ensure aims of the project are efficiently and effectively met, on time and with the resources budgeted and that knowledge and innovation are properly managed
• Provide effective reporting and communication within the project, between partners and stakeholders and between the consortium and the EC
• Provide support for and activities aimed at project internal integration
• Provide connections and interfaces with other projects funded under this topic

Summary of progress towards WP objectives

The Project Coordination Unit (PCU) continued to provide efficient overall scientific and administrative management of the project during this reporting period. The regular monthly meetings with the Steering Committee were continued. The regular exchange about progress, potential for improvement and problems with the co-/leaders of the individual work packages again formed the basis for successful and coordinated cooperation at all organisational levels. The first general project report was submitted in June 2021 and subsequently accepted by the European Commission. All deliverables and milestones of this first reporting period were also accepted and rated as qualitatively very good by the evaluators.

Detailed progress per task (or subtasks)

Task 9.1: Project coordination and management

Task leader: GEOMAR

The PCU has continued and optimised its administrative, coordinating and advisory support to all project partners. In June 2021, the first official Periodic Report for the first 18 project months was submitted to the European Commission. The project and all submitted documents were highly evaluated by the external reviewers. The regular communication with the responsible project officer at the European Commission was continued. One amendment request has been successfully implemented and another is currently in preparation.

Beyond this formal regular communication with the funding agency, there was also a policy review/feedback meeting in October 2021 to assess and discuss the substantive contribution of the EuroSea project to the current and future EC missions and initiatives. This meeting was initiated by the responsible EuroSea policy officer at the European Commission and it was organized and coordinated by the PCU. In addition to all work package leaders and the EuroSea project coordination, representatives of different Directorates General (DG RTD, DG DEFIS, DG ENV, DG MARE) participated in this meeting.

Internally, the proven monthly meetings with all WP leaders and their co-leaders were continued. The regularity of these meetings made it possible, among other things, to maintain a regular exchange across work package boundaries. Also continued was the sending of short internal newsletters to the whole consortium and the advisory boards, in which all persons working in the different tasks of the project receive a short personal view on general current aspects in the field of ocean observing and forecasting by the project coordinator as well as a short update from the project coordination and communication by the project manager.

In addition, the PCU endeavours to review all reports (deliverables and milestone reports) to be submitted not only in terms of form but also in terms of content and to provide constructive feedback. This requires and promotes the equally important communication with those not acting at Steering Committee level (WP co-/leaders) and provides the PCU with valuable insights into the various tasks of the work packages and beyond.

Furthermore, all structures for fast communication and exchange with the consortium are maintained and regularly updated (mailing lists, cloud, reminders, calendar).

Task 9.2: Interfaces to other projects under this topic
Task leader: GEOMAR, Partners: HCMR, IFREMER

The Horizon Results Booster (HRB) activities continued in 2021. Under the lead of the EuroSea project, the group published a joint policy brief listing recommendations for sustainable ocean observation and management with the title “Nourishing Blue Economy and Sharing Ocean Knowledge”[88].

In addition, targeted meetings with the sister projects TechOceanS and NautilOS were initiated on the part of the project coordination. While the meeting with TechOceanS was at the coordination level, meetings were held with NAUTILOS on 5 different common areas of interest, involving participants from different task areas of both projects:

- Technical work in instrumental development and application
- Forecasting
- Sensors and instruments for aquaculture facilities
- Observation System Design
- Joint communication and stakeholder engagement activities

Although some opportunities for collaboration were identified in the process, however, more intensive collaboration has not yet occurred. This is mainly due to the size of the projects and consortia and the very ambitious project plans, which at the moment have hardly any free capacity for additional tasks and the implementation of new ideas. Nevertheless, communication between the projects is maintained and there is still the possibility of future collaboration.

In order to support mutual information and exchange on projects with similar or related focus, several projects were invited to the virtual EuroSea Annual Meeting 2021. In a dedicated session 10 projects were presented to the EuroSea consortium and questions were answered:

- EUMarine Robots
- NautilOS
- Eurofleets+
- Jerico-S3
- OceanPredict
- ODYSSEA

[88] https://doi.org/10.5281/zenodo.5576120

- iAtlantic
- AtlantECO
- Mission Atlantic
- Blue-Cloud

EuroSea has also applied for, and was granted, the Horizon Results Booster (see also WP8 progress above). We have now initiated a cluster group within module A and B consisting of 9 EU funded projects with focus on ocean science and touchpoints on ocean observing and forecasting (Table 4). This cluster includes, among others, the newly started project NautilOS that was also funded under the BG7 call, focusing on technology for ocean observing. In a first virtual meeting on 14 December 2020 with almost all projects represented, a first exchange about common objectives, stakeholders and overarching goals took place.

Cooperation and interaction with other EuroSea WPs

Co-operator	WP activities
All WPs	• Day-to-day communication • Organization of SC meetings • Informal interaction during the weekly virtual EuroSea coffee corner • Maintenance of project mailing lists and project cloud space

Cooperation and interaction with other projects and initiatives

Co-operator	WP activities
HRB projects	• Joint publication of policy brief "Nourishing Blue Economy and Sharing Ocean Knowledge"[89].
TechOceanS, NautilOS	• Synergy meetings
EUMarine Robots, Jerico-S3, OceanPredict, Mission Atlantic, Blue-Cloud	• Presentation at virtual EuroSea Annual Meeting 2021
NautilOS, Eurofleets+, iAtlantic, ODYSSEA, AtlantECO	• Presentation at virtual EuroSea Annual Meeting 2021 • Contribution to workshop about "Ocean observations, marine data and services for the European Green Deal" at European Maritime Day 2022
Blue-Cloud	• Synergy meetings • Memorandum of Understanding • Organisation of joint workshop about "Ocean observations, marine data and services for the European Green Deal" at European Maritime Day 2022
EMODnet	• Organisation of joint workshop about "Ocean observations, marine data and services for the European Green Deal" at European Maritime Day 2022

[89] https://doi.org/10.5281/zenodo.5576120

Co-operator	WP activities
Arctic Passion	• Synergy meeting on coordination level

Achieved main results

Deliverables		
D9.2	Action Progress Report #2	✓
Others (optional)		
	Policy brief	✓

WP10 – Ethics Requirements

Lead: GEOMAR

Objectives
• Ensure compliance with the 'ethics requirements' set out in this work package

Summary of progress towards WP objectives

No new activities were carried out under this work package during the reporting period.

3. Dissemination

Scientific publications

- Pearlman J, Buttigieg PL, Bushnell M, Delgado C, Hermes J, Heslop E, Hörstmann C, Isensee K, Karstensen J, Lambert A, Lara-Lopez A, Muller-Karger F, Munoz Mas C, Pearlman F, Pissierssens P, Przeslawski R, Simpson P, van Stavel J and Venkatesan R (2021) Evolving and Sustaining Ocean Best Practices to Enable Interoperability in the UN Decade of Ocean Science for Sustainable Development. Frontier in Marine Science, 8:619685. doi: 10.3389/fmars.2021.619685 https://www.frontiersin.org/articles/10.3389/fmars.2021.619685/; AWI, EuroGOOS, GEOMAR, IEEE, IOC/ UNESCO, UiB (WP1)
- Hörstmann C, Buttigieg PL,Simpson P, Pearlman J and Waite AM (2021) Perspectives on Documenting Methods to Create Ocean Best Practices. Frontiers in Marine Science, 7:556234.doi: 10.3389/fmars.2020.556234 https://www.frontiersin.org/articles/10.3389/fmars.2020.556234/; AWI, IEEE, IOC/ UNESCO (WP1)
- Révelard A, Tintoré J, Verron J, Bahurel P, Barth JA, Belbéoch M, Heslop E, Hörstmann C, Karstensen J, Pearlman J, and Williams B (2022) Ocean Integration: The Needs and Challenges of Effective Coordination Within the Ocean Observing System. Frontiers in Marine Science, 8:737671. doi: 10.3389/fmars.2021.737671 https://www.frontiersin.org/articles/10.3389/fmars.2021.737671; GEOMAR, HCMR, IEEE, IFREMER, IOC/ UNESCO, NOC, SOCIB, UNIBO (WP1, WP3)
- Maximenko, N., A.P. Palacz, et al. (2021). An integrated observing system for monitoring marine debris and biodiversity. Pp. 52–59 in Frontiers in Ocean Observing: Documenting Ecosystems, Understanding Environmental Changes, Forecasting Hazards. E.S. Kappel, S.K. Juniper, S. Seeyave, E. Smith, and M. Visbeck, eds, A Supplement to Oceanography 34(4), https://doi.org/10.5670/oceanog.2021.supplement.02-22
- Juza, M. and Tintoré, J. (2021). Multivariate sub-regional ocean indicators in the Mediterranean Sea: from event detection to climate change estimations, Frontiers in Marine Science, 8:610589, https://doi.org/10.3389/fmars.2021.610589. ; SOCIB (WP6)
- Juza, M., Fernández-Mora, A., and Tintoré, J. (2022). Sub-regional marine heat waves in the Mediterranean Sea from observations: long-term surface changes, sub-surface and coastal responses, Front. Mar. Sci., https://www.frontiersin.org/articles/10.3389/fmars.2022.785771/full ; SOCIB (WP6)

Presentations

- "Ocean Best Practices System: Toward sustainability in ocean observing methods", 02/03/2021, ESIP Sensors 2021; IEEE (WP1)
- "IOC Ocean Best Practices System (OBPS) & Citizen Science", 05/05/2021, EuroGOOS International conference; GEOMAR, IEEE (WP1, WP3)
- Buttigieg, P.L.; Horstmann, C.; Simpson, P. and Pearlman, J. (2021) Evolving the UNESCO/IOC Ocean Best Practices System: preparing methods for the oceans' digital ecosystem, IMDIS 2021 [online], 12/04/2021; AWI, IEEE (WP1)
- van Stavel et al., "Towards an increase in Diversity, Equity and Inclusion in international ocean observing practices and initiatives", OCEAN Sep 2021 MTS/IEEE Conference, 20/09/2021-24/09/2021; AWI, IEEE (WP1)

- C. Munoz-Mas et al., "Best Practices uptake process across the Ocean Observing Community," OCEAN Sep 2021 MTS/IEEE Conference, 20/09/2021-24/09/2021; AWI, AZTI, GEOMAR, IEEE, IOC/ UNESCO, UiB (WP1)
- "Digitising methodologies and catalysing best practice development and exchange", 14/02/2022, International Ocean Data Conference, Poland, Feb 2022; AWI, GEOMAR, IEEE, IOC/ UNESCO (WP1)
- "Towards best practices for global interoperable coastal ocean observing and forecasting", 21/02/2022, OCEAN 2022; AWI, EuroGOOS, GEOMAR, IEEE, IOC/ UNESCO (WP1)
- Ocean Sciences Meeting 2022 presentation, 03/03/2022; EuroGOOS (WP1)
- "Ocean Best Practices System (OBPS) overview and recommendations for creating Best Practices documents", 11/05/2021, EuroSea OceanGliders Best Practices Workshop; GEOMAR, IEEE, IOC/ UNESCO (WP1)
- "Introduction to the use of CMEMS in fisheries science", 29/09/2021, "The FarFish Data Limited Methods Course", UNESCO GRÓ Fisheries Training Programme workshop; CSIC (WP6)
- Pearlman, J., Karstensen, J. and Simpson, P. (2021) "IOC Ocean Best Practices System (OBPS) overview and recommendations", 1st Autonomous Surface Vehicles (ASV) Network EuroSea workshop, 05/10/2021-06/10/202; GEOMAR, IEEE, IOC/ UNESCO (WP1, WP3)
- "Ocean Best Practices System (OBPS) overview and recommendations for creating Best Practices documents", 08/03/2021, EuroSea WP3 Workshop; GEOMAR, IEEE (WP1, WP3)
- "Ocean Best Practices System (OBPS) overview and recommendations for creating Best Practices documents", 25/03/2021, EuroSea WP6 Meeting; GEOMAR, IEEE, IOC/ UNESCO (WP1, WP3, WP6)
- Oral presentation about results from T2.3 (Observing System Simulation Experiments: impact of multi-platform observations for the validation of satellite observations), 03/06/2021, SWOT Science Team Regional Validation working group meeting; CSIC (WP2)
- Participation in trade fair with virtual stand on "Researching the ocean, sharing the future", 03/06/2021-06/06/2021, Balearic Yatch Show 2021; SOCIB (WP8)
- Pascual, A., B. Barceló-Llull and E. Cutolo, oral presentation about "Summary and advances in inversion activities at IMEDEA. Finescale ocean currents in the Med Sea.", SWOT Inversion Working Group meeting, 13/10/2021; CSIC (WP2)
- "Design of multi-platform sampling strategies for reconstruction of fine-scale ocean currents", 12/04/2022-13/04/2022, 8th meeting of the COSS-TT: International Coordination Meeting; CSIC (WP2)
- Nico Lange, Toste Tanhua, Benjamin Pfeil, Siv Lauvset, Are Olsen, Dorothee Bakker, Björn Fiedler, Annette Kock, Henry Bittig, Reiner Schlitzer, Arne Kötzinger (2022). Towards a comprehensive, FAIR, ocean biogeochemical data product system, International Ocean Data Conference 2022, Sopot Poland, 14/02/2022-16/02/2022, session 2 sub item 2.4; GEOMAR (WP4)
- Nico Lange, Angelique White, Björn Fiedler, Frank Muller-Karger, Kim Currie, Laurent Coppola, Marta Álvarez, Masahide Wakita, Melchor Gonzales, Sólveig Rósa Ólafsdóttir, Arne Körtzinger, Benjamin Pfeil, Toste Tanhua (2022). Towards a Data Synthesis Product Pilot for Ship-Based Biogeochemical Time-Series Stations, Ocean Science Meeting, 24/02/2022-04/03/2022; GEOMAR (WP4)

Other dissemination and communication activities

- Photo exhibition "Researching the ocean, sharing the future", 24/09/2021 European Researchers' Night & Mediterranean Coast Day, Escalera Real of the port of Palma (Majorca Balearic Islands), SOCIB News article, SOCIB Tweet; SOCIB (WP8)

- Photo exhibition "Researching the ocean, sharing the future", 04/11/2021-26/11/2021, Semana de la Ciencia y Tecnología del CSIC (Science week), SOCIB news article, SOCIB Tweet; SOCIB, WP8
- News article at SOCIB website: Expanding Europe's ocean observing and forecasting capacity: SOCIB at the 9th EuroGOOS International Conference, 05/05/2021; SOCIB (WP8)
- "An Ocean of Values: the 5th Community Workshop of the IOC-UNESCO Ocean Best Practices System", [ONLINE], 20/09/2021-24/09/2021; AWI, EuroGOOS, GEOMAR, IEEE, IOC/ UNESCO, NIVA, UiB (WP1, WP3)
- Publication of joint policy brief "Nourishing Blue Economy and Sharing Ocean Knowledge – Ocean information for sustainable development"", 15/10/2022; GEOMAR, EuroGOOS, SOCIB, ISPRA, Marine Institute, RBINS (WP9, WP8)
- Co-organisation and dissemination of and presentation at the UN Decade Satellite event "One Integrated Marine Debris Observing System for a Clean Ocean"; (WP1)
- Organisation of a 3-day virtual Workshop: "Towards a Coordinated European Observing System for Marine Macroalgae", 23/11/2021-25/11/2021; IOC/ UNESCO (WP1)
- Organisation of a Workshop on "Ocean Prediction and Observing System Design", (Emails, social media posting, website, workshop registration and abstract submission announcement), 11/03/2022-14/03/2022; Met Office (WP1)
- Organisation of an Online Workshop "Top 100 Priority questions for conservation and monitoring of seagrass in Europe", 20/03/2022-26/03/2022; IOC/ UNESCO (WP1)
- Organisation of the "EOOS Technology Forum 2022 Workshop", 22/03/2022-24/03/2022; EuroGOOS (WP1)
- Outreach activity – Speed dating with scientists: 'Ocean observations. The EuroSea Project'. At the European Researchers' Night, Palma de Mallorca, Spain, 24/09/2021; Ananda Pascual, CSIC (WP2)
- Presse release about the Saildrone mission conducted as part of WP7, 01/10/2021-31/12/2021; GEOMAR (WP8, WP9)
- Web news about the policy brief for 'Nourishing Blue Economy and Sharing Ocean Knowledge', 15/10/2021; OGS (WP3, WP4)
- Post on LinkdedIn: Policy Brief 'Nourishing Blue Economy and Sharing Ocean Knowledge' was presented to the EU.,26/10/2021; OGS (WP3, WP4)
- News article and Tweet about 2nd EuroSea Annual Meeting and General Assembly, 02/02/2021; SOCIB (WP8)
- New access to Euro-Argo ERIC data, 10/11/2021; Euro-Argo ERIC (WP3, WP7)
- Release and social media launch of new EOOS website, 15/01/2022-17/03/2022; EuroGOOS (WP1)
- News article and Tweet: "The ocean needs integration to optimally combine multiple sources of data", 25/01/2022; SOCIB (WP8)
- Implementation of web-based application and publication "Marine heat waves in the Mediterranaen Sea", 02/03/2022; SOCIB (WP6)

All public EuroSea deliverables are available on the EuroSea website[90]

[90] https://eurosea.eu/

Conclusion

The EuroSea project is mainly evolving and progressing as planned. On a few areas, EuroSea has outperformed expectations, this is partly due to efficient use of funds that could not be used for travel during the pandemic. This report provides an overview of activities across the project, and details activities in the work packages.

References

Aguiar, E., Juza, M., Mourre, B., Pascual, A., Mason, E., Alvera Azcarate, A. and Tintore, J., 2019. Anticyclonic Eddy Anomaly: impact on the boundary current and circulation in the western Mediterranean Sea. Journal of Operational Oceanography, 12. https://www.tandfonline.com/doi/full/10.1080/1755876X.2019.1633075

Bates, P.D. and De Roo, A.P.J., 2000. A simple raster-based model for flood inundation simulation. Journal of hydrology, 236(1-2), pp.54-77. https://www.sciencedirect.com/science/article/pii/S002216940000278X

Bertram C, M Quaas, TBH Reusch, AT Vafeidis, C Wolff, and W Rickels, 2021, The blue carbon wealth of nations. Nature Climate Change 11: 704–709. https://www.nature.com/articles/s41558-021-01089-4

de Boisseson, E., Balmaseda, M., Mayer, M., Zuo, H. 2022. Monitoring and predictions of the series of Marine Heatwave events impacting the Northeast Pacific in 2020, accepted for publication in Journal of Operational Oceanography, to be included in CMEMS Ocean State Report Vol 6.

Fourrier, M., Coppola, L., Claustre, H., D'Ortenzio, F., Sauzède, R. and Gattuso J.-P. 2020. A Regional Neural Network Approach to Estimate Water-Column Nutrient Concentrations and Carbonate System Variables in the Mediterranean Sea: CANYON-MED. Front. Mar. Sci. 7:620. https://www.frontiersin.org/articles/10.3389/fmars.2020.00620/full

Gasparin, F., M. Hamon, E. Rémy, and P.-Y. Le Traon. 2020. How Deep Argo Will Improve the Deep Ocean in an Ocean Reanalysis, Journal of Climate, p.77–94. https://journals.ametsoc.org/view/journals/clim/33/1/jcli-d-19-0208.1.xml

Gruber, N., Clement, D., Carter, B.R., Feely, R.A., Van Heuven, S., Hoppema, M., Ishii, M., Key, R.M., Kozyr, A., Lauvset, S.K. and Lo Monaco, C., 2019. The oceanic sink for anthropogenic CO2 from 1994 to 2007. Science, 363(6432), pp.1193-1199. https://www.science.org/doi/10.1126/science.aau5153

Jiang, L.-Q., Pierrot, D., Wanninkhof, R., Feely, R.A., Tilbrook, B., Alin, S., Barbero, L., Byrne, R.H., Carter, B.R., Dickson, A.G., Gattuso, J.-P., Greeley, D., Hoppema, M., Humphreys, M.P., Karstensen, J., Lange, N., Lauvset, S.K., Lewis, E.R., Olsen, A., Pérez, F.F., Sabine, C., Sharp, J.D., Tanhua, T., Trull, T.W., Velo, A., Allegra, A.J., Barker, P., Burger, E., Cai, W.-J., Chen, C.-T.A., Cross, J., Garcia, H., Hernandez-Ayon, J.M., Hu, X., Kozyr, A., Langdon, C., Lee, K., Salisbury, J., Wang, Z.A., and Xue L. 2022. Best Practice Data Standards for Discrete Chemical Oceanographic Observations. Front. Mar. Sci. 8:705638. https://www.frontiersin.org/articles/10.3389/fmars.2021.705638/full

Lauvset, S.K., Lange, N., Tanhua, T., Bittig, H.C., Olsen, A., Kozyr, A., Álvarez, M., Becker, S., Brown, P.J., Carter, B.R. and Cotrim da Cunha, L., 2021. An updated version of the global interior ocean biogeochemical data product, GLODAPv2. 2021. Earth System Science Data, 13(12), pp.5565-5589. https://essd.copernicus.org/articles/13/5565/2021/

Lima, L.N., Pezzi, L.P., Penny, S.G. and Tanajura, C.A.S., 2019. An investigation of ocean model uncertainties through ensemble forecast experiments in the Southwest Atlantic Ocean. Journal of Geophysical Research: Oceans, 124(1), pp.432-452. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018JC013919

McAdam, R., Masina, S., Balmaseda, M., S. Gualdi, R. Senan, and Mayer, M., 2022. Seasonal forecast skill of upper-ocean heat content in coupled high-resolution systems. Climate Dynamics.

https://link.springer.com/article/10.1007/s00382-021-06101-3

Mignot, A., Claustre, H., Cossarini, G., D'Ortenzio, F., Gutknecht, E., Lamouroux, J., Lazzari, P., Perruche, C., Salon, S., Sauzède, R., Taillandier, V., and Terruzzi, A. (2022). Defining BGC-Argo-based metrics of ocean health and biogeochemical functioning for the evaluation of global ocean models, Biogeosciences Discuss., https://doi.org/10.5194/bg-2021-2, in review. https://bg.copernicus.org/preprints/bg-2021-2/

Pasmans, I., Kurapov, A.L., Barth, J.A., Ignatov, A., Kosro, P.M. and Shearman, R.K., 2019. Why Gliders Appreciate Good Company: Glider Assimilation in the Oregon-Washington Coastal Ocean 4DVAR System With and Without Surface Observations. Journal of Geophysical Research: Oceans, 124(1), pp.750-772. https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2018JC014230

Pinardi, N., Bonazzi, A., Dobricic, S., Milliff, R.F., Wikle, C.K. and Berliner, L.M., 2011. Ocean ensemble forecasting. Part II: Mediterranean forecast system response. Quarterly Journal of the Royal Meteorological Society, 137(657), pp.879-893. https://rmets.onlinelibrary.wiley.com/doi/10.1002/qj.816

Ricke, K., Drouet, L., Caldeira, K. and Tavoni, M., 2018. Country-level social cost of carbon. Nature Climate Change, 8(10), pp.895-900. https://www.nature.com/articles/s41558-018-0282-y

Ricke, K., Drouet, L., Caldeira, K. and Tavoni, M., 2019. Author Correction: Country-level social cost of carbon. Nature Climate Change, 9(7), pp.567-567. https://www.nature.com/articles/s41558-019-0455-3

Rickels, W and M Quaas (2021) Mapping 'blue-carbon wealth' around the world, Carbon Brief, July, 12. 2021. https://www.carbonbrief.org/guest-post-mapping-blue-carbon-wealth-around-the-world

Tanhua, T., Lauvset, S.K., Lange, N., Olsen, A., Álvarez, M., Diggs, S., Bittig, H.C., Brown, P.J., Carter, B.R., Da Cunha, L.C., Feely, R.A., Hoppema, M., Ishii, M., Jeansson, E., Kozyr, A., Murata, A., Pérez, F.F., Pfeil, B., Schirnick, C., Steinfeldt, R., Telszewski, M., Tilbrook, B., Velo, A., Wanninkhof, R., Burger, E., O'brien, K., and Key, R.M., 2021. A vision for FAIR ocean data products. Communications Earth & Environment, 2(1), pp.1-4. https://www.nature.com/articles/s43247-021-00209-4

List of partners

Table 2. List of EuroSea beneficiaries

Acronym	Name of Organisation	Link
GEOMAR	GEOMAR HELMHOLTZ-ZENTRUM FÜR OZEANFORSCHUNG KIEL	https://www.geomar.de/en/
EuroGOOS	EUROGOOS	www.eurogoos.eu
IOC/UNESCO	UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANISATION	www.ioc-unesco.org
MOI	MERCATOR OCEAN INTERNATIONAL	https://www.mercator-ocean.fr
UNIBO	ALMA MATER STUDIORUM – UNIVERSITÀ DI BOLOGNA	https://www.unibo.it/en/homepage
MI	MARINE INSTITUTE	https://www.marine.ie/Home/home
CSIC	AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS	http://www.csic.es/home
ENS	ECOLE NORMALE SUPERIEURE	https://www.ens.fr/en
CLS	COLLECTE LOCALISATION SATELLITES SA	https://www.cls.fr/
OGS	ISTITUTO NAZIONALE DI OCEANOGRAFIA E DI GEOFISICA SPERIMENTALE	www.inogs.it
CMCC	FONDAZIONE CENTRO EURO-MEDITERRANEO SUI CAMBIAMENTI CLIMATICI	www.cmcc.it
UiB	UNIVERSITETET I BERGERN	www.uib.no
SU	SORBONNE UNIVERSITE	http://www.sorbonne-universite.fr
SOCIB	CONSORCIO PARA EL DISENO, CONSTRUCCION, EQUIPAMIENTO Y EXPLOTACION DEL SISTEMA DE OBSERVACION COSTERO DE LAS ILLES BALEARS	http://www.socib.eu/
ECMWF	EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS	https://www.ecmwf.int
IO PAN	INSTYTUT OCEANOLOGII POLSKIEJ AKADEMII NAUK	http://www.iopan.gda.pl/
IfW	INSTITUT FÜR WELTWIRTSCHAFT	https://www.ifw-kiel.de/
Euro-Argo ERIC	EURO-ARGO ERIC	https://www.euro-argo.eu/
CNRS	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE	https://www.cnrs.fr
IFREMER	INSTITUT FRANCAIS DE RECHERCHE POUR L'EXPLOITATION DE LA MER	https://www.ifremer.fr/en
RBINS	INSTITUT ROYAL DES SCIENCES NATURELLES DE BELGIQUE	www.naturalsciences.be
SCIENCETHICS	INSTITUT DE SCIENCE ET ETHIQUE	http://www.sciencethics.org
ISPRA	ISTITUTO SUPERIORE PER LA PROTEZIONE E LA RICERCA AMBIENTALE	http://www.isprambiente.gov.it/en?set_language=en
IEEE	IEEE FRANCE SECTION	https://www.ieeefrance.org/
EMB	EUROPEAN MARINE BOARD IVZW	www.marineboard.eu
IMT	INSTITUT MINES-TÉLÉCOM	https://www.imt.fr/en/
OceanNext	OCEANNEXT	https://www.ocean-next.fr
AZTI	FUNDACIÓN AZTI - AZTI FUNDAZIOA	www.azti.es
EPPE	PUERTOS DEL ESTADO	www.puertos.es
ACRI	ACRI-ST SAS	https://www.acri-st.fr/
ARUP	OVE ARUP & PARTNERS INTERNATIONAL LIMITED	https://www.arup.com
HCMR	HELLENIC CENTRE FOR MARINE RESEARCH	https://www.hcmr.gr/en/
NIVA	NORSK INSTITUT FOR VANNFORSKNING	https://www.niva.no/en/

Acronym	Name of Organisation	Link
Met Office	MET OFFICE	https://www.metoffice.gov.uk
EMSO ERIC	EUROPEAN MULTIDISCIPLINARY SEAFLOOR AND WATER COLUMN OBSERVATORY - EUROPEAN RESEARCH INFRASTRUCTURE CONSORTIUM	http://emso.eu
PLOCAN	CONSORCIO PARA EL DISEÑO, CONSTRUCCIÓN, EQUIPAMIENTO Y EXPLOTACIÓN DE LA PLATAFORMA OCEANICA DE CANARIAS	www.plocan.eu
UBREMEN	UNIVERSITAET BREMEN	https://www.marum.de/en/index.html
UPORTO	UNIVERSIDADE DO PORTO	https://lsts.fe.up.pt
SZN	STAZIONE ZOOLOGICA ANTON DORHN	http://www.szn.it/index.php/en/
AWI	ALFRED-WEGENER-INSTITUT, HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG	www.awi.de
ETT	ETT SPA	https://www.ettsolutions.com
Nologin	NOLOGIN CONSULTING, S.L.	https://www.nologin.es
UPC	UNIVERSITAT POLITECNICA DE CATALUNYA	https://lim.upc.edu
DMI	DANMARKS METEOROLOGISKE INSTITUT	http://www.dmi.dk
TalTech	TALLINNA TEHNIKAULIKOOL	http://www.ttu.ee/
CNR	CONSIGLIO NAZIONALE DELLE RICERCHE	http://www.ismar.cnr.it
IRD	INSTITUT DE RECHERCHE POUR LE DÉVELOPPEMENT	www.ird.fr
UCAM	THE CHANCELLOR MASTERS AND SCHOLARS OF THE UNIVERSITY OF CAMBRIDGE	https://www.cam.ac.uk
XYLEM	XYLEM AANDERAA DATA INSTRUMENTS AS	https://www.xylem.com/
WMO	ORGANISATION METEOROLOGIQUE MONDIALE	www.wmo.int
UERJ	UNIVERSIDADE DO ESTADO DO RIO DE JANEIRO	www.uerj.br
UFPE	UNIVERSIDADE FEDERAL DE PERNAMBUCO	https://www.ufpe.br
MUN	MEMORIAL UNIVERSITY OF NEWFOUNDLAND	www.mun.ca
DAL	DALHOUSIE UNIVERSITY	https://www.dal.ca/diff/cerc.html
NOC	NATIONAL OCEANOGRAPHY CENTRE	https://noc.ac.uk