EuroSea

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Executive summary

The joint WMO-IOC in situ Ocean Observing System Monitoring and Coordination Centre (OceanOPS, formerly JCOMMOPS) was mandated by the observations coordination group of the Global Ocean Observing System (OCG/GOOS) to maintain and manage metadata of OCG networks. Globally OceanOPS needs to make progress on the monitoring of GOOS Eulerian elements. Thus, OceanOPS activity within EuroSea project is an opportunity to highlight challenges and enable progress.

OceanOPS has developed a metadata management system for standardization and harmonization of various OCG networks[1], including long term Eulerian time series stations. The Eulerian stations considered are fixed moorings for ocean observations as against the mobile drifting buoys, floats, gliders under overall GOOS OCG. Other fixed stations like tidal gauges, high frequency radars are beyond current topic.

The OceanSITES netCDF data format specification was reviewed to include metadata as required by OceanOPS. The EMSO community has started to use this format. However, and if this new format is widely used (which is not the case at the moment), it has to be made available before data are made available (often two years after the observations) otherwise our monitoring status will always lag behind. And what about the SITES for which the data sharing is not happening for some reasons. We won't have any monitoring capacity on these as we would only see the platforms sharing data. The alignment of metadata between OceanOPS requirements and final files for data users is needed, but this will not help our monitoring. Metadata have to be channelled to OceanOPS before (or just after) the SITE is serviced.

The current approach to complete the catalogue are based on rare, irregular, and individual submissions to OceanOPS. This is not efficient for any of the stakeholders but is better than nothing.

The prioritization of metadata submission to OceanOPS, according to its developing standard, seems to be the main challenge we face to deliver a robust and accurate metadata catalogue for Eulerian networks in Europe and beyond.

Considering the complexity and often unique specificities of each of these Eulerian systems, the work load required to complete this harmonization might as well be underestimated.

Without an active and regular cooperation between Eulerian platform operators and OceanOPS, our monitoring capacity in Europe for this system will remain rather poor.

1. Introduction

The OceanOPS metadata system is designed to monitor and structure the GOOS networks, to deliver appropriate monitoring tools for the governing bodies (international, European, national, regional e.g.) and implementers (steering teams, scientists, institutions, manufacturers, data managers, etc.), and to make sure final users have also access to high quality metadata together with data. When metadata quality for each GOOS element meets OceanOPS requirements, these are routinely channelled to the WMO/OSCAR system (Observing Systems Capability Analysis and Review Tool). While this WMO metadata system is fuelled by

[1] https://www.ocean-ops.org/metadata

national focal points (for land stations e.g.), OceanOPS is responsible for the metadata delivery for the whole ocean domain of the WMO earth system monitoring.

Common elements under each network include a mandatory “programme” that describes implementing entity usually leading agency or owner. This allows to structure the observing components in GOOS. An OceanOPS programme is affiliated with a country, a list of default contact points and agencies, with dedicated roles. Under the programme, there will be one or more “platforms” operated by the leading agency or owner. Then the metadata structure is further detailed to implementers, platform description, identifiers, operations, hardware, telecommunication, etc. The details of these metadata concepts and design are described in the OceanOPS metadata documentation[2].

Eulerian observing elements we wish to monitor fall back under the following categories:

- OceanSITES moorings (long term multidisciplinary and deep see measurements)
- Data Buoys Cooperation Panel moored buoys (wave buoys, coastal/national and tropical arrays)
- Data Buoys Cooperation Panel tsunami buoys
- European Multidisciplinary Seafloor water column Observatories (EMSO)
- Coastal stations

Some elements can belong to more than one of the above Panel, Steering Groups or Networks. Sometimes they share the same data management (and the same unique identifier) and sometimes they do not. There are a lot of specificities to consider which makes the monitoring task challenging. The last category of “coastal stations” is a domain where OceanOPS does not have much perspective and wishes to further investigate. It is anticipated a large number of these stations and related data are unknown to the international community. OceanOPS is not equipped yet to lead these investigations and the required metadata harmonization work, in each EU member country. Similarly, many observing systems operated at the basin scale (Regional Ocean Observing System, ROOSs hereafter), national and even regional levels do not appear in this catalogue.

A European Eulerian status report, or metadata catalogue, can be produced through the OceanOPS web-based monitoring tools and API.

The gaps between what is monitored at the global level and what is operating at the European level is presented in Section 3. As suggested by EuroSea, WP1, D1.2 report[3], data collection is complemented using European data aggregators like EMODNET Physics, SeaDataNet and Copernicus Marine Service and the EuroGOOS monitoring tools provided by the ROOSs.

Section 4 aims to catalogue the different ways to access metadata related to Eulerian platforms at OceanOPS. It describes the technologies currently operational and how to navigate in the OceanOPS system to quickly access the information.

The implementation of metadata harmonization processes is essential within operational Eulerian observatories objectives to provide consistent and systematic access to a variety of multidisciplinary and harmonized data. Furthermore, metadata sharing and integration in catalogues require cooperation and standardized processes between OceanOPS, European research infrastructures, and EOOS/EuroGOOS and European data aggregators (EMODNET, Copernicus Marine Services and SeaDataNet). For example, the

[2] https://www.ocean-ops.org/metadata
[3] https://eurosea.eu/deliverables/

integration of metadata from distributed heterogeneous facilities is not streamlined and require inefficient, time consuming, and error-prone process. To bridge this gap, EMSO ERIC developed the harmonization process and specification based on OceanSITES described in Section 5. Requirements and actions to improve the monitoring of the European Eulerian platforms at different levels will be proposed.

2. Status of European Eulerian networks at OceanOPS

Eulerian observing elements being, in most of the cases, complex observing systems, they require regular servicing and upgrades, especially on the sensors package they carry. In that sense, it creates a consequent challenge to keep the records up to date with regards to operation at sea (re-deployment and recoveries). OceanOPS intends and attempts to liaise with operators to maintain the metadata up to date and adapt its standard as required. This section intends then to report on the status of what constitutes OceanOPS' metadata set regarding those elements, including historical deployments.

2.1. OceanSITES moorings

Table 1 contains a summary of European Eulerian elements falling under the OceanSITES network, as present in OceanOPS system.

Figure 1 shows the spatial representation of OceanSITES Eulerian elements at OceanOPS.
Figure 2 and Figure 3 break down the same subset per country and observed variable.

Table 1. Summary of Eulerian elements under OceanSITES at OceanOPS for European implementers

	Number of active (pre-operational/operational/ temporarily silent) platforms	Number of historical deployment records (closed)
OceanSITES	133	1276

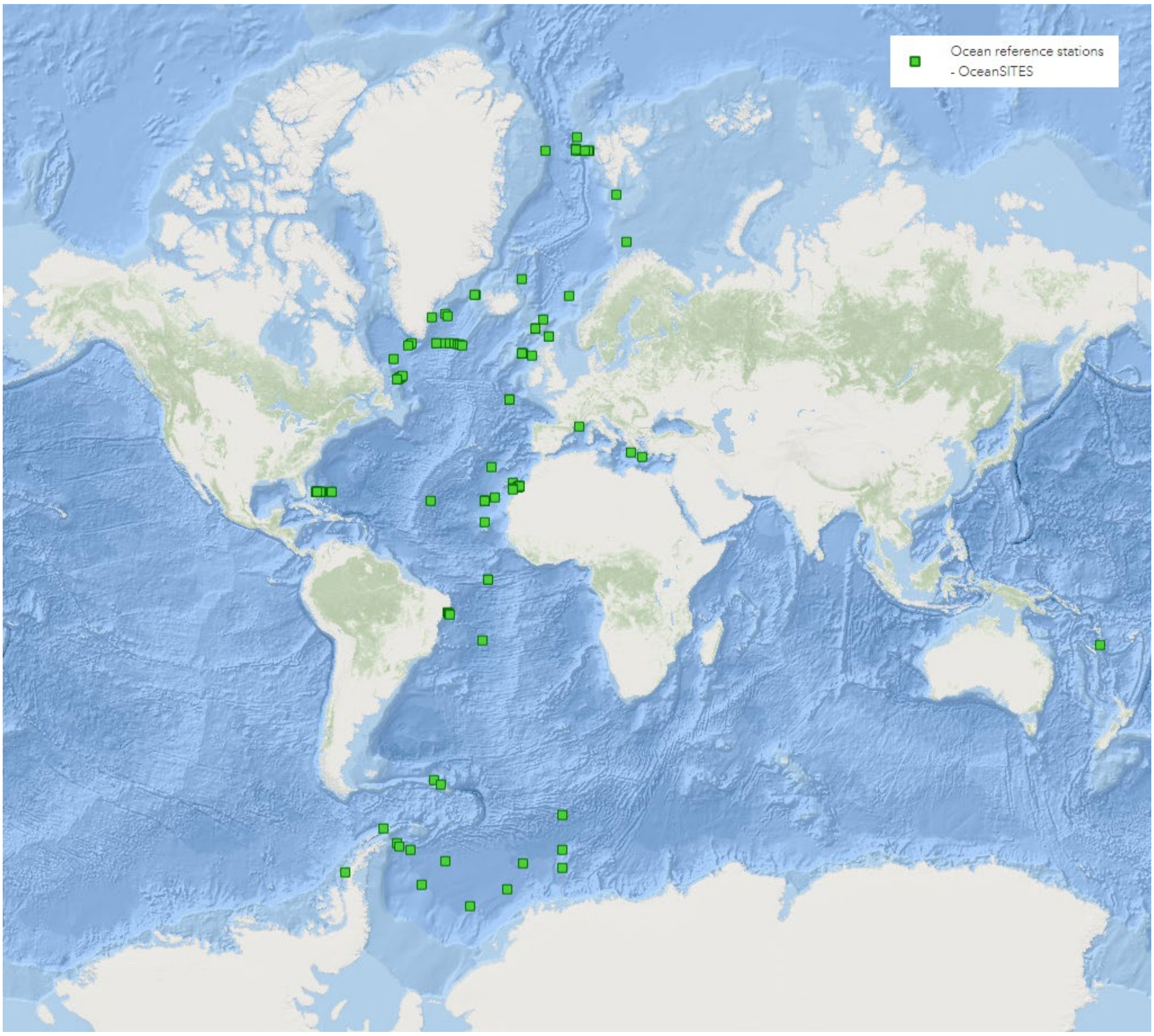

Figure 1. Deployment location of the active OceanSITES platforms

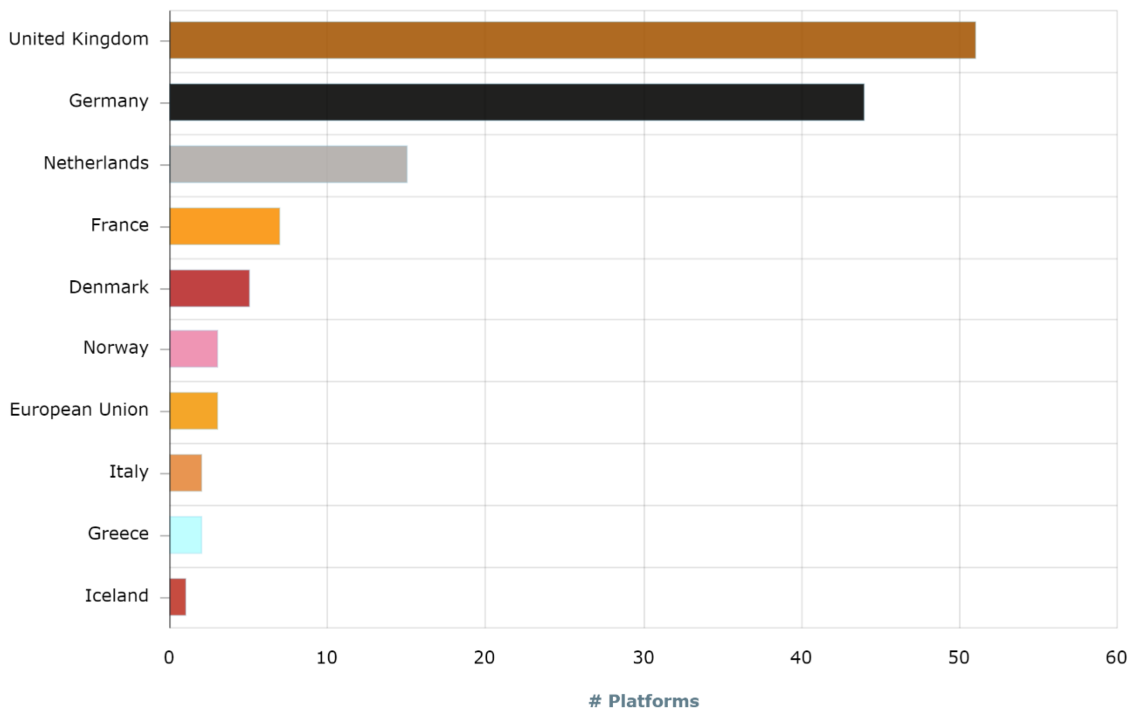

Figure 2. OceanSITES: distribution per country

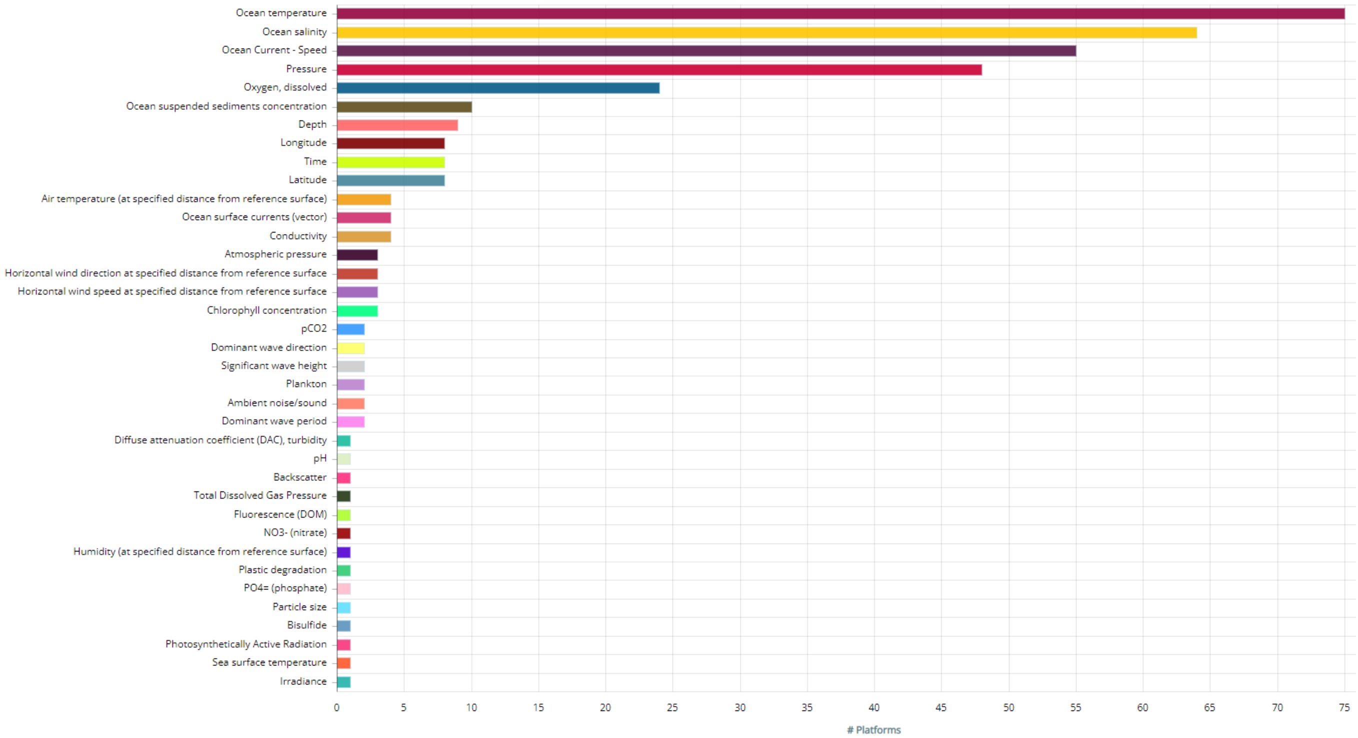

Figure 3. OceanSITES: count of observed variables

2.2. DBCP

Table 2 contains a summary of European Eulerian elements falling under the DBCP network, as present in OceanOPS system.

Figure 4 shows a spatial representation of DBCP Eulerian elements in OceanOPS.
Figure 5 and Figure 6 break down the same subset per country and observed variable.

Table 2. Summary of Eulerian elements under DBCP at OceanOPS

	Number of active (pre-operational/operational/temporarily silent) platforms	Number of historical deployment records (closed)
DBCP	122	391

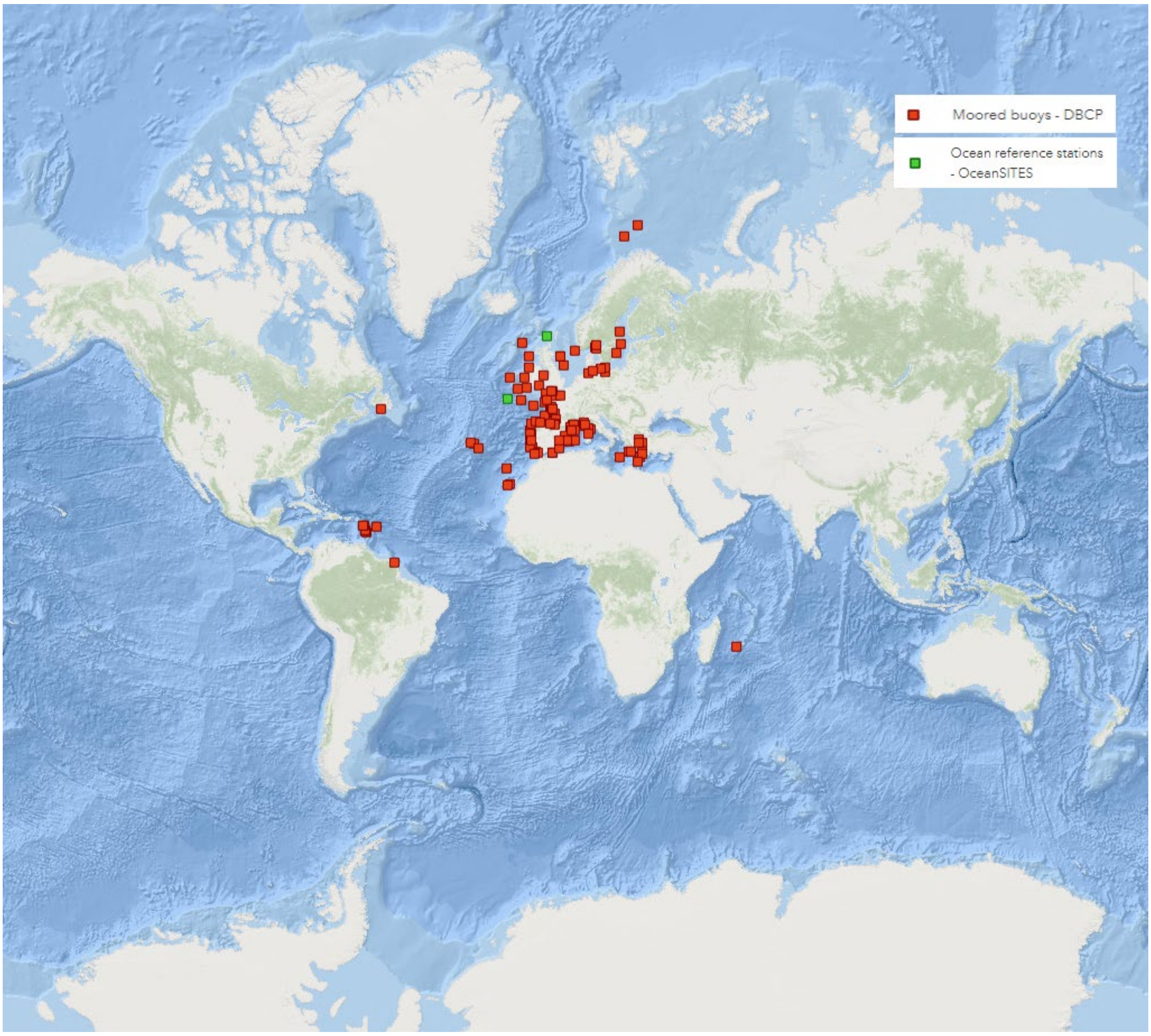

Figure 4. Deployment location of the active DBCP Eulerian platforms

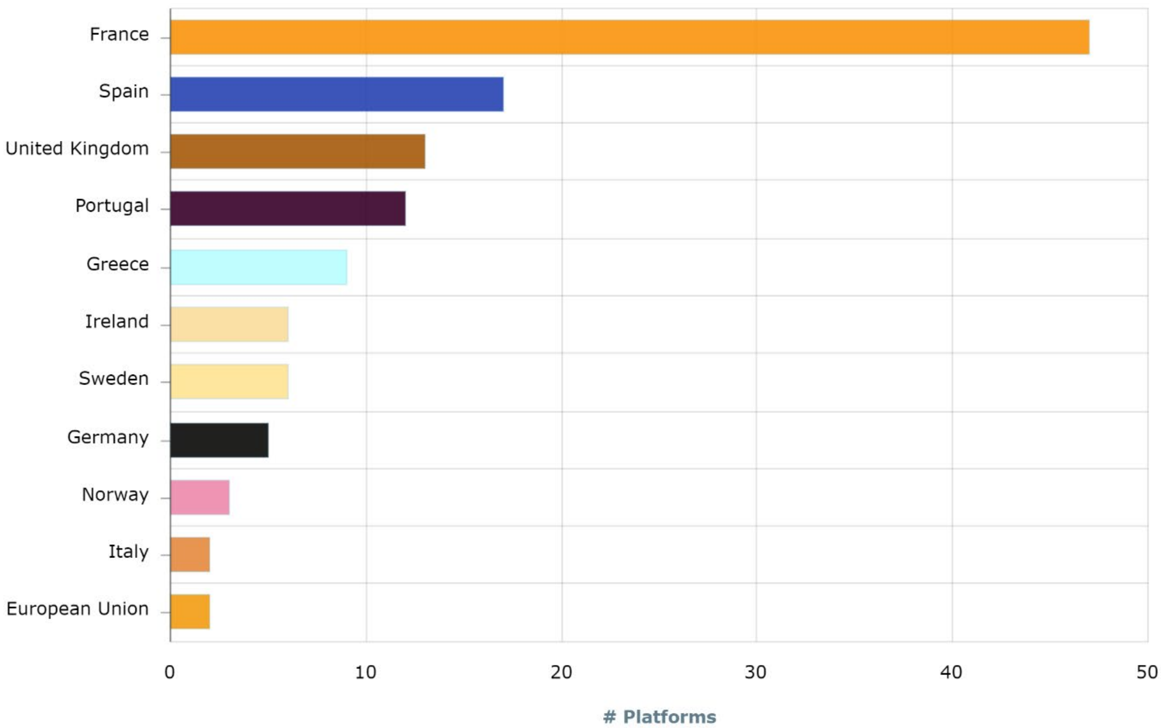

Figure 5. DBCP: distribution per country

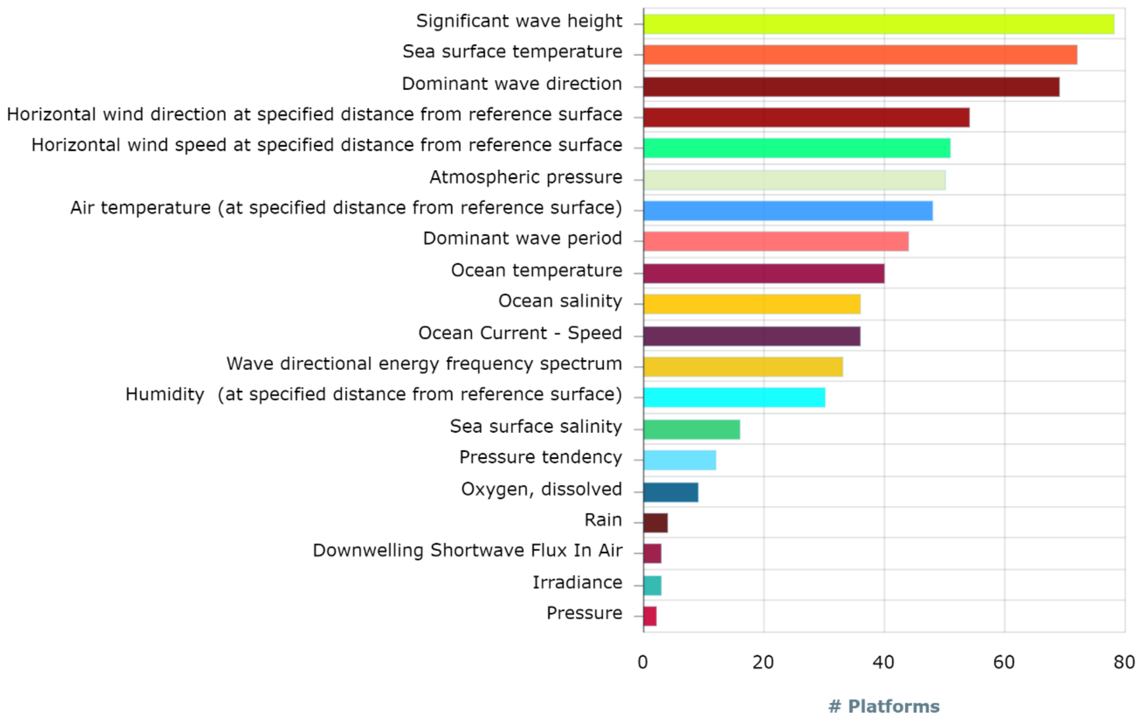

Figure 6. DBCP: count of observed variables

2.3. EMSO

OceanOPS is still working on integrating recently received EMSO elements, thus the following figures and charts are subject to evolve.

Table 3 contains a summary of EMSO (European Multidisciplinary Seafloor and water column Observatory) elements as present in OceanOPS system.

Figure 7 shows a spatial representation of the EMSO Eulerian elements in OceanOPS.
Figure 8 and Figure 9 break down the same subset per country and observed variable.

Table 3. Summary of EMSO elements at OceanOPS

	Number of active (pre-operational/operational/temporarily silent) platforms	Number of historical deployment records (closed)
EMSO	10	98

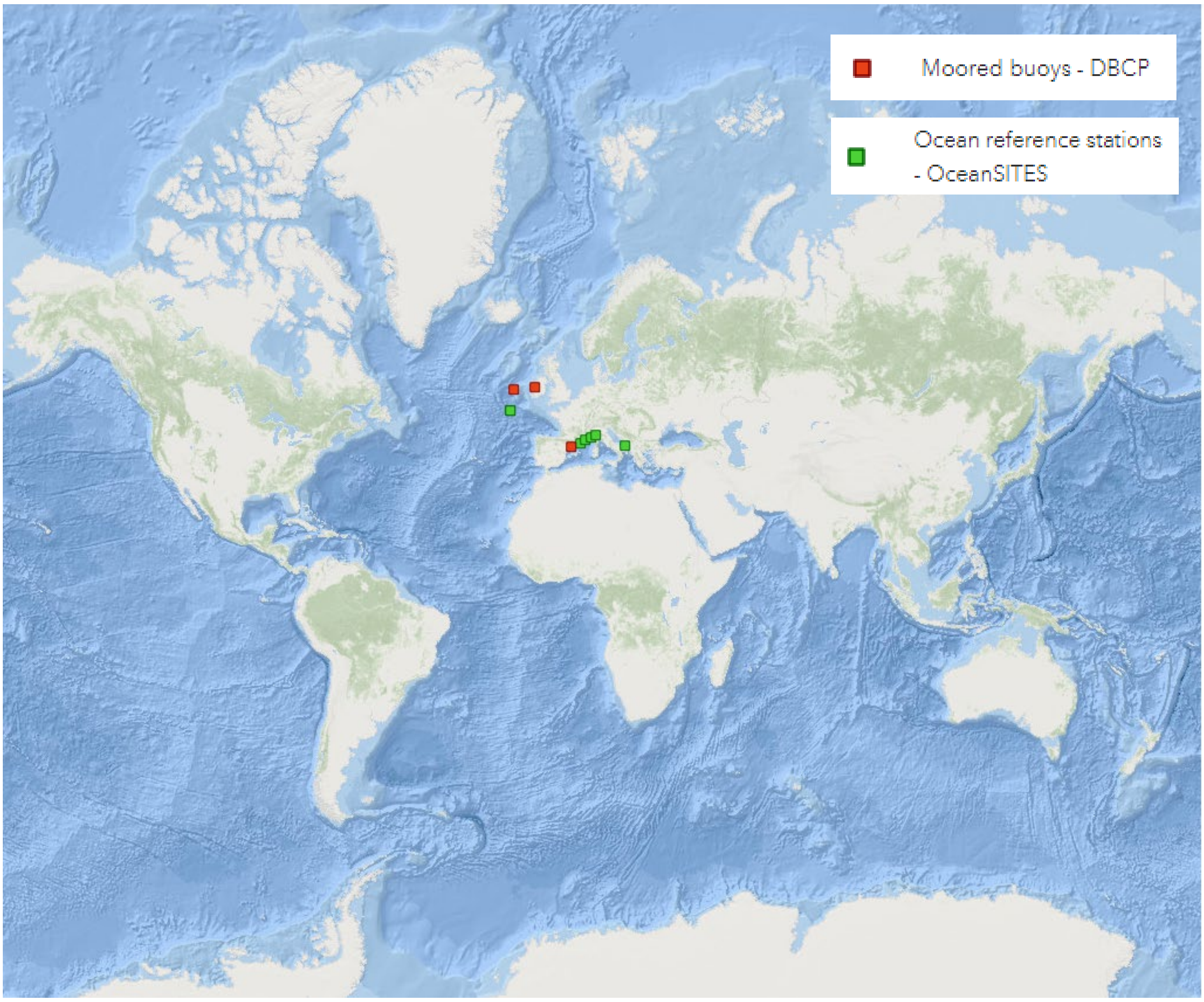

Figure 7. Deployment location of the active EMSO platforms

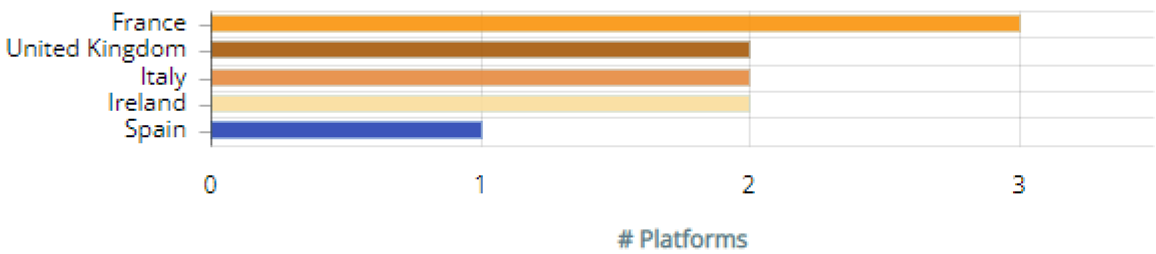

Figure 8. EMSO: distribution per country

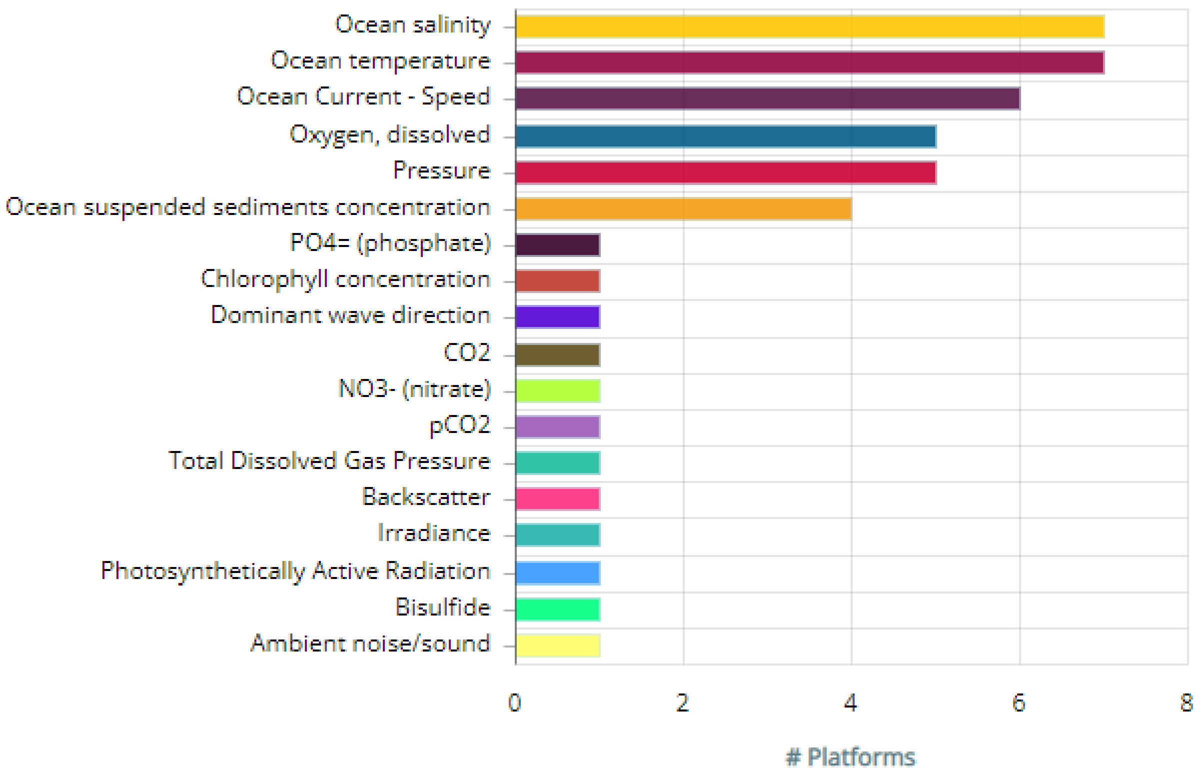

Figure 9. EMSO: count of observed variables

2.4. Gaps and requirements in the monitoring of Eulerian Ocean Observing System at OceanOPS

Based on national reports submitted to the Thirty Seventh Session of the Data Buoy Cooperation Panel (DBCP-37[4]) in November 2021, there were obvious discrepancies for number of coastal/national moored buoys between stations operated by countries and visible at OceanOPS. For example, for national/coastal

[4] https://goosocean.org/index.php?option=com_oe&task=viewEventDocs&eventID=3021

moored buoys, some countries reported moored buoys operation during their intersessional period, but none of them were visible with basic metadata information (WMO IDs, locations, deployment dates, deployment ship, sensors, etc.). Some countries only have a fraction of coastal moored buoys visible at OceanOPS. There are several reasons behind, such as no timely communication with OceanOPS on these deployments, or buoy data not shared to the GTS, or data not in agreed format or no commitment from PI or institute to provide this information to OceanOPS.

Despite those difficulties, the OceanSITES monitoring at OceanOPS accommodates the majority of long term European Eulerian stations as illustrated in Table 1. The cost in terms of human resources (at OceanOPS and outside) to maintain the monitoring of European OceanSITES up to date is disproportionate compared to other networks. Improving the procedure and the support from the OceanSITES community to this work should become a priority in Europe.

OceanOPS is currently trying to gather EMSO platforms (some of them are captured under DBCP or OceanSITES Panels) but this will need close interactions with platform operators. Indeed, unless important work in the curation of the metadata available on the current EMSO API, this strategy does not yet permit to gather the appropriate metadata in a machine-to-machine approach.

Working on control vocabularies between EMSO, OceanSITES and OceanOPS is a strong outcome of this task. This will reduce the cost of monitoring and improve the accuracy. It will also contribute to implement the FAIR principle in the data management of OceanSITES.

3. Metadata interactions with OceanOPS

Metadata at OceanOPS can be edited and accessed through different ways. This section presents a list of the different possibilities offered to users at the moment. To know more about metadata required by OceanOPS to accurately monitor Eulerian platform, the design of the data base, the content and how to improve them, please refer to the metadata documentation[5] that has been edited with the support of the EuroSea project.

Either done through scripting routines, or through User Interface (UI) interactions, OceanOPS handles and processes metadata from pre-defined metadata standards. From netCDF files to APIs, the list is becoming more and more important and OceanOPS has the capability to work with new standards, as long as they are consistent and coherent with what is already existing, and stable.

In any case, OceanOPS value added is in quality controlling (QC) metadata entering the system, in order to report the most accurately possible to GOOS stakeholders. At the moment, the most automated metadata feed process still requires at one or multiple stages human inputs, thus it is eligible to mistakes or inaccuracies. It is precisely why OceanOPS metadata QC is important. On top of that, OceanOPS ensures that the metadata ingested will accommodate and integrate with the other elements of the GOOS present in the system. This work of integration is a major piece of the processing chain, involving the need to have a holistic view over the different standards and vocabularies existing throughout the communities, thus the work with networks so that they adopt existing ones.

[5] https://ocean-ops.org/metadata

3.1. Semi-automated and automated metadata feed

This section gives a non-exhaustive list of metadata feed that OceanOPS processes, in order to give an idea of what is possible. In any case, OceanOPS requires a minimum set of metadata, which much be offered indifferently from the format read.

CSV file

As described on the metadata documentation[6], OceanOPS can handle metadata input following a CSV file format, using some pre-existing vocabularies and some specific to OceanOPS. This CSV can be currently uploaded on OceanOPS web dashboard to enable an easy way to enter metadata through the web.

OceanOPS plans to allow the ingestion of this CSV file through its API, allowing future processes like automated crawling or submission of metadata.

The core of this CSV file requires 8 mandatory columns:

- Platform model
- Program
- Deployment date
- Deployment latitude
- Deployment longitude
- Deployment ship
- Variable/Sensor model (array)
- Telecom type

However, one of these CSV columns includes an array of sensor names (and other array-based columns with their attributes, if known: depth, serial number, etc.). It can often be rather long for Eulerian systems, which can be difficult to read, making it the only complexity of this format. To overcome this, the management of the sensor list and their attributes can be now uploaded through a dedicated file (to keep the original CSV simple to handle), which explodes the sensor array into rows (to be documented).

NetCDF file

Some networks provide NetCDF files complying with different formats. The ones that OceanOPS is able to process can be uploaded on the web dashboard. Further work is required to exploit the new OceanSITES netCDF format and complement "platform metadata" with metadata on data available.

ERDDAP

ERDDAP is an easy way to publish data and metadata. If OceanOPS metadata requirements are met and there is a unified and consistent format, it is easy for OceanOPS to read metadata from such a server.

API and other formats

The same applies to any other format operators might have.

[6] https://ocean-ops.org/metadata

3.2. Web dashboard

For metadata queries and access, this web application offers a rich user interface enabling the user to browse, query, display and analyse the metadata. If the user is logged in and has the required rights, metadata editing is possible to fix or improve the metadata set.

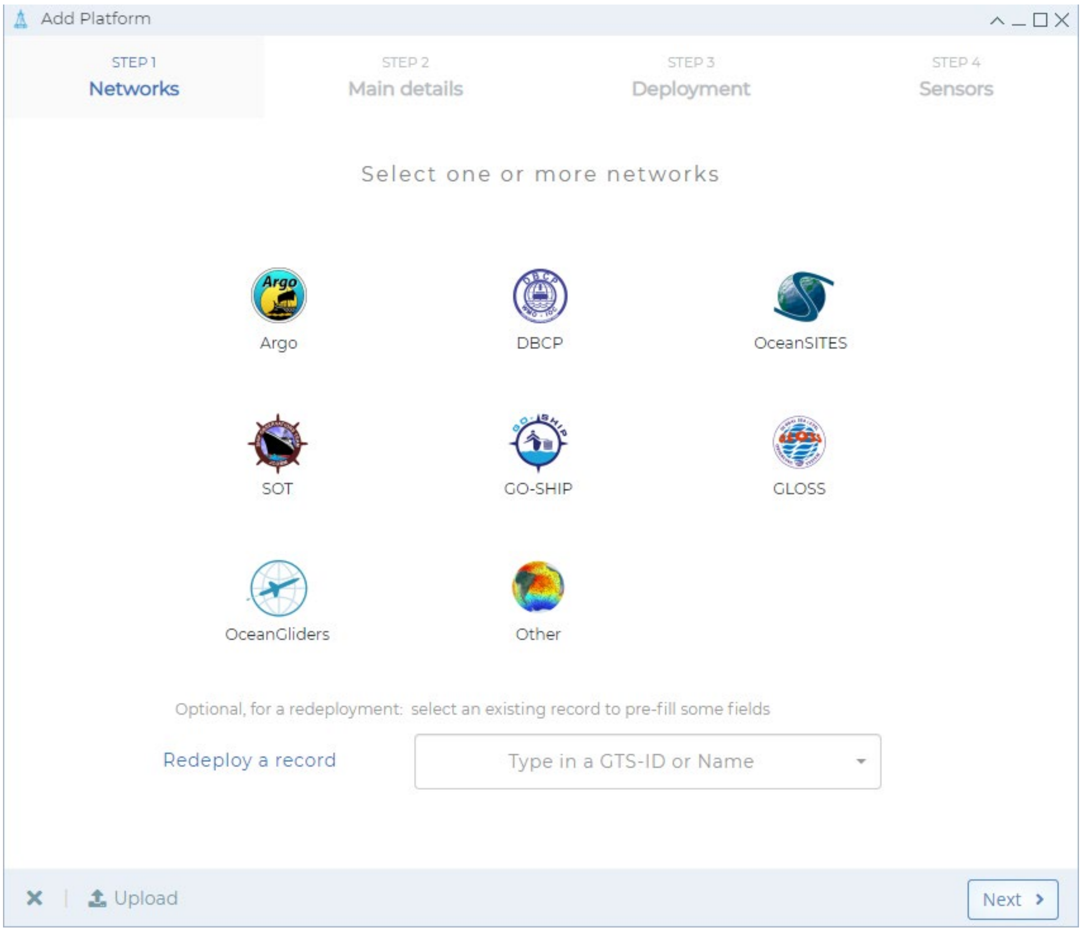

Figure 10. Wizard tool guiding the user through metadata input: main details, deployment, and sensor information.

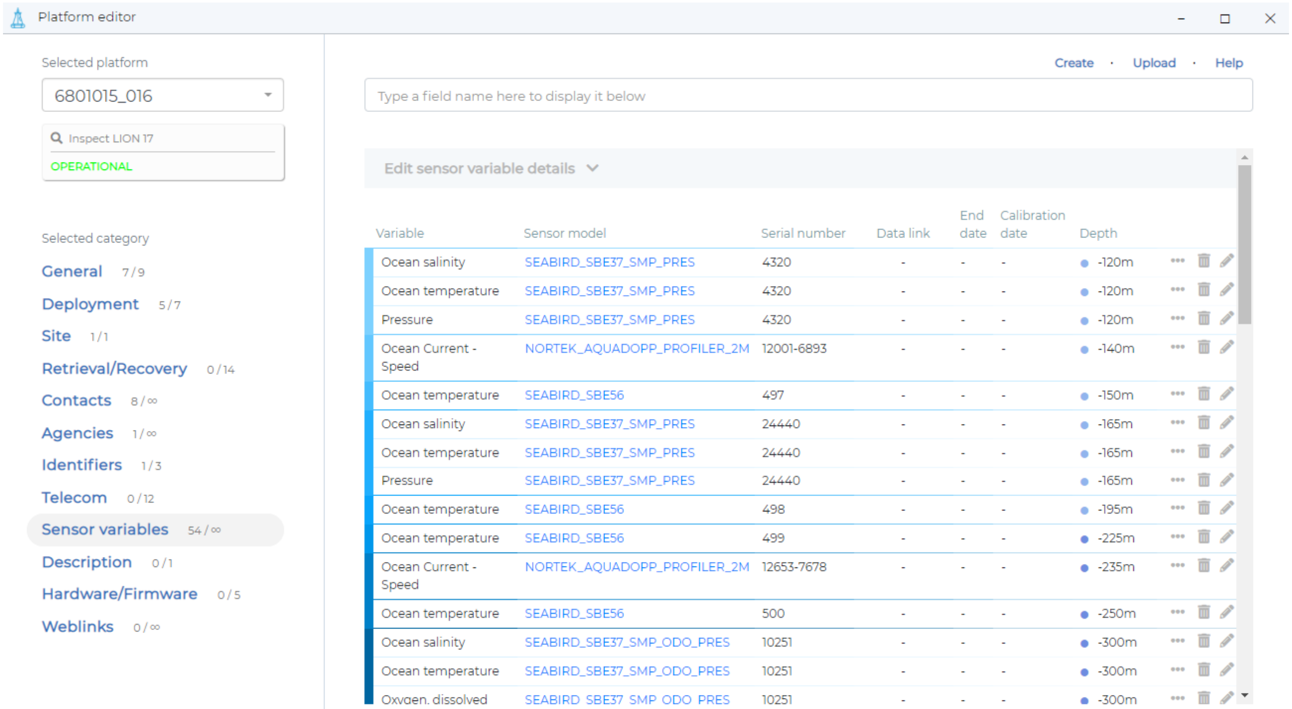

Figure 11. Platform metadata editor, through a flexible and efficient form

Draft #4 T8N110W.csv

×

Requires confirmation

The provided identifier matched with an existing platform. Please confirm the match is correct and that you wish to edit the existing data. Or instead set the draft as a new registration and automatically close the existing platform.

Warning: when adding new sensor variables to a platform, any of it's existing sensor variables will by default be removed, unless user clicks to keep existing variables.

Confirm as edit | Set as new registration

Field name	Existing value	New value
Activity criterion	30	30
Closure criterion	1095	1095
Deployment cruise name	TA-21-02-BLFN	CRUISE BLUE FIN
Deployment date	2021-11-19 07:05:00	2021-11-20 00:00:00
Deployment latitude	8	8.2
Deployment longitude	-110	-119.9
Deployment ship	BLUE FIN	BLUE FIN
GTS-ID	4300001	4300001
Ice detection	No	No
Internal ID	dm431a	dm431a
Model	TAO_REFRESH	TAO_REFRESH
Name	8N110W	8N110W
Networks	DBCP, OceanSITES, Eulerian Elements, Global Tropical Moored Buoy Array, TAO, Tropical Pacific Observing System	DBCP, OceanSITES, Global Tropical Moored Buoy Array, TAO, Tropical Pacific Observing System
Program	NDBC-MB	NDBC-MB
Reference	4300001_038	4300001_038
Retrieval cruise name	-	RHB2022
Retrieval end date	-	2022-10-01 11:00:00
Retrieval ship	-	RONALD H. BROWN
Retrieval start date	-	2022-10-01 10:10:00
Ship IMO	8036586	8036586
Ship call sign	WDC7379	WDC7379
Ship distance bridge-bow	4	4
Ship draft	6	6
Ship freeboard	5	5
Ship height	12	12
Ship reference (ICES)	33I1	33I1
Sites	T8N110W	T8N110W
Telecom type	-	IRIDIUM
Vessel breadth	12	12
Vessel length	50	50
Water depth	-4219	-4300

Figure 12. OceanOPS preview tool when updating metadata by the upload

This interface is customizable and can adapt to the user and the context of the observing system of interest.

In the context of Eulerian observing elements, it is easy to filter out this web application through the query form, by selecting the appropriate fields (example in Figure 13, filtering on the “Eulerian Elements” network and the list of countries involved in EuroSea).

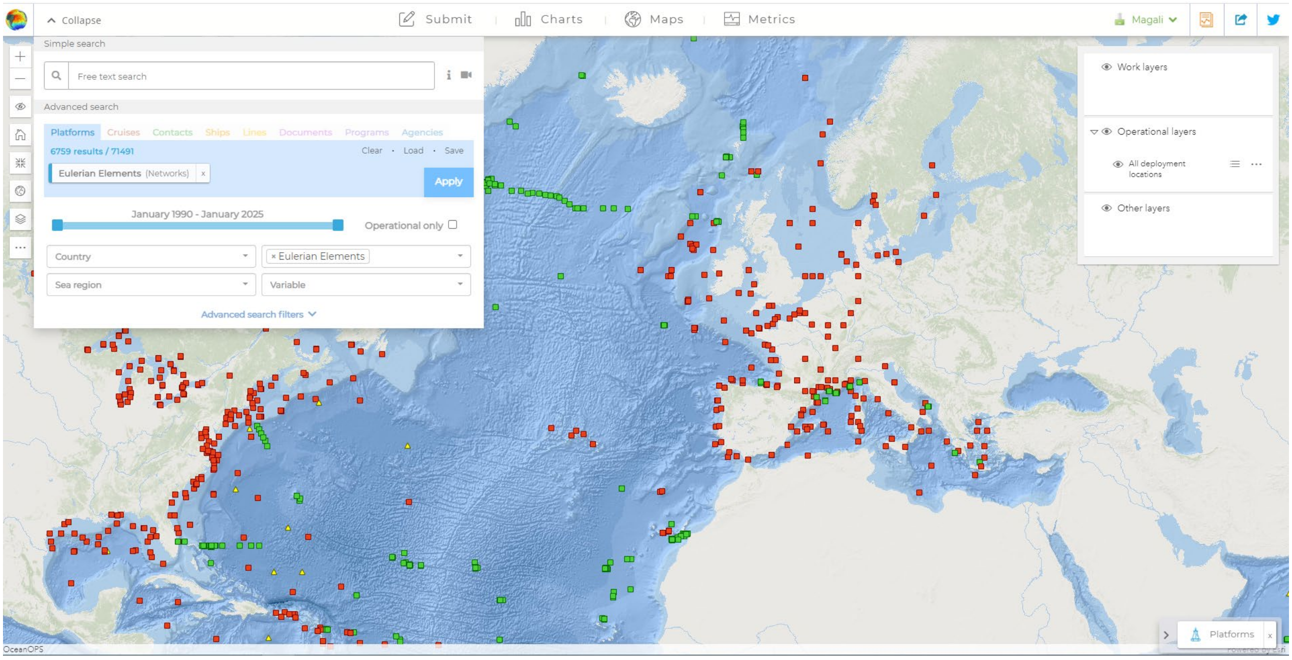

Figure 13. Example of the OceanOPS dashboard, filtered on Eulerian networks (deployment location)

This interface offers the possibility to get an overview of the filtered sample of observing elements and consult the detailed information of each element forming that sample (see Figure 14). The interface allows downloading the metadata for the selected platform sample.

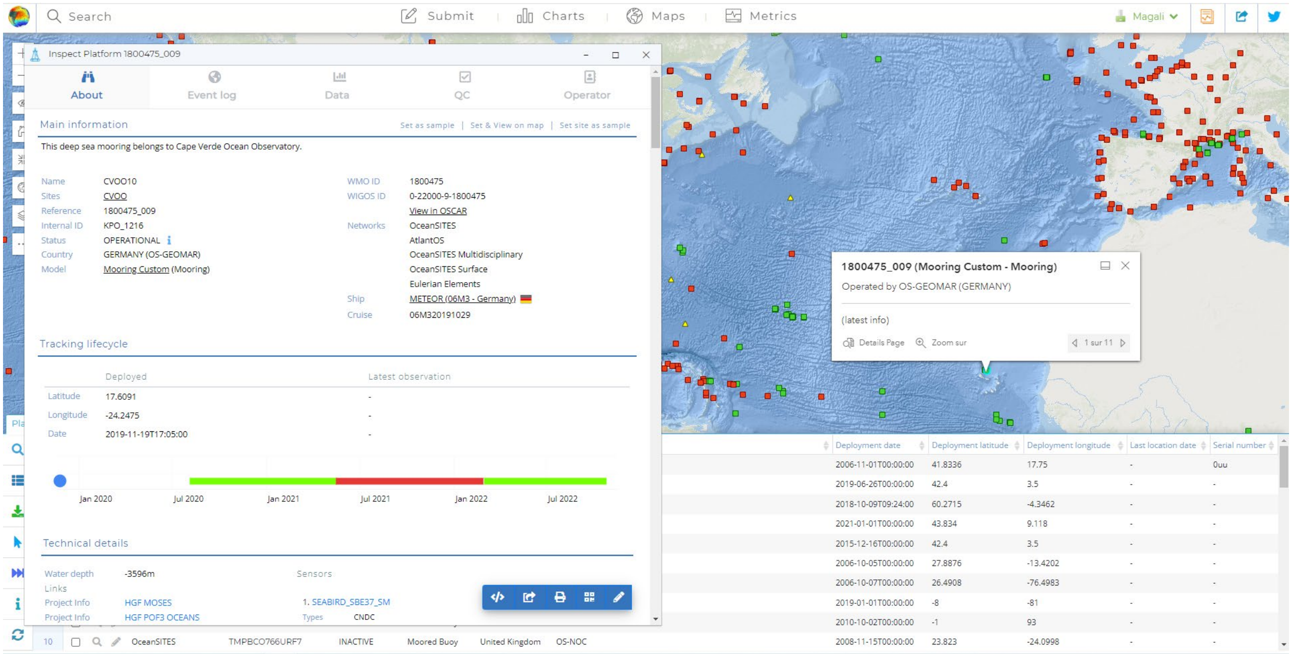

Figure 14. Viewing metadata: overview or detailed information.

3.3. Regular metadata exports

The metadata present in the system (and supporting the web interface) are regularly exported (usually daily) in a Comma Separated Value (CSV) format. This file is available on a HTTPS server: https://ocean-ops.org/share/OceanOPS/Status/oceanops_eulerian_all.csv.

3.4. REST API

A REST API access is available for elements monitored by OceanOPS[7].

To restrict the results of the list of platforms, the user should add the URL parameter 'exp=networkPtfs.network.id=1001380' to the request made to the API (this will ensure that only Eulerian networks are included).

Example: https://www.ocean-ops.org/api/1/data/platform?exp=networkPtfs.network.id=1001380

All the elements resulting there can then be requested individually in the same JSON style, or XML (WMDR[8] compliant) format. Please refer to the API documentation for more information.

[7] https://ocean-ops.org/api
[8] https://library.wmo.int/index.php?lvl=notice_display&id=19925#.YxBtxXZBw6Q

3.5. OGC compliant web services

Web services complying with the Open Geospatial Consortium (OGC) standards, Web Map Service (WMS), are available on the OceanOPS ArcGIS server[9]:

- WMS for DBCP elements (moored buoys and tsunami buoys): https://www.ocean-ops.org/arcgis/services/DBCP/DBCPLocations/MapServer/WMSServer?request=GetCapabilities&service=WMS
- WMS for OceanSITES elements: https://www.ocean-ops.org/arcgis/services/OceanSITES/OceanSITESLocations/MapServer/WMSServer?request=GetCapabilities&service=WMS

4. EMSO ERIC metadata harmonization and catalogues

Despite the technological developments in ocean observations, significant challenges concerning metadata still exist as described in an OceanObs'19 white paper. EMSO ERIC has participated in the scientific and engineering community's efforts to better establish future ocean observation requirements for future ocean observation, in particular with respect to the GOOS EOVs (Miloslavich et al., 2018). Moreover, previous focus was on best practices in ocean observation (Pearlman et al., 2019).

EMSO ERIC has established catalogues of EMSO ERIC (Eulerian) platforms that are available at the distributed regional facilities, the EMSO ERIC data portal (see Figure 15 and Figure 16), the EMSO ERIC federated ERDDAP server (see Figure 17), and EMSO ERIC RESTful machine-to-machine API.

[9] https://www.ocean-ops.org/arcgis/rest/services/

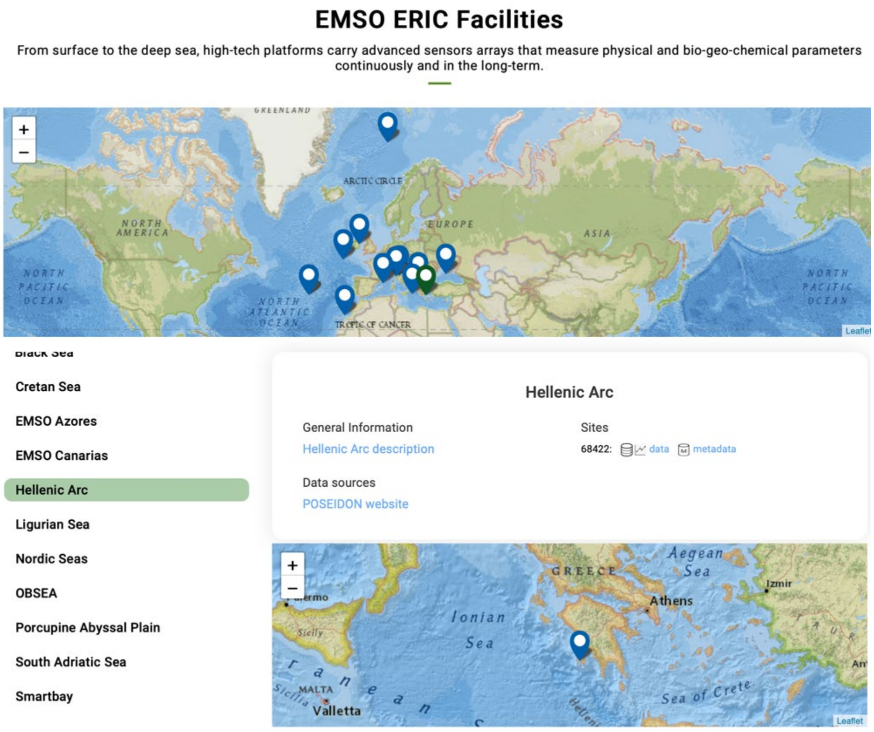

Figure 15. Site catalogue view of the EMSO ERIC data portal (https://data.emso.eu)

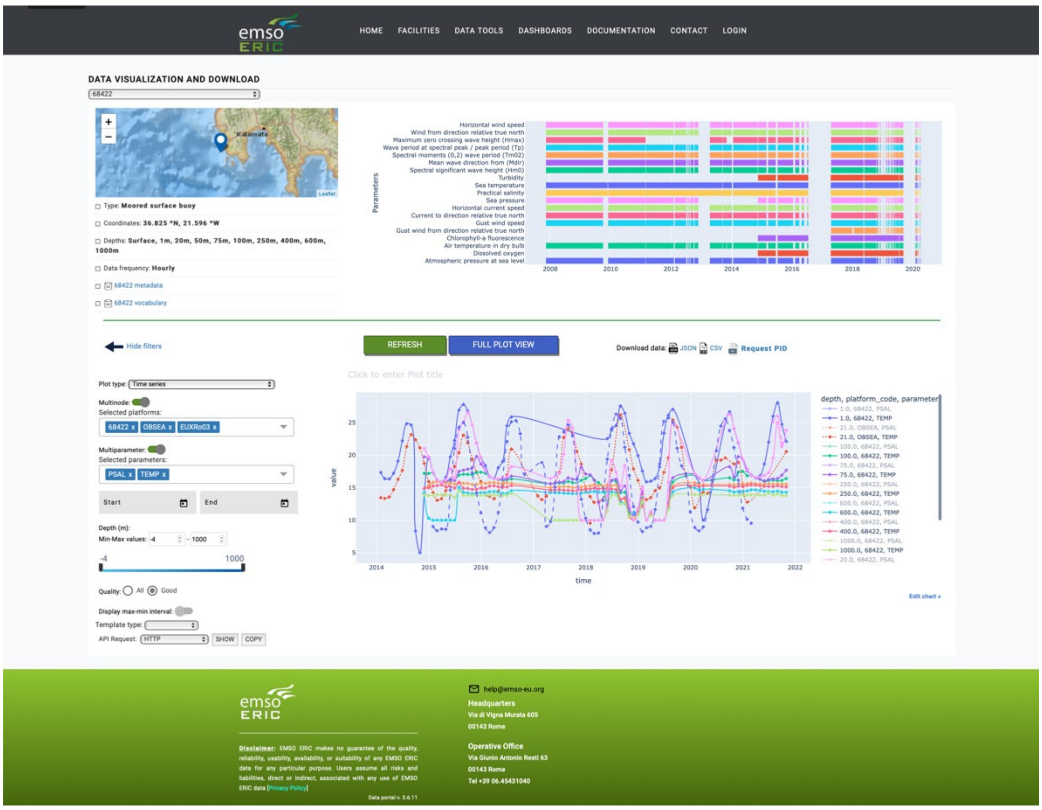

Figure 16. (Metadata) access and preview at the EMSO ERIC data portal (https://data.emso.eu)

ERDDAP
Access to federated EMSO ERDDAP servers

ERDDAP > List of All Datasets

45 matching datasets, listed in alphabetical order.

Grid DAP Data	Sub-set	Table DAP Data	Make A Graph	W M S	Source Data Files	Title	Sum-mary	FGDC, ISO, Metadata	Back-ground Info	RSS	E mail	Institution	Dataset ID
	set	data	graph			* The List of All Active Datasets in this ERDDAP *		M	background			EMSO ERIC	allDatasets
		data	graph			2002-2003 NEMO-SN1 Observatory CTD data		F I M	background	RSS		Istituto Nazional...	EMSO_Western_Ionian_Sea_CTD_2002_2003
		data	graph			2012-2013 NEMO-SN1 Observatory CTD data		F I M	background	RSS		Istituto Nazional...	EMSO_Western_Ionian_Sea_CTD_2012_2013
		data	graph			2012-2013 NEMO-SN1 Observatory Pressure Gauge data		F I M	background	RSS		Istituto Nazional...	EMSO_Western_Ionian_Sea_PRESSURE_GAUGE_2012_2013
	set	data	graph			Azores Seamon-East Chemini dissolved iron concentration		F I M	background	RSS		IFREMER Institut ...	Emso_Azores_Chemini_IRON
	set	data	graph			Dyfamed observatory real-time observations		F I M	background	RSS		Meteo-France	Emso_Ligure_Real_Time
		data	graph			E2M3A timeSeries, NRT in situ Observations		F I M	background	RSS		National Institut...	E2M3A
	set	data	graph			EMSO / MAREGAMI Marmara BPR1 station Lat:40.8703 Long:28.5244 Depth:805m		F I M	background	RSS		CEREGE UMR 7330 CNRS	EMSO_Marmara_BPR_Maregami1
	set	data	graph			EMSO / MAREGAMI Marmara BPR2 station Lat:40.7934 Long:29.0312 Depth:1225m		F I M	background	RSS		CEREGE UMR 7330 CNRS	EMSO_Marmara_BPR_Maregami2
	set	data	graph			EMSO / MAREGAMI Marmara BPR2 station Lat:40.7934 Long:29.0312 Depth:1225m, Seaguard RCM data		F I M	background	RSS		CEREGE UMR 7330 CNRS	EMSO_Marmara_RCM_Maregami2
	set	data	graph			EMSO / MAREGAMI Marmara BPR3 station Lat:40.8568 Long:28.1523 Depth:1184m		F I M	background	RSS		CEREGE UMR 7330 CNRS	EMSO_Marmara_BPR_Maregami3
	set	data	graph			EMSO / MAREGAMI Marmara BPR3 station Lat:40.8568, Long:28.1523, Depth:1184m Seaguard RCM data		F I M	background	RSS		CEREGE UMR 7330 CNRS	EMSO_Marmara_RCM_Maregami3
	set	data	graph			EMSO Ligure Ouest : ALBATROSS capteur AQUADOPP (CSV files from 2021-07)		F I M	background	RSS		MIO UMR7294 CNRS ...	Emso_Ligure_Ouest_Albatross_Aquadopp_CSV_2021
	set	data	graph			EMSO Ligure Ouest : ALBATROSS capteur AQUADOPP (NetCDF files from 2021-07)		F I M	background	RSS		MIO UMR7294 CNRS ...	Emso_Ligure_Ouest_Albatross_Aquadopp_NetCDF_2021
	set	data	graph			EMSO Ligure Ouest : ALBATROSS capteur MICROCAT (CSV files from 2019-08 to 2020-11)		M	background	RSS		MIO UMR7294 CNRS ...	Emso_Ligure_Ouest_Albatross_Microcat_CSV_2019
	set	data	graph			EMSO Ligure Ouest : ALBATROSS capteur MICROCAT (CSV files from 2021-07)		M	background	RSS		MIO UMR7294 CNRS ...	Emso_Ligure_Ouest_Albatross_Microcat_CSV_2021
	set	data	graph			EMSO Ligure Ouest : ALBATROSS capteur MICROCAT (NetCDF files from 2019-08 to 2020-11)		F I M	background	RSS		MIO UMR7294 CNRS ...	Emso_Ligure_Ouest_Albatross_Microcat_NetCDF_2019
	set	data	graph			EMSO Ligure Ouest : ALBATROSS capteur MICROCAT (NetCDF files from 2021-07)		F I M	background	RSS		MIO UMR7294 CNRS ...	Emso_Ligure_Ouest_Albatross_Microcat_NetCDF_2021
	set	data	graph			EMSO Ligure Ouest : DOI files ALBATROSS Microcat (NetCDF files in .tgz 2019-08 to 2020-11)		M	background	RSS		MIO UMR7294 CNRS ...	Emso_Ligure_Ouest_Albatross_DOI2019
	set	data	graph			EMSO Ligure Ouest : DOI files ALBATROSS Microcat and Aquadopp (NetCDF files in .tgz from 2021-08)		M	background	RSS		MIO UMR7294 CNRS ...	Emso_Ligure_Ouest_Albatross_DOI2021
	set	data	graph			EMSO Ligure Ouest : MII capteur AQUADOPP (CSV files)		F I M	background	RSS		MIO UMR7294 CNRS ...	Emso_Ligure_Ouest_MII_Aquadopp_CSV
	set	data	graph			EMSO Ligure Ouest : MII capteur AQUADOPP (NetCDF files)		F I M	background	RSS		MIO UMR7294 CNRS ...	Emso_Ligure_Ouest_MII_Aquadopp_NetCDF
	set	data	graph			EMSO Ligure Ouest : MII capteur CSTAR (CSV files)		F I M	background	RSS		MIO UMR7294 CNRS ...	Emso_Ligure_Ouest_MII_Cstar_CSV
	set	data	graph			EMSO Ligure Ouest : MII capteur CSTAR (NetCDF files)		F I M	background	RSS		MIO UMR7294 CNRS ...	Emso_Ligure_Ouest_MII_Cstar_NetCDF
	set	data	graph			EMSO Ligure Ouest : MII capteur MICROCAT (CSV files)		F I M	background	RSS		MIO UMR7294 CNRS ...	Emso_Ligure_Ouest_MII_Microcat_CSV
	set	data	graph			EMSO Ligure Ouest : MII capteur MICROCAT (NetCDF files)		F I M	background	RSS		OSU Pytheas UMS 3...	Emso_Ligure_Ouest_MII_Microcat_NetCDF
	set	data	graph			EMSO Ligure Ouest : MII capteur OXYGEN (CSV files)		F I M	background	RSS		MIO UMR7294 CNRS ...	Emso_Ligure_Ouest_MII_Oxygen_CSV
	set	data	graph			EMSO Ligure Ouest : MII capteur OXYGEN (NetCDF files)		F I M	background	RSS		OSU Pytheas UMS 3...	Emso_Ligure_Ouest_MII_Oxygen_NetCDF
	set	data	graph			EMSO Ligure Ouest : MII Microcat Cstar Oxygen Aquadopp (All NetCDF files in tar.gz from 09-2017)		M	background	RSS		MIO UMR7294 CNRS ...	Emso_Ligure_Ouest_MII_Allfiles_DOI
		data	graph			Hydrophone Recordings at OBSEA (WAV files)		M	background	RSS		SARTI Research Gr...	NAXYS_hydrophone_wavs_direct_access
	set	data	graph			Ligure Dyfamed carbon data		F I M	background	RSS		LOV Laboratoire O...	Emso_Ligure_Dyfamed_FCO2TW
	set	data	graph			Ligure Dyfamed mooring CTD data		F I M	background	RSS		Observatoire Océa...	Emso_Ligure_Dyfamed_TSCTD
	set	data	graph			Ligure Dyfamed mooring currentmeter data		F I M	background	RSS		Observatoire Océa...	Emso_Ligure_Dyfamed_TScurrents
	set	data	graph			Ligure Dyfamed mooring sediment traps		F I M	background	RSS		Observatoire Océa...	Emso_Ligure_Dyfamed_SedimentTrap
	set	data	graph			Ligure Dyfamed oxygen data		F I M	background	RSS		IMEV Villefranche...	Emso_Ligure_Dyfamed_TSO2
	set	data	graph			Ligure Dyfamed oxygen/fluorescence data		F I M	background	RSS		LABORATOIRE OCEAN...	Emso_Ligure_Dyfamed_TSOF
	set	data	graph			Porcupine Abyssal Plain observatory timeseries data		F I M	background	RSS		National Oceanogr...	nocPapTimeseries_4req3azpg3c723wv
		data	graph			SBE 16 CTD Data		M	background	RSS		SARTI Research Gr...	SBE16_6389_dfb5_bb30
		data	graph			SBE 37 CTD Data		M	background	RSS		SARTI Research Gr...	SBE37_cb46_2bc4_0b4f
	set	data	graph			SmartBay Observatory ADCP data		F I M	background	RSS		Marine Institute	spiddal_obs_adcp
	set	data	graph			SmartBay Observatory CTD data		F I M	background	RSS		Marine Institute	spiddal_obs_ctd
	set	data	graph			SmartBay Observatory Fluorometer data		F I M	background	RSS		Marine Institute	galway_obs_fluorometer
	set	data	graph			SmartBay Observatory Hydrophone data		F I M	background	RSS		Marine Institute	galway_obs_hydrophone
		data	graph			Sound Pressure Levels at OBSEA from a NAXYS Hydrophone		M	background	RSS		SARTI Research Gr...	SPLs_NAXYS_hydrophone_at_OBSEA
		data	graph			Underwater Camera at OBSEA		M	background	RSS		SARTI Research Gr...	Pictures_649f_9d4e_b3b6

Figure 17. View of the EMSO ERIC federated ERDDAP server (https://erddap.emso.eu)

These mechanisms and catalogues were developed with the goal of harmonizing distributed and heterogenous regional facilities in EMSO ERIC; however, the implementation of such a harmonization process goes beyond offering metadata catalogues. For example, EMSO ERIC has developed a data-centric cyberinfrastructure that is capable for integrating (meta)data from multiple ocean observing systems and delivering integrated online data services, with low maintenance cost. This cyberinfrastructure architecture includes different building blocks, from an expandable harmonization subsystem to data analytics capabilities, which allow building added-value services across multiple observatories and complements existing ocean data portals. Using cloud-based abstractions, it also allows scientists to focus on science by outsourcing some administrative aspects of data management and avoiding large (and potentially redundant) data transfers across international networks. The work by (Rodero et al., 2019) provides an illustrative use case experiences using (meta)data from multiple ocean observing systems, including European and other networks such as ONC in Canada, OOI in the United States, and IMOS in Australia.

4.1. Metadata harmonization process

The use of OceanSITES metadata specification by distributed regional facilities has not been as effective as expected due to the open nature of the specification. As a result, a process for EMSO ERIC data harmonization was essential and includes the definition of a rich agreed specification and the use of appropriate tools and interfaces.

The adoption of harmonization processes along with the adoption of FAIR principles improves interoperability such as more mature standardization, better semantics, and standard metadata. It targeted adopting standard metadata formats such as OceanSITES with the overarching goal to deliver data and products from all EMSO ERIC data sources following FAIR principles:

- Agreed metadata for harmonizing EMSO ERIC data discovery and access, including dataset and variable metadata.
- Profile EMSO metadata requirements to ensure they fulfil the requirements of OceanSITES and other community data formats (e.g. SeaDataNet, CMEMS, EMODNet).
- Determine appropriate vocabularies to populate metadata attributes not covered by existing community standards and generic specifications (e.g., OceanSITES).

The deployment of software tools with data discovery capabilities that are widely used in the marine domain (e.g., ERDDAP, an open source data brokering technology). Such tools enable the integration of higher-level tools such as data portal, tools for data analytics (e.g., notebooks), and visualization components (e.g. dashboards).

The abovementioned process improves access to data for each regional facility through the EMSO-ERIC data portal and the other interfaces:

- Compiled catalogue of datasets from the different regional facilities delivered following standard procedures (multi-node data access) distinguishing real-time, delayed mode and data products.
- Federated EMSO ERDDAP server datasets metadata enhanced using inputs from the harmonised metadata specification.
- Deliver data according to the P01 NVS vocabulary starting through the ERDDAP API (followed by the EMSO ERIC API).

Furthermore, it enables multi-node added-value data access services such as scientifically relevant online exploration, (meta)data aggregation tools and on-demand derived data products.

4.2. EMSO ERIC harmonized metadata specification

This section summarizes the data and metadata format specifications, compliant with the OceanSITES requirements, which needed to be provided and kept up to date for each EMSO ERIC site.

OceanSITES adopts as data format netCDF with certain metadata specifications with the following advantages:

- Works across different computers, operating systems, software.
- Metadata is stored together with the data.
- Capability to access only subsets of the file content (efficient for large files).
- Commonly used and maintained across geosciences community.

NetCDF file contains usually moored-based observations at the instrumental resolution in time and space and metadata fields that describe the data. More in details, NetCDF files can contain:

- Dimensions: provide information on the size of the variables (a.k.a. "parameters").
- Coordinate variables: orient the data in time and space.
- Data variables: contain the actual measurements.
- Quality control variables: contain the quality control values.
- Metadata fields: refer to variables a.k.a. "variables attributes".

- Metadata fields: refer to the whole file, not just to one variable a.k.a. "global attributes".

File format and metadata conventions are based on existing conventions: ACDD (Attribute Convention for Data Discovery) and CF (Climate and Forecast) and some OceanSITES bookkeeping requirements.

For EMSO ERIC, additional metadata coming from other initiatives (e.g., SeaDataNet and curated vocabularies) are considered since they can add meaningful information to the distributed dataset.

This document provides the fundamental aspects of the EMSO ERIC metadata specification, including the catalogue of EMSO ERIC facilities (Table 4), dimensions (Table 5), coordinates (Table 6), specific parameters (e.g., temperature, conductivity, pressure), quality control (Table 7), global attributes (Table 8), and instrument mapping. Some of these aspects are provided in Appendix A. Please note that the information below represents the current status of a living/curated document of the EMSO ERIC metadata specification that will be made available through Zenodo.

Table 4. EMSO ERIC FACILITIES

EMSO Facility Code	EMSO Facility Label	EMSO Site code	OceanSITES site code	OceanSITES platform code	OceanOPS reference code
Azores	Azores				
Black_Sea	Black Sea	EUXINUS-EuxRO01			
		EUXINUS-EuxRO02			
		EUXINUS-EuxRO03			
Canary_Islands	Canary Islands	ESTOC	ESTOC	-	-
Cretan_Sea	Cretan Sea	E1M3A	E1M3A	E1M3A	
Hellenic_Arc	Hellenic Arc	PYLOS	PYLOS	PYLOS	
Iberian_Margin	Iberian Margin	IbMa-CSV			
Ligurian_Sea	Ligurian Sea				
Molene	Molène				
Nordic_Seas	Nordic Seas	StationM	STATION-M	STATION-M-1	
		Svinoy	-	-	
		FramStrait	-	-	
OBSEA	OBSEA	OBSEA	-	-	-
PAP-SO	PAP-SO	PAP1	PAP-MO	PAP-MO	6200442_009
		PAP3	PAP-3	PAP-3	TMP-297000308
SmartBay	SmartBay	SmartBay	-	-	-
South_Adriatic_Sea	South Adriatic Sea	E2M3A	E2M3A	E2M3A	
Western_Ionian_Sea	Western Ionian Sea	NEMO-SN1			
Western Mediterranean Sea	Western Mediterranean Sea	W1M3A	W1M3A	W1M3A	TMPAHMHSMWBA0

DIMENSIONS: they provide information on the size of the data variables and their name is fixed.

Table 5. EMSO metadata - DIMENSIONS

Name	Definition
TIME	Number of time steps
DEPTH	Number of depth levels
LATITUDE	Dimension of LATITUDE co-ordinate
LONGITUDE	Dimension of LONGITUDE co-ordinate

COORDINATES: they orient the data in time and space and for this purpose have an "axis" attribute defining that they represent X,Y,Z or T axis. They have fixed names and specific attributes. Note that missing value are not allowed in coordinates variables.

Table 6. EMSO metadata - COORDINATES

Name	Attributes	Attribute name/value	Notes
TIME	long_name	time of measurements	
	standard_name	time	
	units	days since 1950-01-01T00:00:00Z	
	axis	T	
	ancillary_variables	TIME_QC	
	sdn_parameter_name	Elapsed time relative to 1950-01-01T00:00:00Z	
	sdn_parameter_urn	SDN:P01::ELTJLD01	
	sdn_uom_name	days	
	sdn_uom_urn	SDN:P06::UTAA	
DEPTH	long_name	depth of measurements	
	standard_name	depth of measurements	
	units	meters	
	axis	Z	
	ancillary_variables	DEPTH_QC	
	sdn_parameter_name	Depth (spatial coordinate) relative to water surface in the water body	
	sdn_parameter_urn	SDN:P01::ADEPZZ01	
	sdn_uom_name	SDN:P06::ULAA	
	sdn_uom_urn	meters	
LATITUDE	long_name	latitude of measurements	
	standard_name	latitude	
	units	degrees_north	
	axis	Y	
	ancillary_variables	POSITION_QC	OceanSITES combines the flag variables for latitude and longitude into a single flag for POSITION
	sdn_parameter_name	Latitude north	
	sdn_parameter_urn	SDN:P01::ALATZZ01	
	sdn_uom_name	Degrees north	
	sdn_uom_urn	SDN:P06::DEGN	

Name	Attributes	Attribute name/value	Notes
LONGITUDE	long_name	longitude of measurements	
	standard_name	longitude	
	units	degrees_east	
	axis	X	
	ancillary_variables	POSITION_QC	
	sdn_parameter_name	Longitude east	
	sdn_parameter_urn	SDN:P01::ALONZZ01	
	sdn_uom_name	Degrees east	
	sdn_uom_urn	SDN:P06::DEGE	

Quality Control (QC): they contain quality flags for values of associated parameter.

Table 7. EMSO metadata - Quality Control

QC	Attributes	Attribute name/value	Notes
TIME_QC	**long_name**	Time quality flag	
	conventions	OceanSITES QC Flags	prefilled with these proposed standards
	flag_values	0,1,2,3,4,5,~~6,7,~~8,9	prefilled with these proposed standards
	flag_meanings	unknown good_data probably_good_data potentially_correctable_bad_da ta bad_data nominal_value interpolated_value missing_value	prefilled with these proposed standards
POSITION_QC	**long_name**	Position quality flag	
	conventions	OceanSITES QC Flags	prefilled with these proposed standards
	flag_values	0,1,2,3,4,5,~~6,7,~~8,9	prefilled with these proposed standards
	flag_meanings	unknown good_data probably_good_data potentially_correctable_bad_da ta bad_data nominal_value interpolated_value missing_value	prefilled with these proposed standards
DEPTH_QC	**long_name**	Depth quality flag	
	conventions	OceanSITES QC Flags	prefilled with these proposed standards
	flag_values	0,1,2,3,4,5,~~6,7,~~8,9	prefilled with these proposed standards
	flag_meanings	unknown good_data probably_good_data potentially_correctable_bad_da ta bad_data nominal_value interpolated_value missing_value	prefilled with these proposed standards

QC	Attributes	Attribute name/value	Notes
TEMP_QC	**long_name**	Temperature quality flag	
	conventions	OceanSITES QC Flags	prefilled with these proposed standards
	flag_values	0,1,2,3,4,5,~~6,7,~~8,9	prefilled with these proposed standards
	flag_meanings	unknown good_data probably_good_data potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value	prefilled with these proposed standards
CNDC_QC	**long_name**	Conductivity quality flag	
	conventions	OceanSITES QC Flags	prefilled with these proposed standards
	flag_values	0,1,2,3,4,5,~~6,7,~~8,9	prefilled with these proposed standards
	flag_meanings	unknown good_data probably_good_data potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value	prefilled with these proposed standards
PRES_QC	**long_name**	Pressure quality flag	
	conventions	OceanSITES QC Flags	prefilled with these proposed standards
	flag_values	0,1,2,3,4,5,~~6,7,~~8,9	prefilled with these proposed standards
	flag_meanings	unknown good_data probably_good_data potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value	prefilled with these proposed standards

GLOBAL ATTRIBUTES: The global attributes provide details of the whole dataset and allow for data discovery.

Table 8. EMSO metadata - GLOBAL ATTRIBUTES

Attributes	Attribute name/value	Notes	Required
date_created	2020-05-19	specific for each dataset	X
Conventions	OceanSITES v1.4,SeaDataNet_1.0,COARDS, CF-1.6	prefilled with these proposed standards	
institution_edmo_code	3917	each institution has a EDMO code and must be search through https://edmo.seadatanet.org/search	
geospatial_lat_min	37.54765	specific for each dataset	X
geospatial_lat_max	37.54765	specific for each dataset	X

Attributes	Attribute name/value	Notes	Required
geospatial_lon_min	15.3975	specific for each dataset	X
geospatial_lon_max	15.3975	specific for each dataset	X
geospatial_vertical_min	2036	specific for each dataset	X
geospatial_vertical_max	2036	specific for each dataset	X
time_coverage_start	2012-06-10T00:00:47Z	specific for each dataset	X
time_coverage_end	2013-06-12T19:03:01Z	specific for each dataset	X
update_interval	void	specific for each dataset	X
site_code	e.g., SN-1		X
emso_facility	e.g., Western Ionian Sea		
source	fixed benthic node		
platform_code		Leave blank if there isn't OceanSITES code associated	X
wmo_platform_code		If available	X
data_type	OceanSITES time-series data		X
format_version	1.5		X
network	EMSO-ERIC	If it is the case of double network put OceanSITES,EMSO-ERIC	
data_mode	R		X
title	NEMO-SN1 Observatory CTD data	specific for each dataset	
summary	The dataset contains sea bottom Conductivity, Temperature and Pressure data (about 1 m above the bottom) acquired through a SBE 37-SM installed on SN-1 station.	specific for each dataset	
keywords		Mapping parameter to P01 than it will be possible to use P02 to populate this field.	
keywords_vocabulary	SeaDataNet parameter discovery vocabulary		
project	SMO	give name of project if any that supported the acquisition of the dataset	
QC_indicator	probably good	Could be: unknown (no QC done) , excellent (all important QC done), probably good (validation phase), mixed (some problems)	
principal_investigator	Aaa Bbb	specific for each dataset	
principal_investigator_email	aaa.bbb@	specific for each dataset	
doi			
license	CC-BY	Interaction between EMSO data policy and each Institution data policy. It can be considered as a suggestion considering FAIR data	

The section above (prepared by EMSO colleagues) shows the different interpretation of "metadata". In this netCDF data format, almost no metadata is of any use by OceanOPS, at least in a first step of structuration of core metadata. This might be useful in a second step when OceanOPS link its metadata to data available to users.

In practice, these files do not include any information on the hardware (type of mooring), on the sensors (BODC vocabulary L22 e.g.) and their attributes (depth/height, serial numbers, etc), on the operations (when and how these are serviced), on the telemetry means if any, sampling frequency, etc. Observing elements do not have a unique identifier that can enable interoperability. OceanOPS will allocate them only when all core metadata will be available and quality controlled. These mandatory metadata are listed in section 3.1 and do not seem to be too much demanding to platform operators.

OceanOPS has exchanged with OceanSITES to enrich this netCDF format with mandatory metadata as required by OceanOPS, and specified in its documentation. However, this improved format is not yet on use by the community at large but offers some good perspective (see annex A) Another challenge is that these metadata coming with data files, are generally made available when data are made available, sometimes two years after the operations.

OceanOPS aims to capture metadata on the capabilities of the GOOS yesterday, today and tomorrow from operators directly and not from a data hub. This enables e.g. to improve the flow of data for users by monitoring the difference between the declared capability, and the effective availability for data for users.

Conclusion

The EuroSea project has enabled very modest improvement on Eulerian system metadata catalogues, but it was useful to identify the challenges, and better connect community members.

Only a few operators of Eulerian systems have been sending metadata to OceanOPS according to its minimal requirements, beyond what was already registered at OceanOPS.

The metadata format and exchanges system can always be improved. The real challenge we face is the lack of prioritization of metadata submission by platform operators to a central node such as OceanOPS. So we have to continue to communicate on this need until we can deliver a complete catalogue of Eulerian systems and keep it up to date.

It is noted that the different Eulerian Ocean observing system catalogues, albeit overlapping (which is not an issue at all), contain discrepancies. This could only be resolved by improving the cooperation between the following key stakeholders (i.e. sites principal operators, European data aggregators, EMSO ERIC, OceanSITES and DBCP program, National and regional Eulerian networks and OceanOPS):

- For avoiding one-to-one engagements with distributed research infrastructures and networks.
- For more complete (and automated) records of current and historical deployments.
- For certain adjustments of metadata structure to meet tailored service of metadata management.
- Working with harmonized metadata specifications.

The eulerian community appears highly fragmented in Europe. One key outcome of this task is to acknowledge this situation and identify effective solution to overcome this issue that is strongly impacting the European capacity to monitor its fixed observatories.

The EuroGOOS fixed platform task team (EuroGOOS FP TT here after) should be the place where those monitoring issues could be raised high in the agenda and debated within the previously identified stakeholders. By doing so, we create a place for more effective communication between the different stakeholders around metadata sharing and further consideration for machine-to-machine metadata interoperability and exchange.

Many national and regional eulerian ocean observing systems are not part of OceanSITES, EMSO ERIC or DBCP for many good reasons that we will not discuss here. However, EuroGOOS, EOOS and EuroSea aim to integrate those systems in their scope. Today, OceanOPS is the only monitoring system offering this capability. Following WP1.2 recommendation, the first priority is to integrate OceanOPS in the discussion around data and metadata in the EuroGOOS FP TT, as it is already done for Argo TT and glider TT.

Harmonizing basic common vocabularies across the different components of the European Eulerian Ocean observing system community should be a second priority. Without common vocabularies, the workload to monitor of this distributed network is multiplied by the number of networks. Again, EuroGOOS FP TT should be the place to launch this activity with the support of the OceanOPS expert team.

The third high level recommendation of this task is to acknowledge, at the level of EuroSea, EuroGOOS and EOOS the importance of an operational monitoring of the Eulerian Ocean observing system and define the scope and boundaries of this activity.

We should as well recognize that when platform operators do not consider metadata submission as mandatory, not much is happening. With the cooperation of the community, it can be possible to complete the catalog. It works very well for other networks (Argo, OceanGliders, GO-SHIP e.g.). Hence OceanOPS mandate and support capacity should be further communicated within Europe. EOOS and EuroGOOS have started this work and developed a business plan for European OceanOPS dedicated services. In these, the need to better monitor coastal observing systems was identified. However, it will request additional resources and expertise to capture, at national level, all the diversity of the coastal systems, including Eulerian elements.

Final recommendations can be then summarized below:

- Acknowledge the role and capacity of OceanOPS to manage Eulerian metadata or identify another actor to take that role.
- Strongly communicate on the importance to deliver metadata to OceanOPS at European level.
- Strongly encourage European platform operators to communicate with OceanOPS to:
    - Identify uniquely their platform in the GOOS
    - Routinely deliver the required metadata
    - Provide inputs to improve metadata format/content as needed by Eulerian systems
- Engage OceanOPS expertise in EuroGOOS FP TT and other relevant task teams in Europe
- Support the development of OceanOPS within Europe, and enable dedicated services.

References

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Appendix A: Key elements of the current EMSO ERIC metadata specification

TEMPERATURE, CONDUCTIVITY, PRESSURE (PARAMETERS): they contain respectively the actual temperature, conductivity, pressure measurements and their specific attributes. Other parameters can be added following these examples.

TEMPERATURE

Name	Attributes	Attribute name/value	Notes
TEMP	**long_name**	temperature	
	standard_name	sea_water_temperature	
	units	degrees C	
	comment		
	coordinates	TIME DEPTH LATITUDE LONGITUDE	
	ancillary_variables	TEMP_QC	
	_FillValue	-999	
	sdn_parameter_name	Temperature of the water body	See reference_scale attributes for details
	sdn_parameter_urn	SDN:P01::TEMPPR01	
	reference_scale	ITS-90	
	sdn_uom_name	Degrees Celsius	
	sdn_uom_urn	SDN:P06::UPAA	
	sensor_model		Text field using L22 (https://vocab.seadatanet.org/v_bodc_vocab_v2/search.asp?lib=L22) vocabulary as a reference.
	sensor_manufacturer		
	sensor_reference		
	sensor_serial_number		
	sensor_mount	mounted on mooring line	See sensor mount characteristics in OceanSITES manual
	sensor_orientation	vertical	See sensor orientation in OceanSITES manual

CONDUCTIVITY

Name	Attributes	Attribute name/value	Notes
CNDC	**long_name**	conductivity	
	standard_name	sea_water_electrical_conductivity	
	units	mS/cm or mS cm-1	as in OceanSITES
	comment		
	coordinates	TIME DEPTH LATITUDE LONGITUDE	
	ancillary_variables	CNDC_QC	
	_FillValue	-999	
	sdn_parameter_name	Electrical conductivity of the water body	
	sdn_parameter_urn	SDN:P01::CNDCZZ01	
	sdn_uom_name	MilliSiemens per centimetre	
	sdn_uom_urn	SDN:P06::MSCM	

Name	Attributes	Attribute name/value	Notes
	sensor_model		Text field using L22 (https://vocab.seadatanet.org/v_bodc_vocab_v2/search.asp?lib=L22) vocabulary as a reference.
	sensor_manufacturer		
	sensor_reference		
	sensor_serial_number		
	sensor_mount	mounted on mooring line	See sensor mount characteristics in OceanSITES manual
	sensor_orientation	vertical	See sensor orientation in OceanSITES manual

PRESSURE

Name	Attributes	Attribute name/value	Notes
PRES	**long_name**	pressure	
	standard_name	sea_water_pressure	
	units	decibar	
	comment		
	coordinates	TIME DEPTH LATITUDE LONGITUDE	
	ancillary_variables	PRES_QC	
	_FillValue	-999	
	sdn_parameter_name	Pressure (measured variable) exerted by the water body plus atmosphere by fixed in-situ pressure sensor	
	sdn_parameter_urn	SDN:P01::PRSTPS01	
	sdn_uom_name	Decibars	
	sdn_uom_urn	SDN:P06::UPDB	
	sensor_model		Text field using L22 (https://vocab.seadatanet.org/v_bodc_vocab_v2/search.asp?lib=L22) vocabulary as a reference.
	sensor_manufacturer		
	sensor_reference		
	sensor_serial_number		
	sensor_mount	mounted on mooring line	See sensor mount characteristics in OceanSITES manual
	sensor_orientation	vertical	See sensor orientation in OceanSITES manual

PARAMETER P01 VOCABULARY MAPPING

L22 code	L22 Label	Parameter	P01 code	P01 label
TOOL0724	General Oceanics model 8050 pCO2 measuring system	Atm xCO2 (dry, running mean)	XCO2DRAT	Mole fraction in dry air of carbon dioxide {CO2 CAS 124-38-9} {xCO2} in the atmosphere
TOOL0724	General Oceanics model 8050 pCO2 measuring system	Atm. xCO2 (dry)	XCO2DRAT	Mole fraction in dry air of carbon dioxide {CO2 CAS 124-38-9} {xCO2} in the atmosphere
TOOL0724	General Oceanics model 8050 pCO2 measuring system	fCO2 (SST, 100hum)	FCO2XXXX	Fugacity of carbon dioxide (at 100% humidity) {fCO2 CAS 124-38-9} in the water body
TOOL0724	General Oceanics model 8050 pCO2 measuring system	pCO2 (SST, 100hum)	PCO2XXXX	Partial pressure of carbon dioxide {CO2 CAS 124-38-9} {pCO2} in the water body
TOOL0724	General Oceanics model 8050 pCO2 measuring system	xCO2 (equi temp, dry)	XCO2WBDY	Mole fraction in dry air of carbon dioxide {CO2 CAS 124-38-9} {xCO2} for the water body
TOOL0078	Global Positioning Satellite System	heave	HEAVZZZZ	Vertical displacement {heave}
TOOL0078	Global Positioning Satellite System	pitch	PTCHEI01	Orientation (pitch) of measurement platform by inclinometer
TOOL0078	Global Positioning Satellite System	roll	ROLLEI01	Orientation (roll angle) of measurement platform by inclinometer
TOOL0078	Global Positioning Satellite System	speed	APSAZZ01	Speed of measurement platform relative to ground surface {speed over ground}
TOOL0078	Global Positioning Satellite System	true_heading	HEADCM01	Orientation (horizontal relative to true north) of measurement device {heading}
TOOL0861	Idronaut Ocean Seven 304 CTD	conductivity	CNDCZZ01	Electrical conductivity of the water body
TOOL0861	Idronaut Ocean Seven 304 CTD	pressure	PRSTPS01	Pressure (measured variable) exerted by the water body plus atmosphere by fixed in-situ pressure sensor
TOOL0861	Idronaut Ocean Seven 304 CTD	salinity	PSALZZXX	Practical salinity of the water body by computation using UNESCO 1983 algorithm
TOOL0861	Idronaut Ocean Seven 304 CTD	sound velocity	SVELXXXX	Sound velocity in the water body
TOOL0861	Idronaut Ocean Seven 304 CTD	temperature	TEMPPR01	Temperature of the water body
TOOL0667	Sea-Bird SBE 21 Thermosalinograph	conductivity	CNDCZZ01	Electrical conductivity of the water body
TOOL0667	Sea-Bird SBE 21 Thermosalinograph	salinity	PSALZZXX	Practical salinity of the water body by computation using UNESCO 1983 algorithm
TOOL0667	Sea-Bird SBE 21 Thermosalinograph	temperature	TEMPSU01	Temperature of the water body by thermosalinograph and NO verification against independent measurements

L22 code	L22 Label	Parameter	P01 code	P01 label
TOOL0042	Sea-Bird SBE 19 SEACAT CTD	average_sound_velocity	SVELXXXX	Sound velocity in the water body
TOOL0042	Sea-Bird SBE 19 SEACAT CTD	depth	DEPHPR01	Depth (spatial coordinate) relative to water surface in the water body by profiling pressure sensor and conversion to seawater depth using UNESCO algorithm
TOOL0042	Sea-Bird SBE 19 SEACAT CTD	pressure	PRESPR01	Pressure (spatial coordinate) exerted by the water body by profiling pressure sensor and correction to read zero at sea level
TOOL0042	Sea-Bird SBE 19 SEACAT CTD	salinity	PSALST01	Practical salinity of the water body by CTD and computation using UNESCO 1983 algorithm
TOOL0042	Sea-Bird SBE 19 SEACAT CTD	sigma theta	SIGTEQST	Sigma-T of the water body by computation from salinity and temperature using UNESCO algorithm
TOOL0042	Sea-Bird SBE 19 SEACAT CTD	temperature	TEMPST01	Temperature of the water body by CTD or STD
TOOL0018	Sea-Bird SBE 37 MicroCat SMP-CT with optional pressure (submersible) CTD sensor series	conductivity	CNDCZZ01	Electrical conductivity of the water body
TOOL0018	Sea-Bird SBE 37 MicroCat SMP-CT with optional pressure (submersible) CTD sensor series	pressure	PRSTPR01	Pressure (measured variable) exerted by the water body plus atmosphere by semi-fixed in-situ pressure sensor
TOOL0018	Sea-Bird SBE 37 MicroCat SMP-CT with optional pressure (submersible) CTD sensor series	salinity	PSLTZZ01	Practical salinity of the water body
TOOL0018	Sea-Bird SBE 37 MicroCat SMP-CT with optional pressure (submersible) CTD sensor series	temperature	TEMPPR01	Temperature of the water body
TOOL1450	Sea-Bird SBE 37 MicroCat IM-CTP (submersible) CTD sensor	conductivity	CNDCZZ01	Electrical conductivity of the water body
TOOL1450	Sea-Bird SBE 37 MicroCat IM-CTP (submersible) CTD sensor	salinity	PSLTZZ01	Practical salinity of the water body
TOOL1450	Sea-Bird SBE 37 MicroCat IM-CTP (submersible) CTD sensor	temperature	TEMPPR01	Temperature of the water body
TOOL1393	Sea-Bird SBE 37 MicroCat CTP (submersible) CTD sensor series	temperature	TEMPPR01	Temperature of the water body
TOOL1393	Sea-Bird SBE 37 MicroCat CTP (submersible) CTD sensor series	conductivity	CNDCZZ01	Electrical conductivity of the water body

L22 code	L22 Label	Parameter	P01 code	P01 label
TOOL1393	Sea-Bird SBE 37 MicroCat CTP (submersible) CTD sensor series	pressure	PRSTPS01	Pressure (measured variable) exerted by the water body plus atmosphere by fixed in-situ pressure sensor
TOOL1451	SeaBird SBE-37IMP MicroCAT	Pressure	PREXPR01	Pressure (measured variable) exerted by the water body by semi-fixed in-situ pressure sensor and corrected to read zero at sea level
TOOL1451	SeaBird SBE-37IMP MicroCAT	Depth	PPSBPR01	Depth below surface of the water body by semi-fixed in-situ pressure sensor and correction to zero at sea level and conversion to depth using unspecified algorithm
TOOL1451	SeaBird SBE-37IMP MicroCAT	Conductivity	CNDCPR01	Electrical conductivity of the water body by in-situ conductivity cell
TOOL1451	SeaBird SBE-37IMP MicroCAT	Salinity	PSALTC01	Practical salinity of the water body by in-situ conductivity cell and computation using UNESCO 1983 algorithm
TOOL1451	SeaBird SBE-37IMP MicroCAT	Temperature	TEMPP901	Temperature (ITS-90) of the water body
TOOL1451	SeaBird SBE-37IMP MicroCAT	Density	NEUTDENS	Density (neutral) of the water body
TOOL1451	SeaBird SBE-37IMP MicroCAT	Sound Velocity	SVELCA01	Sound velocity in the water body by computation from temperature and salinity using UNESCO algorith
TOOL0191	Sea-Bird SBE 38 thermometer	temperature	TEMPPR01	Temperature of the water body
TOOL0036	Sea-Bird SBE 43 Dissolved Oxygen Sensor	oxygen concentration per kg	DOXMZZXX	Concentration of oxygen {O2 CAS 7782-44-7} per unit mass of the water body [dissolved plus reactive particulate phase]
TOOL0036	Sea-Bird SBE 43 Dissolved Oxygen Sensor	oxygen concentration per litre	DOXYZZXX	Concentration of oxygen {O2 CAS 7782-44-7} per unit volume of the water body [dissolved plus reactive particulate phase]
TOOL0036	Sea-Bird SBE 43 Dissolved Oxygen Sensor	oxygen saturation	OXYSZZ01	Saturation of oxygen {O2 CAS 7782-44-7} in the water body [dissolved plus reactive particulate phase]
TOOL0036	Sea-Bird SBE 43 Dissolved Oxygen Sensor	oxygen sensor voltage	OXYOCPVL	Raw signal (voltage) of instrument output by oxygen sensor
TOOL0036	Sea-Bird SBE 43 Dissolved Oxygen Sensor	oxygen concentration per litre	DOXYSU01	Concentration of oxygen {O2 CAS 7782-44-7} per unit volume of the water body [dissolved plus reactive particulate phase] by Sea-Bird SBE 43 sensor and no calibration against sample data
TOOL0058	Sea-Bird SBE 911plus CTD	average_sound_velocity	SVELXXXX	Sound velocity in the water body
TOOL0058	Sea-Bird SBE 911plus CTD	conductivity	CNDCST01	Electrical conductivity of the water body by CTD
TOOL0058	Sea-Bird SBE 911plus CTD	conductivity (secondary sensor)	CNDCST02	Electrical conductivity of the water body by CTD (sensor 2)

L22 code	L22 Label	Parameter	P01 code	P01 label
TOOL0058	Sea-Bird SBE 911plus CTD	depth	DEPHPR01	Depth (spatial coordinate) relative to water surface in the water body by profiling pressure sensor and conversion to seawater depth using UNESCO algorithm
TOOL0058	Sea-Bird SBE 911plus CTD	pressure	PRESPR01	Pressure (spatial coordinate) exerted by the water body by profiling pressure sensor and correction to read zero at sea level
TOOL0058	Sea-Bird SBE 911plus CTD	salinity	PSALST01	Practical salinity of the water body by CTD and computation using UNESCO 1983 algorithm
TOOL0058	Sea-Bird SBE 911plus CTD	sigma theta	SIGTEQST	Sigma-T of the water body by computation from salinity and temperature using UNESCO algorithm
TOOL0058	Sea-Bird SBE 911plus CTD	temperature	TEMPST01	Temperature of the water body by CTD or STD
TOOL0058	Sea-Bird SBE 911plus CTD	temperature (secondary sensor)	TEMPST02	Temperature of the water body by CTD or STD (second sensor)
TOOL0870	Sea-Bird SBE 16Plus V2 SEACAT C-T Recorder	temperature	TEMPPR01	Temperature of the water body
TOOL0870	Sea-Bird SBE 16Plus V2 SEACAT C-T Recorder	conductivity	CNDCZZ01	Electrical conductivity of the water body
TOOL0870	Sea-Bird SBE 16Plus V2 SEACAT C-T Recorder	pressure	PRSTPS01	Pressure (measured variable) exerted by the water body plus atmosphere by fixed in-situ pressure sensor
TOOL0269	anemometer	relative wind direction	ERWDZZ01	Direction (from) of wind relative to moving platform and heading {wind direction} in the atmosphere
TOOL0269	anemometer	relative wind speed	ERWSZZ01	Speed of wind relative to moving platform and heading {wind speed} in the atmosphere
TOOL0269	anemometer	true wind direction	EWDAZZ01	Direction (from) of wind relative to True North {wind direction} in the atmosphere
TOOL0269	anemometer	true wind speed	EWSBZZ01	Speed of wind {wind speed} in the atmosphere
TOOL0269	anemometer	wind gust speed	EGTSZZ01	Speed of wind (gust) {wind speed} in the atmosphere
TOOL0197	Gill Windsonic anemometer	wind speed	EWSBSS01	Speed of wind {wind speed} in the atmosphere by in-situ anemometer
TOOL0197	Gill Windsonic anemometer	wind direction	EWDASS01	Direction (from) of wind relative to True North {wind direction} in the atmosphere by in-situ anemometer
TOOL1550	Vaisala HMP 45 humidity and temperature probe	air temperature	CTMPZZ01	Temperature of the atmosphere

L22 code	L22 Label	Parameter	P01 code	P01 label
TOOL1550	Vaisala HMP 45 humidity and temperature probe	relative humidity	CRELZZ01	Relative humidity of the atmosphere
TOOL0281	Barometer	atmospheric pressure	CAPHZZ01	Pressure (measured variable) exerted by the atmosphere
TOOL0281	Barometer	dew point	CDEWZZ01	Dew point temperature of the atmosphere
TOOL0125	Vaisala PTB100 barometer	atmospheric pressure	CAPHZZ01	Pressure (measured variable) exerted by the atmosphere
TOOL1733	Kukseflux SR20 D2 {Digital secondary} pyranometer	shortwave radiation	CSLRR101	Downwelling vector irradiance as energy of electromagnetic radiation (solar (300-3000nm) wavelengths) in the atmosphere by pyranometer
TOOL1734	Kipp and Zonen SGR-V, Kipp and Zonen SGR-V	longwave radiation	LWRDZZ01	Downwelling vector irradiance as energy of electromagnetic radiation (longwave) in the atmosphere
TOOL0193	LI-COR LI-190 PAR sensor	Photosynthetically active radiation	DWIRRXSD	Downwelling vector irradiance as energy of electromagnetic radiation (PAR wavelengths) in the atmosphere by cosine-collector radiometer
TOOL1730	Vaisala WXT530 weather transmitter series	Rainfall	CPRRRG01	Precipitation rate (liquid water equivalent) in the atmosphere by in-situ rain gauge
TOOL1730	Vaisala WXT530 weather transmitter series	Hmax	GCMXZZ01	Wave height maximum of waves on the water body
TOOL1730	Vaisala WXT530 weather transmitter series	Mean Wave Direction	GWDRZZ01	Direction (from) of waves on the water body
TOOL1730	Vaisala WXT530 weather transmitter series	Wave Height	GTDHZZ01	Significant wave height of waves {Hs} on the water body
TOOL1730	Vaisala WXT530 weather transmitter series	Wave Period	GSZZXXXX	Period of waves (swell) on the water body
TOOL0215	WETLabs ECO-FLNTU combined fluorometer and turbidity sensor	chlorophyll	CPHLPM01	Concentration of chlorophyll-a {chl-a CAS 479-61-8} per unit volume of the water body [particulate >unknown phase] by in-situ chlorophyll fluorometer and manufacturer's calibration applied
TOOL0215	WETLabs ECO-FLNTU combined fluorometer and turbidity sensor	turbidity	TURBXXXX	Turbidity of water in the water body
TOOL1283	WETLabs ECO-FLNTU(RT) combined fluorometer and turbidity sensor	chlorophyll	CPHLPR01	Concentration of chlorophyll-a {chl-a CAS 479-61-8} per unit volume of the water body [particulate >unknown phase] by in-situ chlorophyll fluorometer
TOOL1283	WETLabs ECO-FLNTU(RT) combined fluorometer and turbidity sensor	turbidity	TURBXXXX	Turbidity of water in the water body

L22 code	L22 Label	Parameter	P01 code	P01 label
TOOL1283	WETLabs ECO-FLNTU(RT) combined fluorometer and turbidity sensor	ph sensor voltage	PVLTGC01	Instrument output (voltage) by pH sensor
TOOL1283	WETLabs ECO-FLNTU(RT) combined fluorometer and turbidity sensor	transmissometer voltage	TVLTZZ01	Raw signal (voltage) of instrument output by transmissometer
TOOL1283	WETLabs ECO-FLNTU(RT) combined fluorometer and turbidity sensor	turbidity sensor voltage	NVLTSC11	Raw signal (voltage) of instrument output by turbidity meter
TOOL1283	WETLabs ECO-FLNTU(RT) combined fluorometer and turbidity sensor	fluorometer voltage	FVLTZZ01	Raw signal (voltage) of instrument output by in-situ chlorophyll fluorometer
TOOL1283	WETLabs ECO-FLNTU(RT) combined fluorometer and turbidity sensor	oxygen sensor voltage	OXYOCPVL	Raw signal (voltage) of instrument output by oxygen sensor
TOOL1717	RBRcoda³ T.ODO | Temperature & Dissolved Oxygen Sensor	temperature	TEMPPR01	Temperature of the water body
TOOL1717	RBRcoda³ T.ODO | Temperature & Dissolved Oxygen Sensor	Dissolved oxygen	DOXYZZXX	Concentration of dissolved oxygen per unit volume of the water column
TOOL1718	RBR Maestro3 Multiparameter logger system	temperature	TEMPPR01	Temperature of the water body
TOOL1718	RBR Maestro3 Multiparameter logger system	conductivity	CNDCZZ01	Electrical conductivity of the water body
TOOL1718	RBR Maestro3 Multiparameter logger system	pressure	PRSTPS01	Pressure (measured variable) exerted by the water body plus atmosphere by fixed in-situ pressure sensor
TOOL1447	Turner Designs Cyclops-7F fluorometer (chl-a)	chlorophyll	CPHLPR01	Concentration of chlorophyll-a {chl-a CAS 479-61-8} per unit volume of the water body [particulate >unknown phase] by in-situ chlorophyll fluorometer
TOOL1447	Turner Designs Cyclops-7F fluorometer (chl-a)	turbidity	TURBXXXX	Turbidity of water in the water body
TOOL0017	Sea-Bird SBE 37 MicroCat SM-CT with optional pressure (submersible) CTD sensor series	Temperature	TEMPPR01	Temperature of water body
TOOL0017	Sea-Bird SBE 37 MicroCat SM-CT with optional pressure (submersible) CTD sensor series	Conductivity	CNDCZZ01	Electrical conductivity of the water body
TOOL0931	Paroscientific Digiquartz depth sensors	Pressure	PRSTPS01	Pressure (measured variable) exerted bye the water boby plus atmosphere by fixed in-situ pressure sensor
TOOL1119	Pro Oceanus CO2-Pro Submersible pCO2 Sensor	pCO2	PCO2EG01	Partial pressure of carbon dioxide {CO2 CAS 124-38-9} {pCO2} in the water body by equilibration with air, drying and infra-red gas analysis

L22 code	L22 Label	Parameter	P01 code	P01 label
TOOL0056/ TOOL0392	Teledyne RDI Workhorse Long-Ranger ADCP / Nortek Aquadopp 400 kHz Doppler current profiler	Horizontal current speed m s-1	LCSAZZ01	Speed of water current (Eulerian measurement) in the water body
TOOL0056/ TOOL0392	Teledyne RDI Workhorse Long-Ranger ADCP / Nortek Aquadopp 400 kHz Doppler current profiler	Current to direction relative true north	LCDAZZ01	Direction (towards) of water current in the water body
TOOL0056/ TOOL0392	Teledyne RDI Workhorse Long-Ranger ADCP / Nortek Aquadopp 400 kHz Doppler current profiler	Spectral significant wave height (Hm0)	HMZEZZ01	Spectral significant wave height of waves {Hm0} on the water body
TOOL0056/ TOOL0392	Teledyne RDI Workhorse Long-Ranger ADCP / Nortek Aquadopp 400 kHz Doppler current profiler	Mean wave direction from (Mdir)	GMWDZZ01	Direction (from) mean of waves {mean wave direction} on the water body by computation from 1st order Fourier coefficients of directional distribution of energy, A1 and B1
TOOL0056/ TOOL0392	Teledyne RDI Workhorse Long-Ranger ADCP / Nortek Aquadopp 400 kHz Doppler current profiler	Spectral moments (0,2) wave period (Tm02)	GTZAM2ZZ	Period at second spectral moment of waves on the water body
TOOL0056/ TOOL0392	Teledyne RDI Workhorse Long-Ranger ADCP / Nortek Aquadopp 400 kHz Doppler current profiler	Wave period at spectral peak / peak period (Tp)	GTPKZZ01	Period at spectral maximum of waves {peak period Tp} on the water body
TOOL0056/ TOOL0392	Teledyne RDI Workhorse Long-Ranger ADCP / Nortek Aquadopp 400 kHz Doppler current profiler	Maximum wave period (Tmax)	GTZMZZ01	Zero-crossing period maximum of waves on the water body
TOOL0056/ TOOL0392	Teledyne RDI Workhorse Long-Ranger ADCP / Nortek Aquadopp 400 kHz Doppler current profiler	Maximum zero crossing wave height (Hmax)	GZMXZZ01	Zero-crossing wave height maximum of waves {Hmax} on the water body