Report summarising the results of consultations with end-users of hydrographic consultations

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1. Abstract

This deliverable report 4.4 (D4.4) presents the work undertaken within work package 4 (WP4), Task 4.4, Consultation with end-users of hydrographic information of the Horizon Europe European Global Ocean Ship-based Hydrographic Investigations Programme (herein and thereafter, EuroGO-SHIP) research infrastructure (RI) concept project (December 2022 - October 2025). EuroGO-SHIP WP4 ran between December 2022 and October 2024, primarily involving stakeholder engagements (e.g., ocean data originators (Task 4.2), governments and funding agencies (Task 4.3), end-users of hydrographic information (e.g. ocean modelling and satellite communities) (Task 4.4)) to narrow down stakeholders' needs and requirements and further directly contribute to achieving project objectives (O) O1 and O5, and indirectly to O2, O3, and O4, thus, enabling the concept design of a future operational EuroGO-SHIP RI. The report consists of six main sections, where we first provide a background to the EuroGO-SHIP RI concept project and its main objectives (Section 2. Background), followed by an introduction to WP4, Task 4.4 activities (Section 3. Introduction), an outline of the employed stakeholder engagement strategies (Section 4. Engagement strategies with end-users of hydrographic information), a detailed presentation of stakeholder engagements (Section 5. Engagement strategies with mapped end-users of hydrographic information), an outline of findings and recommendations (Section 6. Overall findings and recommendations) and finally, conclusions (Section 7. Conclusions).

2. Background

The EuroGO-SHIP research infrastructure (RI) concept project aim is to strengthen the current state of European hydrographic observing by designing services, which will support at-sea operations following a rigorous and concise set of sampling practices, in turn collecting and delivering reliable ocean data for scientific, operational, and hence, societal purposes. To achieve this, the project has been centred around five complementary objectives (O):

- O1. To develop a RI concept (architecture, governance, financing) in support of European hydrography, following user requirements (e.g., the ocean science community, funders, exciting marine RIs).
- O2. To demonstrate the feasibility of the provision of new facilities and technologies within the European Research Area (ERA) ambition.
- O3. To showcase the power of a new marine RI in support of evolving science excellence, i.e., addressing key research challenges not possible to tackle now.
- O4. To address the need for hydrographic RI services across European Regional Seas, the Baltic, the Black, the Mediterranean, and Northeast Atlantic European waters.
- O5. To map ocean data flows and to propose an optimal data curation and preservation strategy adhering to the FAIR principles (Findable, Accessible, Interoperable, Reusable) in service of the wider scientific community.

Below, we present core activities within EuroGO-SHIP WP4, Task 4.4, and alignment with specific project's objectives.

3. Introduction

The aim of the consultations under EuroGO-SHIP work package 4 (WP4) Task 4.4 was to engage with ship operators, marine forecasting centres, the European satellite community, i.e., end-users of hydrographic information, with the purpose of narrowing down the requirements and needs of the individual groups and to identify (potential) mechanisms, where the marine operational, modelling and satellite communities can contribute to each other's work and ambitions. Between December 2022 and October 2024, we engaged with European ship operators, European marine forecasting centres, the European Space Agency (ESA), the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the European ocean satellite community at large, the Baltic Operational Oceanographic System (BOOS) (Table 1), part of the Regional Operational Oceanographic System (ROOS) of the European Global Ocean Observing Systems (EuroGOOS). We built on our earlier efforts to push forward the implementation of automated near-real time (NRT) oceanographic data feeds from research vessels, to enable real-time reporting of high-quality oceanographic data (e.g., temperature, salinity, dissolved oxygen, currents) collected within European Seas and oceanic waters, notably targeting data-sparse regions. It is a long-term EuroGO-SHIP vision that European research vessels, once enabled with such onboard data systems, will have the potential to supply NRT data when executing work at sea. Such NRT data feeds will aid the work of marine forecasting modellers, and thus, improve the reliability of delivered marine forecasts. Marine/ocean forecasting services rely on better tuned models. In turn, assessing the skills and limitations of ocean (forecasting) models relies on good quality in-situ observations and improved satellite data and data products. To ensure good data quality, ocean satellite data and derived satellite data products undergo verification, calibration, validation, quality control assessment activities, and for these, satellite data experts require external in-situ validation measurements, undertaken by independent scientific experts (Goryl et al., 2023). High-quality, well-documented, traceable, following metrology standards, or community-approved best practices, i.e., fiducial reference measurements (FRMs), in-situ ocean measurements are thus essential (Goryl et al., 2023). Hence, engaging first hand with the groups noted above and further outlined in Table 1 below, gave an opportunity to gather most recent information on current in-situ data needs and requirements, and on occasions, to facilitate the exchange of information between the stakeholder groups.

Event name/Engagement activity	**Year-Month-Date**	**Event purpose/theme/details**
Online correspondence engagement with European research ship operators and marine forecasting centres	Between 23-09 and 24-10	Online correspondence with selected European research ship operators and marine forecasting centres to gather details on needs and requirements with respect to near-real time (NRT) oceanographic data (temperature, salinity, dissolved oxygen, currents).
BOOS STG - EuroGO-SHIP joint meeting	24-01-12	First engagement with the BOOS community: overview of BOOS activities, overview of the EuroGO-SHIP project, and objectives. Joint discussions on how to exchange expertise, and how EuroGO-SHIP could assist

		BOOS with continuing and improving their operational work in the Baltic Sea region.
EuroGO-SHIP - ESA CEOS Cal/Val Group meeting	24-01-24	Exploring the feasibility of providing ship-based fiducial reference measurements (FRM) (e.g., SST, ocean colour, altimetry, GHGs) for calibration and validation (Cal/Val) purposes in ongoing and/or planned ESA projects and programmes, data gaps, future collaborations.
1st EuroGO-SHIP - ESA CEOS OCR-VC meeting	24-02-23	As above: Exploring the feasibility of providing ship-based fiducial reference measurements (FRM) for calibration and validation (Cal/Val) purposes in ongoing and/or planned ESA projects and programmes, data gaps, future collaborations.
ISFRN workshop	24-04-22 24-04-23	The 2-day workshop centred on ship-based sea surface temperature (SST) satellite validation measurements, mostly in-situ radiometer SST data and reviewing progress and developments (e.g., calibration techniques, uncertainty models).
BOOS scientific workshop	24-05-07	Processes and implementation steps of near-real time (NRT) delivery of ship-based conductivity, temperature, depth (CTD) data.
ESA Ocean Salinity conference	24-05-15	To provide a platform for exchange on latest scientific advancement in relation to ocean salinity (surface and subsurface) studies, ocean salinity observing technologies, and relevant needs.
CCVS post-project meeting	24-06-17	The post-project meeting of Horizon 2020 Copernicus Cal/Val Solution (CCVS) project aimed to exchange information on project relevant Cal/Val topics, to coordinate actions on project recommendations, and available updates on uncertainties, Fiducial Reference Measurements (FRMs), Research Infrastructures (RIs), and project communication activities (e.g., ESA's Living Planet Symposium 2025).
2nd EuroGO-SHIP - ESA CEOS OCR-VC meeting	24-09-08	Continuation of discussions that took place during the 1st EuroGO-SHIP - ESA CEOS OCR-VC meeting (Feb 23rd, 2024), with a focus on ocean carbon data.
1st EuroGo-SHIP - EUMETSAT Cal/Val meeting	24-10-23	Scoping meeting to exchange preliminary information on the 1) EuroGO-SHIP RI concept project, 2) EUMETSAT in-situ oceanographic data needs and requirements and 3) possible future collaborations.
2nd EuroGo-SHIP - EUMETSAT Cal/Val meeting	24-11-05	Continuation of discussions, which took place during the 1st scoping EuroGO-SHIP - EUMETSAT meeting (Oct 23rd, 2024), focusing on good data documentation, and the delivery of near-real time (NRT) oceanographic data (temperature, salinity, dissolved oxygen, currents).

Table 1: Summary of engagement activities under EuroGO-SHIP work package 4 (WP4), Task 4.4, Consultation with end-users of hydrographic information over WP4 lifespan (December 2022 - November 2024).

3.1. Contributions towards EuroGO-SHIP objectives

Activities under EuroGO-SHIP work package 4 (WP4), Task 4.4 contribute directly to project objectives (O), O1 and O5 (Section 2). More specifically, identifying end-users needs, including satellite calibration and validation communities, and operational modellers (O1), and engagements with end-users (e.g., data originators, operational modelling, and satellite communities) regarding near-real time and delayed mode data needs and provisions (O5). Additionally, the work and findings described here contribute indirectly to project objectives O2, O3 and O4 (e.g., sharing of data flow practices and hence, showcasing the feasibility to adopt widely across the European ocean observing and modelling communities, identifying needs for improved in-situ data quality (pre-processed, post-processed), fundamental in the delivery of model-based and satellite derived information and products).

4. Engagement strategies with end-users of hydrographic information

4.1. Mapping of end-users of hydrographic information

Main end-users, i.e., stakeholders of hydrographic observations were identified during the proposal stage of the project, namely, European research vessels/ship operators, i.e., data collectors/data originators (e.g., Eurofleets network), the ocean modelling and the satellite calibration and validation communities (e.g., Horizon 2020 Copernicus Calibration and Validation Solution (CCVS) project). The link between the three groups above is ocean data, the backbone of ocean and climate research and operational oceanography, and the core interest and focus of our engagement activities. Thus, to pinpoint our stakeholders more directly, notably within the ocean modelling and satellite calibration and validation communities, we used the following criteria: 1) stakeholders with extensive experience in working with ocean data and can provide insights towards resolving ocean data problems and issues, 2) stakeholders that work towards societal good and benefits, 3) stakeholders that are representatives of a formal ocean-related entity/institution. We assessed these three criteria to be most relevant for narrowing down the selection of our stakeholders, and additionally, to help us secure "ease of access" to stakeholders that share our interest in facilitating high quality and freely available data for ocean and climate research, and European operational oceanography services. Thus, our mapped stakeholder groups are 1) European research ship operators, 2) European marine forecasting centres, 3) the Baltic Operational Oceanographic System (BOOS), 3) the European Space Agency (ESA) calibration and validation (Cal/Val) team and 4) the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Cal/Val team. While our engagement with the four listed stakeholder groups was direct, we also undertook indirect approach to gathering of information and input from the wider ocean satellite community. Details on the type of engagements are described further in Section 4.2 *Type of engagements, engagement channels* below.

4.2. Type of engagements, engagement channels

Our engagement activities (Table 1, Section 3) were both direct (email correspondence, online meetings, and workshops) and indirect (conferences and workshops attendance)[1]. In our direct engagements, we aimed to:

- Inform our stakeholders of the EuroGO-SHIP research infrastructure (RI) concept project, bringing visibility to our work, and additionally, inform about the engagement goals.
- Consult with our stakeholders on in-situ ocean data-related problems and issues that they experience and involve them in discussions, where they provide their input and perspectives on possible solutions and measures.

Ultimately, the aim of our engagements was to reach a good level of communication and connection with our mapped stakeholder groups, such that we present the opportunity for continued and/or near-future collaborations, where we further elaborate and work together on addressing ocean data problems (e.g., change in data practices, adopting optimal data practices widely across Europe, mutual support and partnership in ocean observing and data-related activities. Details of our stakeholder engagements are presented in Section 5. Engagement strategies with end-users of hydrographic information. Prior to that, we address relevant ethical General Data Protection Regulation (GDPR) Law and ethical compliances.

4.3. General Data Protection Regulation (GDPR) Law and ethical compliances

The engagement activities under EuroGO-SHIP work package 4 (WP4), Task 4.4 involved email correspondence, online meetings, and online workshops. The most vital ethical and personal data protection compliances and rules in accordance with the EU General Data Protection Regulation (GDPR) Law (2018), as featuring in GDPR.EU (2024), in relation to identified stakeholders' engagements within WP4, Task 4.4 are with respect to:

- Consent to participate in research activities (GDPR Article 6).
- Information provided to participants (GDPR Articles 13-14).
- Research participants' rights (GDPR Articles 12-23).
- Data security measures (GDPR Article 32).
- Personal data breach notification (GDPR Article 33).

All stakeholders (individuals and groups) were informed of the nature of the request to engage (e.g., project background, intend of information gathering and use thereafter). The distribution and collection of consent forms for individual participation in our stakeholder meetings was not found necessary, as all engagements with individuals were in their

[1] All engagement activities considered applicable ethical and personal data protection compliances and rules in accordance with the EU General Data Protection Regulation (GDPR) Law (2018) (GDPR.EU, 2024). The most vital in relation to identified stakeholders' engagements under WP4, Task 4.4, are with respect to: Consent to participate in research activities (GDPR Article 6), Information provided to participants (GDPR Articles 13-14), Research participants' rights (GDPR Articles 12-23), Data security measures (GDPR Article 32), Personal data breach notification (GDPR Article 33) (GDPR.EU, 2024).

professional capacity, opposed to their status as citizens and/or community members. Apart from personal names, professional emails accounts, and professional roles, no other personal data were acquired by or made available to EuroGO-SHIP WP4 Task 4.4 members. To be compliant with GDPR Articles 6, 12-23, 32, 33, and as some of our stakeholder needs and requirements were collected indirectly, stakeholders' personal names are not recorded in this deliverable report and engagement events participants lists are not provided.

5. Engagement strategies with mapped end-users of hydrographic information

The engagement activities under EuroGO-SHIP work package 4 (WP4), Task 4.4 involved email correspondence, online meetings, and online workshops. Below, we present details of our engagement strategies with the mapped end-users of hydrographic information under EuroGO-SHIP work package 4 (WP4) Task 4.4, i.e., WP4 Task 4.4 main stakeholder groups:

- European research ship operators (Sections 5.1).
- European marine forecasting centres (Section 5.2).
- The Baltic Operational Oceanographic System (BOOS) (Section 5.3).
- The European Space Agency (ESA) (Section 5.4).
- The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) (Section 5.5).
- The wider ocean satellite community (Section 5.6).

5.1. Engagement with European research ship operators

Research vessels remain the core platforms enabling the collection of high-quality oceanographic data from regions with sparce data coverage, and/or from regions considered of significant scientific research (e.g., deep sea, polar regions). The demand for vessel-based data and information is often seen as one directional, i.e., from the research vessels to the various stakeholder groups (e.g., basic scientific research, applied scientific research, industry). Research vessels and any operational at sea vessels greatly benefit from near-real time (NRT) information on local weather systems and potential hazard warnings, issued by marine forecasting centres. Thus, research vessels, i.e., ship operators, are both the supplier of highly needed by marine forecasting centres NRT ocean data, and the receiver and user of weather forecasting information, based on ship-derived data.

Our engagement protocol with research ship operators consisted of making contact via an email, where we expressed our interest in exploring the feasibility of setting up a system, which could automatically send conductivity, temperature, depth (CTD) data collected from research vessel to the Global Telecommunication System (GTS) in near real-time, for ingestion within operational weather forecasting models. Over the past decade, the Plymouth Marine Laboratory (PML), UK and UK Meteorological Office (UKMO) have developed an onboard automated system, which ingests individual CTD casts as soon as the instruments are on deck, interpolates the data onto a pre-set grid and then emails the data within one hour of acquisition to the GTS. Currently, the following UK research vessels (RVs) are equipped with the system: National Oceanography Centre (NOC) RVs RRS Discovery, James Cook, Sir David Attenborough, PML RV Plymouth Quest and Marine Scotland's RV MRV Scotia., A schematic representation of the automated system shown in Fig. 1 below. We expressed our ambition to expand and implement the UK-developed system to other European research vessels in the future. Additionally, we informed the ship operators that we are looking to add the provision of NRT dissolved oxygen and currents, i.e., upper, and possibly full water column acoustic doppler current profiler (ADCP) data to the standard CTD data suit.

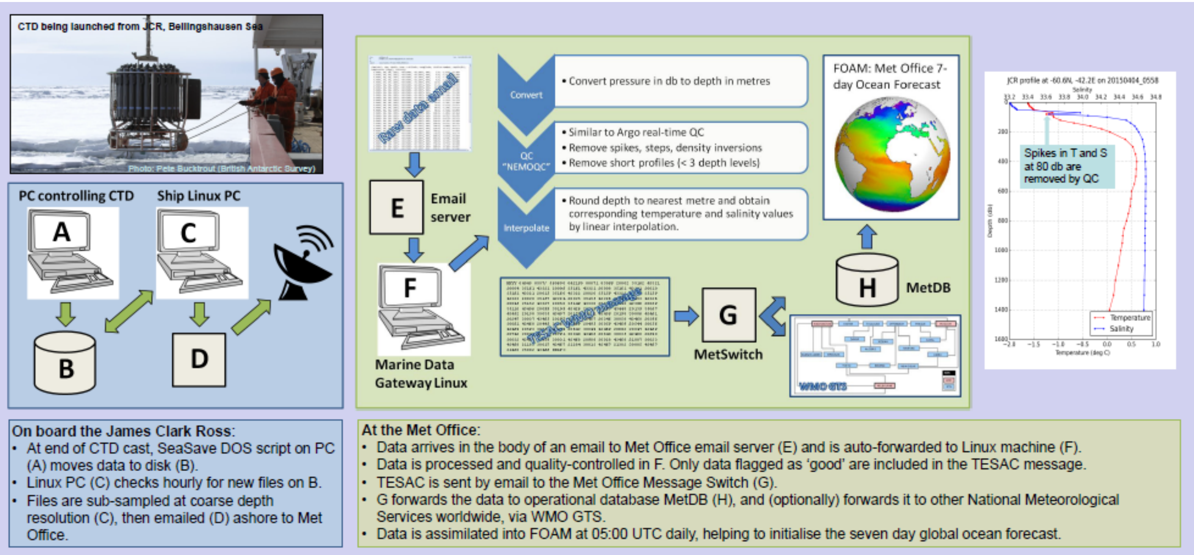

Fig. 1. Schematic representation of the automated onboard system available onboard UK research vessels.

The selection of research ship operators was done through accessing available information on the Eurofleets website (https://www.eurofleets.eu/infrastructure-type/research-vessels/). Individual research ships were chosen based on their advertised oceanographic sampling capabilities. The initial selection centred on seventeen research vessels, as shown in Table 2 below. One of the main, or minimum criterion was that the research vessels were equipped with a SeaBird (manufacturer) CTD instrument, as this implies that that the ships are technically ready to at least provide NRT CTD data.

Nationality	**Name of Vessel**	**Equipment**
Irish	RV Celtic Explorer	CTD and Rosette sampler – 2 x SBE 911 CTD with SBE 32 carousel (24 Bottle), 6000m deployment capability.
Faroes	RV Jakup Sverri	Seabird CTD equipped with rosette sampler, 1.7 and 5 L Niskin bottles, fluorometer and PAR sensor. 3000m cable
Danish	RV Dana	CTD and Rosette sampler – SBE 911 CTD carousel 12 bottles, 3000m deployment capability.
French	RV Thalassa	Unclear
French	RV L'Europe	Unclear
Norwegian	RV G.O. Sars	CTD and Rosette Sampler – Seabird SBE 911 w/12 bottle carousel and 4500m cable, Seabird SBE 911 w/24 bottle carousel and 6000m cable

Spanish	RV Sarmiento de Gamboa	2 x CTD SeaBird SBE911 plus
Dutch	RV Pelagia	CTD and Rosette sampler – 2 x SBE 911 CTD with SBE 32 carousel (24 Bottle, 12L), 7000m deployment capability.
German	RV Alkor	CTD and Rosette sampler – 1 x SBE 911 CTD with Hydrobios carousel (12 Bottle), 1000m deployment capability.
Spanish	RV Ramon Margalef	CTD (on request): SB911, SB25; Rosette sampler 12 bottles.
Romanian	RV Mare Nigrum	CTD Rosette system:SBE 32C Carousel water Sampler with 12 five liters bottles;
Turkish	RV Tubitak Marmara	Unclear
Portuguese	RV Mario Ruivo	CTD and Rosette sampler, 6000m deployment capability.
Belgium	RV Belgica	Sea-Bird SBE19 CTD (2x), Sea-Bird SBE9plus CTD (2x), Sea-Bird SBE21 thermosalinograph (2x), SBE 911 CTD (2x)
Greek	RV Aegaeo	CTD and Rosette sampler – 2 x SBE 911plus CTD with SBE 32 carousel (24 x 10 lt or 12 x 12 lt Niskin Bottles), 6000 m deployment capability.
Swedish	RV Skagerak	CTD SeaBird911 with 24 bottles, plankton nets
Finnish	RV Aranda	SBE 911 CTD w/ 12 bottle Rosette sampler 4000m deployment,

Table 2: Summary of selected of ship operators and description of relevant equipment. Successful engagement with research vessel operators between December 2022 and November 2023 highlighted in green.

Up to November 2023, we had received four positive replies from research vessel operators, highlighted in green in Table 2 above, where engagement with Marine Institute (MI), Ireland research ship operators is ongoing.

The reply to research ship operators was largely in the form of a template, where we outlined the pre-requisites for the installation of the data pipeline on the ships to allow onward transmission to marine forecasting centres. The pre-requisites are 1) a SeaBird CTD system, which uses their proprietary software for onward processing, and 2) (ideally) a Linux/UNIX system, installed on the ship, enabling the systems to be as automatable as possible. The freely available CTD2MET software (https://github.com/timjsmyth/MetOffice_CTD_send) is accompanied by instructions on installing and running the code on the research vessels. Currently, the CTD2MET code is configured to process just temperature and salinity, though EuroGO-SHIP scientists are actively working on including dissolved oxygen data into the same system. Importantly, we encouraged suggestions on improving the code, and we offered to provide checks on the NRT data transmissions.

During summer 2024, the CTD2MET software was briefly tested and used on the two MI, Ireland research vessels Tom Crean and Celtic Explorer. However, it has been suspended since late summer due to unknown issue, likely related to interactions with the ships' back up software, causing large volumes of old CTD data to be sent out in an intermittent and uncontrolled manner. A future software upgrade on board is anticipated and testing of the

CTD2MET software on MI, Ireland research vessels is expected to re-commence in the (near) future.

Regarding NRT ADCP data transmissions, namely vessel mounted ADCP (VMADCP) data, i.e., horizontal ocean current profiles, research ship operators (e.g., Marine Institute, Ireland, and UK RV operators (UK National Marine Facilities Operations (NMF-Ops) and British Antarctic Survey (BAS)) remain interested to build capacity in. However, assessments are that NRT VMADCP data transmissions are behind the better progressing NRT CTD data transmissions and ingestion. Here, research ship operators define the lack of local expertise to implement and oversee the process a major obstacle, and it is anticipated NRT VMADCP sea-to-shore data transmissions to take considerably longer. The NRT VMADCP data transmissions and their eventual assimilation into marine forecasting models is thus "work in progress", which we envisage to build upon in the next stage of the project. Here, we foresee collaborations with international (e.g., School of Ocean and Earth Science and Technology (SOEST), USA) and European (e.g., Alfred Wegener Institute (AWI), Germany, GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany) marine and ocean institutes, and industry (e.g., Fugro), important to exchange experience and working methods regarding NRT VMADCP data transmissions, and possible considerations for practices adoption. The University of Hawaii Data Acquisition System (UHDAS), hosted by SOEST, USA and AWI, Germany have a long-standing experience in NRT VMADCP data transmissions and the full workflow, and their open source VMADCP software tools are readily available for the scientific and operational communities to use for designated purposes (e.g., 3. UHDAS Operations Guide — UHDAS+CODAS Aug 20 13:44:31 2024 -1000 (291:5ea392f9821a) documentation, dam / OSADCP Toolbox · GitLab). The UHDAS CODAS software tool, facilitating the NRT VMADCP data transmission, is in use by many USA research vessels (RVs), as well as European RVs. We present examples of NRT VMADCP data transmissions (November 14th, 2024) from the USA RV Nathaniel B. Palmer, https://currents.soest.hawaii.edu/uhdas_fromships/nbpalmer/figs/index.html, and the Norwegian Institute of Marine Research (IMR) RV Johan Hjort, https://currents.soest.hawaii.edu/uhdas_fromships/jhjort/figs/indexN.html. The AWI-developed OSADCP software tool is successfully implemented on German RVs Maria S. Merian, Meteor and Sonne. Further Details of the UHDAS CODAS software tool are available on the SOEST UHDAS webpage (UHDAS ADCP web page, 2024), and details on the AWI-developed OSADCP software tool can be found in Koppe et al. (2015; 2024).

Underway systems on research vessels can also provide NRT data that is valuable for ocean and weather forecasting systems. Underway systems typically run continuously during science cruises, and sometimes during passage journeys. Instruments such as thermosalinographs provide measurements of the near-surface layer of the sea, usually at about 4 - 5 m depth, every 5 to 10 minutes. Common parameters are sea temperature and salinity, with some systems additionally measuring biogeochemical parameters including dissolved oxygen, Chlorophyll-a fluorescence, and turbidity. Many European RVs already provide these data, via the Copernicus Marine Service's INSTAC data product. Although it has not been a focus for work package 4 (WP4), EuroGO-SHIP seeks to increase participation in the sharing of underway data by more European RV operators, and we suggest that it is included in future work plans.

5.2. Engagement with European marine forecasting centres

Marine forecasting centres rely on both satellite and in-situ data for the improvement of prediction models and the provision of reliable forecasts and warnings. Operational ocean prediction systems require surface and subsurface observations of sea water temperature, salinity, and ocean currents (e.g., Bell et al., 2015), and ship/research ships can provide both.

Our engagement protocol with the marine forecasting centres followed the approach to engaging with ship operators (Section 5.1), making contact by email. Our initial email outlined our interest in exploring the utility of near-real time (NRT) research ship data to the forecasting or operational observing system in use. We provided background to our UK-based expertise, developed over the past decade through a collaboration between Plymouth Marine Laboratory (PML), UK and the UK Meteorological Office (UKMO). This collaborative work has resulted in the development of CTD2MET software (Section 5.1) and an onboard automated system, which ingests individual conductivity, temperature, depth (CTD) casts as soon as the instruments are back on deck, interpolating the data onto a pre-set grid, then emailing the data within one hour of acquisition to the Global Telecommunication System (GTS). We noted that currently UK research vessels (RVs) (RRS Discovery, James Cook, Sir David Attenborough (National Oceanography Centre (NOC)) and Plymouth Quest (PML) and MRV Scotia (Marine Scotland) are equipped with the system, and we would like to provide and expand the UK-developed service to other Eurofleets vessels. Finally, we noted the ambition to expand the provision of near-real time (NRT) CTD data to dissolved oxygen data, and to explore the options for reporting ocean currents in NRT.

The marine forecasting centres were chosen from the Copernicus Marine Environment Monitoring Service (CMEMS, https://marine.copernicus.eu/). The initial selection of thirteen marine forecasting centres is presented in Table 3 below.

Organisation	Response
Mercator Ocean International (MOi), France	We assimilate CTD data in our real time global …
UK Met Office (UKMO), UK	AMM15, AMM7, and global ORCA025 are assimilating …
Nansen Environmental and Remote Sensing Centre (NERSC), Norway	
Danish Meteorological Institute (DMI), Denmark	Keen to be involved. Sent information on how …
Organismo Público Puertos del Estado, Spanish State Ports Agency, Spain	

Centro EuroMediterraneo Sui Cambiamenti Climatici (CMCC), Italy	the Mediterranean forecasting group are interested …
Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), France	
Danish Meteorological Institute	Keen to be involved. Sent information …
Centro de Investigacion Marina y Alimentaria (AZTI), Spain	
Royal Belgian Institute of Natural Sciences (KBIN-IRSNB), Belgium	Interested in more information (20/9/23); sent more information on 21/9/23 concerning how to get data from the GTS and the historical datasets too.
Institute of Marine Research (IMR), Norway	Redirected email …

Table 3: Summary of marine forecasting centres, contacted between December 2022 and November 2023. Successful engagements highlighted in green.

Up to November 2023, we received seven positive responses (Table 3). Though our responses were individually tailored, they all included information on accessing NRT CTD data, released in BUFR format via the GTS and through the US national oceanic and atmospheric administration (NOAA)'s environmental research division's data access program (ERDDAP) data server (http://osmc.noaa.gov/erddap/tabledap/OSMC_flattened.html).

5.3. Engagement with the Baltic Operational Oceanographic System (BOOS)

The Baltic Operational Oceanographic System (BOOS) is a large regional network of 22 operational marine agencies in the Baltic Sea, and one of the five currently active regional operational oceanographic systems (ROOSs) of the European Global Ocean Observing Systems (EuroGOOS). The BOOS overall purpose is to provide timely, high-quality information service for public safety, operations at sea, marine climate change adaptation plans and ocean health, among others. Ocean observing and modelling are the two main pathways used by BOOS members in developing the services. BOOS operational monitoring activities and consequent data collection is performed by mostly using buoys, tide gauges, gliders, and Argo floats, whereas in-depth environmental monitoring and concurrent data collections is undertaken with the use of research vessels. Engaging with BOOS members was of great interest to us, as BOOS activities and objectives are directly relevant to work package 4 (WP4) Taks 4.2, Consultation with hydrographers (data originators) through regional networks, and notably, Taks 4.4, Consultation with end-users of hydrographic data, as BOOS has a well-established near-real time (NRT) ship data working group, led by the Swedish Meteorological and Hydrological Institute (SMHI), Sweden and the Danish Meteorological Institute (DMI), Denmark.

Our initial contact with the BOOS community was by email, where we briefly introduced the EuroGO-SHIP research infrastructure (RI) concept project, with main objective to enable systematic ship-based observing within European Northeast Atlantic waters and regional seas, namely the Baltic, the Black and the Mediterranean, and our interests to engage with key to EuroGO-SHIP stakeholders, such as BOOS, in dialogues on user requirements with respect to ship-based hydrography and observing, notably our interest in exploring with BOOS the utility of real-time research ship data to support particular forecasting or operational observing system in the Baltic Sea.

Following a successful connection, and together with the BOOS scientific steering group (STG), we organized our first meeting, which took place in January 2024 (Table 1, Section 2). We gave two presentations, the first of which outlined the project and provided an overview of EuroGO-SHIP long-term objectives, and the second presentation provided details on the onboard automated system, developed by the Plymouth Marine Laboratory (PML) and the UK Met Office (UKMO), which allows the transmission of conductivity, temperature, depth (CTD) data in near-real time (e.g., details on ingesting individual CTD casts as soon as the instruments are on deck, data being interpolated onto a pre-set grid, then the data being emailed within one hour of acquisition to the Global Telecommunication System (GTS)). We noted that EuroGO-SHIP is assessing the feasibility in adding the provision of NRT dissolved oxygen and currents data to the provision standard CTD data. BOOS also find that there is a clear need to achieve the delivery of NRT ship-based CTD data on a larger scale, and to expand the BOOS and EuroGO-SHIP experience broadly, as currently, most European operational oceanographic data are delivered and made available in a delayed mode. BOOS member DMI presented the value of using NRT CTD data for the improvement of frequently updated reanalysis and noted that this work has been further extended by BOOS member TalTech (the Tallin University of Technology), Estonia, to improve eutrophication assessments in the Baltic Sea. Currently, BOOS members SMHI and TalTech are successfully delivering NRT CTD data, and BOOS members the Leibniz Institute for Baltic Sea Research (IOW), Germany and the Institute of Oceanology, Polish Academy of Sciences (IOPAN), are undergoing testing of the system. Our meeting concluded with concrete agreement that EuroGO-SHIP and BOOS share a common interest in improving the delivery of NRT ship-based CTD data and that we will continue information exchanges and collaboration activities (e.g., EuroGO-SHIP participation in internal BOOS scientific workshops).

Following our first engagement with BOOS colleagues in January 2024 (Table 1, Section 3), we provided a summary on how to implement the UK approach on the delivery of NRT ship-based CTD data, adopted and further improved on within EuroGO-SHIP WP4, Task 4.4 work. Consequently, we took part in an internal BOOS scientific workshop in May 2024 (Table 1, Section 3), to exchange new information and developments on the delivery of NRT ship-based CTD data.

5.4. Engagement with the European Space Agency (ESA)

The European Space Agency (ESA)'s goal is to develop and oversee Europe's overall space capacity for benefits of European and world citizens (ESA, 2024). Together with the European

Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the European Centre for Medium-range Weather Forecasts (ECMWF), ESA is a partner in the Destination Earth initiative, an ambitious European Union (EU) initiative to develop a digital model of Earth to aid the monitoring of natural effects and human activities on our planet, and thus help shape possible adaptation and mitigation strategies to current climate change (ESA, 2024). ESA's agency of interest to us was the Committee on Earth Observation Satellites (CEOS), as one CEOS's objectives and efforts is directed towards the needs of diverse satellite data users, requiring different data types, and importantly, to deliver validated data requirements (CEOS, 2024), and thus, high-quality satellite data products, which is highly dependent on high-quality in-situ observations.

Our engagement protocol with relevant ESA working groups was by sending a meeting invitation email, where we briefly outlined 1) the main objective of the EuroGO-SHIP research infrastructure (RI) concept project, i.e., to further enable systematic ship-based observing within European Northeast Atlantic waters and regional seas, namely the Baltic, the Black and the Mediterranean, and 2) the main objectives of work package 4 (WP4), under Task 4.4, i.e., to engage with key stakeholders (e.g., oceanographic data originators, modelling, and satellite communities), specifically, to engage in dialogues on user requirements with respect to ship-based hydrography and observing, including the acquirement of autonomously collected data from ship-board instruments and the provision of Fiducial Reference Measurements (FRMs). The most relevant stakeholder groups, which we identified within the ESA's CEOS, were the Working Group on Calibration and Validation (WGCV), responsible for assuring data quality, and the CEOS's Ocean Colour Radiometry Virtual Constellation (OCR-VC), working on the development of a CEOS Aquatic Carbon Roadmap. We received positive responses to our requests for dialogues, consequently setting-up meetings accordingly, and as outlined in Table 1, Section 3. Meetings followed similar structure, starting with a short meet and greet session, a presentation by EuroGO-SHIP, then opening the floor for collective discussions.

Our January 2024 meeting with members of the ESA's CEOS WGCV (Table 1, Section 3) centred on the feasibility of providing ship-based FRM (e.g., sea surface temperature (SST), ocean colour, altimetry) for calibration and validation (Cal/Val) purposes in ongoing and/or planned ESA projects and programmes. As the EuroGO-SHIP RI project is its concept development stage, and long-term, dedicated and secured transect lines, serviced by EuroGO-SHIP RI are not yet in place, discussions focused on geographical and variable data gaps, and/or data continuity. Globally, the polar regions were identified as data-poor, and in terms of sea ice related variables, freeboard, sea ice thickness, sea ice extension were noted. The need for data continuation with respect to carbon dioxide (CO_2), methane (CH_4), sea surface temperature (SST), and sea surface salinity (SSS) was also noted. Short discussions on the possibility to facilitate collaborative projects, or field campaigns also took place. At the first instance, the ESA CEOS WGCV recommended following the ESA satellite mission campaigns and tender calls and extended an invitation to the 2024 ESA-sponsored International Sea Surface Temperature (SST) Fiducial Reference Measurements Radiometer Network (ISFRN) workshop, which we attended virtually (Table 1, Section 3). ESA WGCV colleagues further referred us to ESA's CEOS Cal/Val portal (Cal/Val Home - Cal/Val Portal), where we could explore in greater detail ESA's Cal/Val activities (e.g. Cal/Val sites, campaigns, projects) and atmospheric and ocean related Cal/Val protocols. Ensuring long-term, sustained data provision, which aligns with the future needs of ESA, beyond 2025, will require new discussions to identify opportunities and measurements needed, and data collection protocols to be followed.

Our February 2024, and first meeting with a member of the ESA's CEOS's Ocean Colour Radiometry Virtual Constellation (OCR-VC) (Table 1, Section 3), working on the development of a CEOS Aquatic Carbon Roadmap, centred mainly on presenting EuroGO-SHIP objectives and receiving a confirmative response on the need of in-situ ocean data. This led to our second meeting with the ESA's CEOS OCR-VC members, which took place in September 2024.

The September 2024, and second meeting with a member of ESA's CEOS OCR-VC (Table 1, Section 3) allowed us to follow on what observational data may be of (most) interest, or relevant to long-term ESA's strategy, which European waters, sea basins may lack coverage, how often may observational data be required to fulfil ESA's needs, and EuroGO-SHIP's role as a high-quality observational data facilitator. Much of the discussion centred around the provision of high quality in-situ data (near-real time (NRT) and delayed mode), in particular any future EuroGO-SHIP RI contributions and their integration with the Copernicus In-situ Thematic Assembly Centre (In-situ TAC), and the anticipated feed into the European Marine Observation and Data Network (EMODnet). Some of the key findings of this meeting were that in-situ data from the central-eastern and southern Mediterranean (northern African coast), as well as the Baltic (salinity, currents, and Chlorophyll-a), and the Black Sea remain a need for Cal/Val purposes. Further, in addition to ocean carbon parameters (e.g., dissolved inorganic carbon (DIC), total alkalinity (T_A), partial pressure carbon dioxide (pCO_2), pH), ocean currents, at surface and depth, were seen as a particular need by the Cal/Val community, as well as vertical, i.e., full-depth profiles of temperature, salinity, Chlorophyll-a. A clear need for 4D (latitude, longitude, depth, and time) fields in these parameters emerged. Importantly, it was stressed that the availability and provision of high-quality in-situ data is critical for the development of new algorithms and methodologies for satellite data products, in turn maximising the application and usability of satellite-based products in various ocean disciplines (e.g., ocean carbon, ocean dynamics, biodiversity), and recurring events (e.g., marine heatwaves, extreme events).

5.5. Engagement with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)

The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), together with the European Space Agency (ESA), the European Centre for Medium-range Weather Forecasts (ECMWF) is a partner in the European Union's (EU) Destination Earth initiative, compiling digital twins of the entire Earth system (EUMETSAT, 2024). EUMETSAT is also one of the EU's Copernicus Earth Observation programme key partners, operating

Copernicus Sentinel-3 and Sentinel-6 ocean satellite monitoring missions, collecting, and providing data for the Copernicus atmosphere, climate, and marine environment monitoring services (EUMETSAT, 2024). Over more than 40 years, EUMETSAT has been supplying climate long-term, homogeneous data for the monitoring and assessment of climate change (EUMETSAT, 2024). To achieve high-quality, homogenous satellite data and data products, EUMETSAT, and the satellite community require high-quality in-situ data for reference, calibration, and validation purposes.

The engagement protocol with EUMETSAT followed the engagement protocol with ESA colleagues (Section 5.4). We approached with a meeting invitation email, where we briefly outlined 1) the main objective of the EuroGO-SHIP research infrastructure (RI) concept project, i.e., to further enable systematic ship-based observing within European Northeast Atlantic waters and regional seas, namely the Baltic, the Black and the Mediterranean, and 2) the main objectives of work package 4 (WP4), under Task 4.4, i.e., to engage with key stakeholders (e.g., oceanographic data originators, modelling, and satellite communities), specifically, to engage in dialogues on user requirements with respect to ship-based hydrography and observing, including the acquirement of autonomously collected data from ship-board instruments and the provision of fiducial reference measurements (FRMs).

Prior to our scoping meeting with EUMETSAT colleagues in October 2024 (Table 1, Section 3), we exchanged questions by email, prompting an online dialogue. In addition to altimetry, ocean colour, and ocean temperature data, EUMETSAT colleagues are also curious about the provision of greenhouse gases (GHGs) and water vapor data. With respect to GHGs, we asked if EUMETSAT would be interested in the acquirement of GHGs and auxiliary data from ship-board instruments (e.g., the set-up of atmospheric and oceanic GHGs observation rooms/labs). With respect to water vapour data, we asked if EUMETSAT may be interested in water vapour - content retrieval from the ships' navigation and positioning systems (e.g., Bosser et al., 2021; Männel et al., 2021). We further enquired if on a smaller scale, the set-up of GHGs labs could be a collaborative effort, and/or where else, and how, we may be able to form synergies.

In the October 2024 scoping meeting, we provided a brief overview of the EuroGO-SHIP research infrastructure (RI) concept project, outlining the objectives and readiness to re-shape, if needed, in accordance with provided stakeholders' requirements. EUMETSAT colleagues noted expectations for continuous, long-term good quality in-situ data, accompanied by comprehensive metadata (e.g., data uncertainty characteristics, data traceability, instrumentation quality, data interoperability) of fiducial quality, i.e., FRMs. Regarding their input towards the future design and evolvement of the EuroGO-SHIP RI concept project, the EUMETSAT Cal/Val team recommended that we refer to the World Meteorological Organisation (WMO) Commission for Observation, Infrastructure, and Information Systems (INFCOM) four-tier classification approach, approved in 2022 to aid the standardization of observing networks and observing systems programmes across domains. The WMO INFCOM tiered network approach aims to provide a hierarchy of data usage in accordance with and in support of user application areas. Based on data quality and usability characteristics (e.g., and amongst others, long-term data, maintained data quality, consistent data documentation, i.e., metadata practices, instrumentation quality and standards of observational methods, data uncertainty characterisation, data traceability), observational networks and programmes are assessed under a four-tier system, 1) Reference, 2) Baseline, 3) Additional, and 4) Ancillary/Unclassified (WMO INFCOM, 2022). The four-tier system and tier classification criteria are broadly summarised in Fig. 2 below, and further details available in the WMO INFCOM Abridged final report of the Second Session, held in Geneva, Switzerland in 2022. Similarly to ESA's Cal/Val team, we were encouraged to follow ESA - EUMETSAT satellite mission campaigns and tender calls (e.g., Sentinel - Validation Team (S3VT)). We conclude the meeting on a positive note, with a proposition for a joint EUMETSAT Cal/Val - ESA Cal/Val - EuroGO-SHIP workshop, welcomed by both teams.

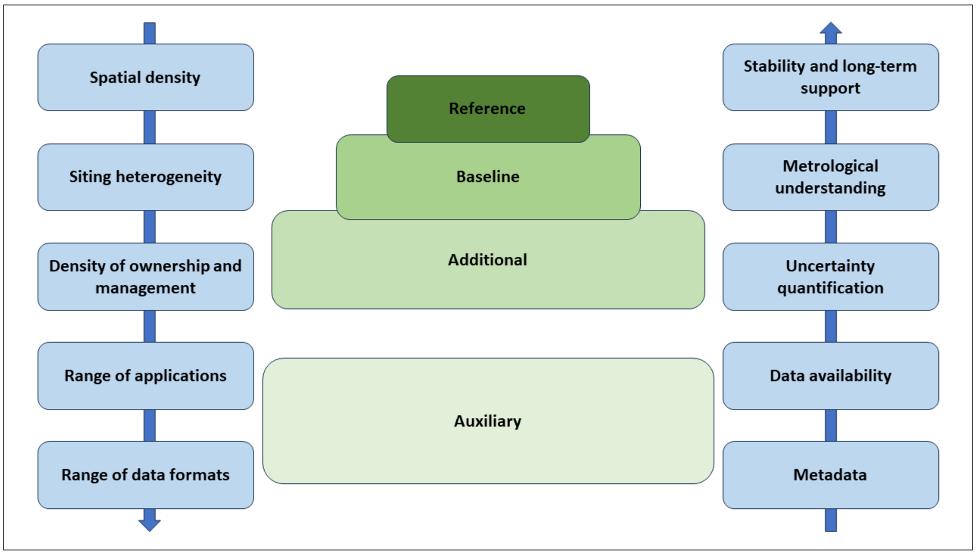

Fig. 2. A schematic representation, adapted from the World Meteorological Organisation (WMO) Commission for Infrastructure, Observation, and Information Systems (INFCOM) four-tier approach for classifying observing networks and programmes, based on non-exhaustive data-related criteria (WMO INFCOM, 2022).

The November 2024, our second meeting with members of the EUMETSAT Cal/Val team, involved an in-depth and an interactive presentation of the EuroGO-SHIP RI concept project, with questions and a conversation centred on EUMETSAT validation needs on marine applications with respect to sea surface temperature (SST), ocean colour, and altimetry. Similarly to feedback from ESA's Cal/Val team, the polar regions were noted as observing priority, namely, sea ice thickness, snow depth above sea ice, surface ocean currents. With respect to ocean colour data, we noted the success behind the UK-run Atlantic Meridional Transect (AMT) program and the possibility of extending AMT on-board ocean colour data practices to future EuroGO-SHIP RI run or supported field campaigns. That opened discussions on data delivery modes (near-real time (NRT), delayed mode), their varying temporary sliding scales and the need for community consolidation on NRT temporary threshold(s), data documentation, i.e., metadata availability, as well as data and metadata standards homogeneity. EUMETSAT Cal/Val team also noted the use of in-situ data, derived from other observing platforms (e.g., drifting buoys, mooring buoys, sea drones). Here, a complementary opportunity for synergy with existing observing marine/ocean RIs was noted by both of our teams, as well as a coordination with the WMO-Intergovernmental Oceanographic Commission (IOC) Joint Centre for Oceanography and Meteorology in-situ Observations Programmes Support (OceanOPS). We noted EuroGO-SHIP UK partners' PML and UKMO expertise in NRT sea-to-shore delivery and the potential in collaborations with industry with respect to NRT delivery of vessel mounted acoustic doppler current profiler (VMADCP) data. Timeliness is important for the EUMETSAT team, and a request for clear definitions of 'near real time' was raised. The need for FRMs was reiterated by the EUMETSAT Cal/Val team. The meeting concluded with both teams expressing willingness for dialogues continuation, with EUMETSAT Cal/Val colleagues' offer to promote the visibility of the EuroGO-SHIP RI concept project.

5.6. Indirect engagements with the ocean satellite community

During the January 2024 - October 2024 period we attended ocean satellite workshops and/or conferences (Table 1, Section 3), organised by relevant to work package 4 (WP4), Task 4.4 identified stakeholder groups. This allowed us to indirectly collect information on past and current ocean satellite community needs and requirements with respect to general and ocean parameter-specific in-situ data. The most relevant to EuroGO-SHIP findings from 1) the International Sea Surface Temperature (SST) Fiducial Reference Measurements Radiometer Network (ISFRN) workshop (April 2024), 2) the European Space Agency (ESA) Ocean Salinity conference (May 2024), and 3) the Horizon 2020 Copernicus Calibration and Validation Solutions (CCVS) project post-project meeting (June 2024), (Table 1, Section 3) are presented below:

1) ISFRN workshop
    - Ship-based radiometric measurements remain highly reliable, generating high accuracy, traceable sea surface temperature (SST) measurements, uncertainty less than 0.1 K (e.g., Donlon et al., 2008); such high accuracy measurements are needed to validate high accuracy satellite SST sensors-derived data, in turn used to generate long-term climate data records.
    - The importance of satellite and in-situ SST measurements, including ship-based, and consequently derived SST data records for global carbon assessments used to guide new policies is increasing (e.g., Shutler et al., 2024).
    - Coincident ship-based observing provides the opportunity to generate large datasets over wide range of conditions, providing an opportunity to combine with and improve large spatial scale satellite-derived atmosphere-ocean flux/transfer systems (e.g., Shutler et al., 2019).

2) ESA Ocean Salinity conference
    - Sea surface salinity (SSS) satellite and in-situ observations are vital for initialising, validating, and improving seasonal predictions of ocean physics, ocean circulation, ocean biogeochemistry (e.g., Boutin et al., 2021).

- Combining SSS satellite and in-situ observations with optimal interpolation removes artefacts towards the North Pole observed in satellite only data products (e.g., Greiner et al., 2023; Xie and Bertino, 2023).
- Historical and new in-situ measured ocean salinity, including ship-based, are essential in 1) relating satellite-derived SSS (SMOS, AQUARIUS) with subsurface ocean salinity with respect to atmospheric forcing, including wind and rain, 2) deriving magnitude of SSS variability within a satellite footprint (SMOS, 40 km; AQUARIUS, 50-150 km) (e.g., Boutin et al., 2016; Boutin et al., 2021; Vinogradova et al., 2019).

3) CCVS post-project meeting, including consolidated during the project recommendations (e.g., Clerc et al., 2023)
   - EU member states are expected to continue the in-kind contribution of in-situ data; in-situ data collection, mostly local activity, is the responsibility of member states.
   - In-situ data collection needs to be acquired geographically, such that it is optimised for Calibration/Validation (Cal/Val) purposes.
   - There is a great need for the harmonisation of in-situ measurement protocols and processing, as well as the need for calibration consistency, and centralised in-situ data archiving and distribution.
   - Synergies with RIs would increase the scientific value of the collected data and will overall reduce costs.
   - Fiducial reference measurements (FRMs) remain limited, available mostly for imaging radar and altimeters measurements; overall lack of commonly agreed and adopted measurement protocols and uncertainty analysis for FRMs.
   - Improving the quality of Cal/Val activities remains both short and long-term high priority.

6. Overall findings and recommendations

6.1. Overall findings

Collectively, based on consultations with European research ship operators, European marine forecasting centres, the European Space Agency (ESA) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Calibration/Validation teams, and indirect engagements with the wider ocean satellite community, and with respect to in-situ ocean data, we found the need for:

- The provision of near-real time (NRT) in-situ data (e.g., temperature, salinity, dissolved oxygen, currents),
- A clear definition of the threshold delivery time of NRT data, to be provided to the observational, modelling and satellite communities.
- The provision of long-term in-situ data of fiducial quality.
- The harmonising of metadata and data community practices and standards.

- Centralised and openly accessible in-situ databases, including historical data records.
- Timely delivery of both NRT and delayed mode in-situ data.
- Co-locating of in-situ and satellite measurements (logistics/coordinating and financial challenges/restrictions being recognised).
- Synergies with existing marine research infrastructures (RIs), thus increasing the value of collected data and reducing costs of ocean observing.
- Alignment with the tiered classification of observing networks and programmes (WMO INFCOM, 2022), developed under the World Meteorological Organisation (WMO) Integrated Global Observing System (WIGOS) Rolling Review of Requirements (RRR) process (WMO WIGOS, 2023) and tiered classification of observing networks and programmes (WMO INFCOM, 2022).

6.2. Recommendations

Based on community recommendations (e.g., Sterckx et al., 2020, Thorne et al., 2017) and our consultations with the European Space Agency (ESA) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Calibration/Validation teams, indirect engagements with the wider ocean satellite community, and with respect to in-situ ocean data, a future EuroGO-SHIP research infrastructure (RI) can exert added value by providing and/or facilitating the provision of data, which are:

- Of Fiducial Reference Measurement (FRM) quality.
- Co-located with satellite data.
- Accessible.
- Readily available in a timely manner.
- Spatially and temporarily rich.

More specifically and drawing from the overall findings listed above (Section 6.1), a future EuroGO-SHIP RI can showcase added value by facilitating:

- The provision of near-real time (NRT) in-situ data (e.g., temperature, salinity, dissolved oxygen, currents).
- The provision of long-term in-situ data of fiducial quality.
- The harmonising of in-situ metadata and data community practices and standards (e.g., closer collaboration with the European Marine Observation and Data Network (EMODnet)).
- The co-locating of in-situ and satellite measurements (logistics/coordinating and financial challenges/restrictions being recognised (e.g., closer collaborations with ESA's and EUMETSAT's Cal/Val teams)).
- Synergies with existing marine observing RIs to increase the value of ocean in-situ data and reduce ocean observing costs (e.g., closer collaborations with the World Meteorological Organisation (WMO)-Intergovernmental Oceanographic Commission (IOC) Joint Centre for Oceanography and Meteorology in-situ Observations Programmes Support (OceanOPS)).

- Alignment with the tiered classification of observing networks and programmes approach (WMO INFCOM, 2022), developed under the WMO Integrated Global Observing System (WIGOS) Rolling Review of Requirements (RRR), an experts' knowledge and impact studies-based process, which provides a systematic, transparent compilation of information on requirements for observations, observing system capabilities (including marine and ocean), their cost effectiveness, thus identifying priorities for addressing gaps between requirements and capabilities (WMO WIGOS, 2023).

More specifically, and similarly to recommendations outlined by Sterckx et al., (2020) and Thorne et al., (2017), a future EuroGO-SHIP RI could develop, or contribute towards the establishment and/or the development of:

- Widely accepted, harmonised and consistent data quality indicators, and in turn,
- A measurement maturity assessment approach, further formalising the need for harmonised metadata and data practices and standards.

The above provisional recommendations in support of the projects upcoming statement of requirements we found critical endeavours, requiring high effort and strong commitment across all process levels and stakeholder groups, including the EuroGO-SHIP consortium.

7. Conclusions

Our direct engagements with mapped end-users of hydrographic information, i.e., selected European ship operators (Table 2, Section 5. 1), selected European marine forecasting centres (Table 3, Section 5.2), the European Space Agency (ESA) (Section 5.3) and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) (Section 5.4) satellite data calibration and validation (Cal/Val) teams, yielded good information gathering, needs and requirements identification, as well as gathering advice on possible EuroGO-SHIP research infrastructure (RI) future structure and activities. We find that some of EuroGO-SHIP RI concept project main objectives align with those of ESA's and EUMETSAT's Cal/Val teams, i.e., supporting and facilitating the collection and provision of high(er) quality ocean data (e.g., Essential Ocean Variables (EOV), Essential Climate Variables (ECV)), which will ultimately contribute towards the assessment of climate change status and the prediction of future climate change impacts. EuroGO-SHIP RI "added value" could be the continued provision of high(er) quality hydrographic data, with instances where satellite data being calibrated and validated with the use of ship-based fiducial reference measurements (FRMs), resulting in an improvement in estimating uncertainties to constrain model-derived climate projections.

Collaborations with ESA's and EUMETSAT's Cal/Val teams are feasible, where the needs to plan for European ocean and space observing sections can be addressed, notably closing data gaps in data-poor European Seas regions. Here, ocean observing continuity, and the required coordination to realize it, we find are vital. Based on the level of their input and interest towards a future, i.e., operational EuroGO-SHIP RI, stakeholders (e.g., ESA and EUMETSAT

Cal/Val teams) have the potential to contribute to the development of a fit-for-purpose RI, steady in its activities to deliver long-term services. Hence, stakeholders' engagements should remain an ongoing process throughout the development and establishing stages of a future EuroGO-SHIP RI, where both current and new stakeholder needs and requirements are continuously reviewed, assessed, and improved on, such that stakeholders' transitioning from consultants to active collaborators, and/or partners, becomes an integral part of the sustainable growth of a future EuroGO-SHIP RI.

8. Acronyms

ADCP	Acoustic Doppler Current Profiler
BOOS	Baltic Operational Oceanographic System
CCVS	Copernicus Calibration and Validation Solutions (Horizon 2020 project)
CEOS	Committee on the Earth Observation Satellites
CTD	Conductivity, Temperature, Depth
ECMWF	European Centre for Medium-range Weather Forecasts
EMODnet	European Marine Observation and Data Network
ERA	European Research Area
ECV	Essential Climate Variable
EOV	Essential Ocean Variable
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EuroGO-SHIP	European Global Ocean Observing Ship-base Hydrographic Investigations Programme
EuroGOOS	European Global Ocean Observing System
FAIR	Fair, Accessible, Interoperable, Reusable
GDPR	General Data Protection Regulation
GOOS	Global Ocean Observing System
INFCOM	Commission for Observation, Infrastructure, and Information Systems
IOC	International Oceanographic Commission
ISFRN	International Sea Surface Temperature Fiducial Reference Measurements Radiometer Network
NRT	Near-Real Time
OceanOPS	Oceanography and Meteorology in-situ Observations Programmes Support
OCR-VC	Ocean Colour Radiometry Virtual Constellation
RI	Research Infrastructure
ROOS	Regional Operational Oceanographic System
WGCV	Working Group on Calibration and Validation
WMO	World Meteorological Organisation

Table 4. Summary of acronyms used in this report.

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