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Deliverable number	D3.13
Deliverable title	**EuroSea data handbook**
Description	The purpose of this deliverable is to describe and highlight specificities of the observing networks involved in Eurosea and to display a list of main data management points done at European level in comparison to what exists at international level.
Work Package number	WP3
Work Package title	Network integration and Improvement
Lead beneficiary	IFREMER
Lead authors	Dominique Obaton, Cécile Liétard
Contributors	Antonio Novellino, Alessandra Giorgetti
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Comments	A postponement of the submission of this document was requested, since differences of the networks in terms of data management and maturity required additional questions to be answered in order to produce a useful and high-qualitative document.

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Executive summary

This handbook has been written in complementarity of the deliverable D3.7 “networks harmonisation recommendations”. Its aim is to be useful to observing network experts and data integrators such as EMODnet, Copernicus Marine Service or SeaDataNet to, on both sides, ease visibility, ingestion procedures and improve Findability, Accessibility, Interoperability and Reusability (FAIR). An additional objective is to help marine data users to find their way around the various ocean observing networks.

To start, this handbook provides an educational description of the eight ocean observing networks considered in the EuroSea project, namely:

- Argo network,
- Glider network,
- ASV network,
- Vessel network,
- Eulerian network,
- Tide gauge network,
- HF Radar network,
- Augmented observatory network.

Moreover, this handbook mentions for each of the networks, the Quality Control (QC) procedures applied as well as how it is possible to find and consult the data.

Finally, the handbook has also attempted to present, for each network, its structuration and maturity at the International and the European levels.

1. Glossary

Acronym	Meaning
ACO	ALOHA Cabled Observatory
ADCP	Acoustic Doppler Current Profiler
AdriFOOS	Fishery & Oceanography Observing System of CNR
AO	Augmented Observatory
AODN	Australian Ocean Data Network
ARC	Argo Regional Centres
ASV	Autonomous Surface Vehicles
AUV	Autonomous Underwater Vehicle
BGC Argo	BioGeoChemical Argo
BODC	British Oceanographic Data Centre (UK)
BUFR	Binary Universal Form for the Representation
Chl	Chlorophyll
CMEMS	Copernicus Marine Environment Monitoring Service
CNR-IRBIM	Istituto per le Risrse Biologiche e le Biotecnologie Marine del Consiglio Nazionale delle Ricerche (Italy)
CNR-ISMAR	Istituto di Scienze Marine (Italy)
CNRS-UPMC	Centre National de la Recherche Scientifique – Sorbonne Université campus Pierre et Marie Curie (France)
CNDC	Conductivity
CORDS	Coastal Observing Research and Development Center
CRM	Certified Reference Materials
CSR	Cruise Summary Report
CTD	Conductivity Temperature and Depth
DATAMEQ	Data Management, Exchange and Quality working group (of EuroGOOS)
DBCP	Data Buoy Cooperation Panel
DM	Delayed-Mode
DOI	Digital Object Identifier
ECMWF	European Centre for Medium-Range Weather Forecasts
EGO	European Gliders Observatories
EMODNet	European Marine Observation and Data Network
EMSO	European Multidisciplinary Seafloor and water column Observatory
EOOS	European Ocean Observing System
ERDDAP	Environment Research Division Data Access Protocol
ERIC	European Research Infrastructure Consortium
ESONET	European Seas Observatory NETwork
EU	European Union
FAIR	Findability, Accessibility, Interoperability and Reusability
FB	FerryBox
FOOS	Fishery & Oceanography Observing System
FR	France
FVON	Fishing Vessel Ocean Observing network
GDAC	Global Data Assembly Centre

GDC	Global Drifter Center
GEO	Group on the Earth Observation
GLOSS	Global Sea Level Observing System
GCOS	Global Climate Observing System
GCN	GLOSS Core Network
GNSS	Global Navigation Satellite System
GOOS	Global Ocean Observing System
GO-SHIP	Global Ocean Ship-based Hydrographic Investigation Program
GOSUD	Global Ocean Surface Underway Data
GPS	Global Positioning System
GTS	Global Telecommunication System
HFR, HF Radar HFRNet	High Frequency Radar Network
HR	High Resolution
ICES	International Council for the Exploitation of the Sea
IMOS	Integrated Marine Observing System
IOC	Intergovernmental Oceanographic Commission (of Unesco)
IOCCP	International Ocean Carbon Coordination Project
IODE	International Oceanographic Data and Information Exchange
IOOS	Integrated Ocean Observing System
ISDM	Integrated Science Data Management (formerly MEDS (Marine Environmental Data Service of Canada))
ISO	International Organization for Standardization
JCOMM	Joint Commission for Oceanography and Marine Meteorology
JERICO	Joint European Research Infrastructure of Coastal Observatories
JULD	Julian Day
MARS	Monterey Accelerated Research System
MBARI	Monterey Bay Aquarium Research Institute
MCDS	Marine Climate Data System
MOODA	Module for Ocean Observatory Data Analysis
MONGOOS	Mediterranean Operational Network for the Global Ocean Observing System
NAUTILOS	New Approach to Underwater Technologies for Innovative Low cost Ocean obServation
NDBC	National Data Buoy Center
NEPTUNE	North East Pacific Time-integrated Undersea Networked Experiments
NEXOS	NEXt generation, cOSt Effective, compact, multifunctional web enabled sensor systems empowering Marine, Maritime and fisheries management
NIVA	Norwegian Institute for water Research
NOAA	National Oceanic and Atmospheric Administration (USA)
NODC	National Oceanographic Data Centre
NRT	Near Real Time
NSF	National Science Foundation
OCG	Observations Coordination Group
OOI	Ocean Observatories Initiative
OOPC	Ocean Observations Physics and Climate Panel
ONC	Ocean Networks Canada
PARAM	Parameter

pCO2	Partial Pressure of Carbone dioxide
PI	Principal Investigator
PMEL	Pacific Marine Environmental Laboratory
PSAL	Salinity
PRES	Pressure
PSMSL	Permanent Service for Mean Sea Level
QARTOD	Quality Assurance/Quality Control of Real Time Oceanographic Data
QC	Quality Control
QF	Quality Flag
RECOPESCA	Réseau de mesure de l'activité de pêche et de données physiques spatialisées
ROOSes	EuroGOOS Regional Operational Systems
RV	Research Vessel
SAL	Salinity
SEANOE	Sea Scientific Open Data Publication
SOCAT	Surface Ocean CO_2 Atlas
SONEL	Système d'Observation du Niveau des Eaux Littorales
SOOP	Ship Of Opportunity Program
TEMP	Temperature
THREDDS	Thematic Real-time Environmental Distributed Data Services
TOROS	Taiwan Ocean Radar Observing System
TRL	Technology Readiness Level
TS	Temperature Salinity
TSG	ThermoSalinoGraph
UHSLC	University of Hawaii Sea Level Center
UNESCO	United Nations Educational, Scientific and Cultural Organisation
US or USA	United States of America
USV	Unmanned Surface Vehicle
VENUS	Victoria Experimental Network Under the Sea
UK	United Kingdom
UVP	Underwater Video Profiler
VLIZ	Flanders Marine Institute (Belgium)
WOCE	World Ocean Circulation Experiment
WMO	World Meteorological Organisation
XBT	Expendable bathythermograps
XCTD	Expendable Conductivity Temperature and Depth

2. Introduction

Observation of the oceans is a fundamental and unavoidable issue for all scientific marine studies. These observations have an exploratory dimension because they are used to collect quantitative information at different spatial and temporal scales. They have a thematic dimension because they aim to answer specific scientific questions as on sea level variation for example. Finally, they provide the first answers to questions concerning the living organisms that have been used for decades as indicators of environmental changes of both anthropogenic and climatic origin.

Eight major ocean observing networks are considered in the EuroSea project: seven physical and chemical networks and one biological network with different histories and maturities:

- Argo network,
- Glider network,
- ASV network,
- Vessel network,
- Eulerian network,
- Tide gauge network,
- HF Radar network,
- Augmented observatory network.

Several communities of users and among them the scientific users (non-network experts) who look for marine variables available over a region – and multi networks- need to have a general understanding of the different observation types and networks to be able to make a better and more complete use of the marine in situ data. This general understanding, detailing shortly the specificity of each network, is firstly described in this document.

It is followed by a table displaying some data management points proposed at global (GOOS) level and their equivalences at European (EuroGOOS) level in 2 different columns. When there is no difference between the international and European data management proposed, the information is provided all together in one column.

As for the previous deliverable, D3.7 "networks harmonisation recommendations", all this harmonisation work is based on the Findability, Accessibility, Interoperability and Reusability (FAIR) principles. This guideline to data management was first proposed by Wilkinson et al. (2016), completed by the exhaustive marine in situ data review and recommendations detailed by Tanhua et al. (2019) and then enhanced by the trans-disciplinary approach suggested by Révelard et al. (2022).

3. What is an ocean observing network?

An ocean observing network is a "tool and/or program" to collect ocean in situ data which are keys for the scientific assessments of climate change and the health of the environment and other purposes. Therefore, it makes sense to gather the information in a way that facilitates the data management and the processing within the group of scientists working on the data. It is far from a user point of view who will look more on a variable over a specific region for a certain period.

Within the EuroSea project and beyond (**bold** in EuroSea, *italic* not in EuroSea), we have:

1. Profiling measurements (or autonomous profiles "vehicles"): **Argo Floats**, **gliders**, *sea animals,*
2. Autonomous surface vehicles: **robotic vehicles, drifting buoys, drones**…,
3. Fixed ocean observing platforms: **Eulerian observations**, **tide gauges,** *sea floor observatories,*
4. Surface field measurements: **HF radars,**

There are 2 exceptions within the EuroSea observing networks:

5. The **vessels** network is considered as observing network but is sometimes also a support to other observing networks (for example, we need a ship for the deployment of an Argo float, a glider, a drifting buoy, an Eulerian platform…). In the vessel network, ships of opportunity will also be considered,
6. The **augmented observatory** (biology) that is a prototype for a genomic network. Most probably, as we have several physical & chemical data networks, we will have several biological data networks to cover the trophic chain.

Some part of the document has been reviewed by the observation network experts: Delphine Dobler for Argo, Christoph Waldmann for ASV, Martin Kramp and Anthonin Lize for vessel, Begoña Pérez Gomez for tide gauge, Lorenzo Corgnati, Anna Rubio and Lohizune Solabarrieta for tide gauge, Elena Mauri for glider, Long Jiang for Eulerian observatories.

4. Ocean observing networks considered in EuroSea project

4.1. Argo network

The international Argo programme was initiated in 1999 as a pilot project endorsed by the Climate Research Program of the World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission (IOC) as part of the Global Ocean Observing System (GOOS). Argo is a broad-scale global array of approximately 4,000 free-drifting profiling floats, designed to measure the temperature and salinity of the upper 2,000 m of the ocean (Figure 1). The array covers the global ocean and is one of the main in-situ observation data sources for ocean data analysis and processing. This network has revolutionised the distribution of ocean data within the research and operational communities (Roemmich et al., 2009).

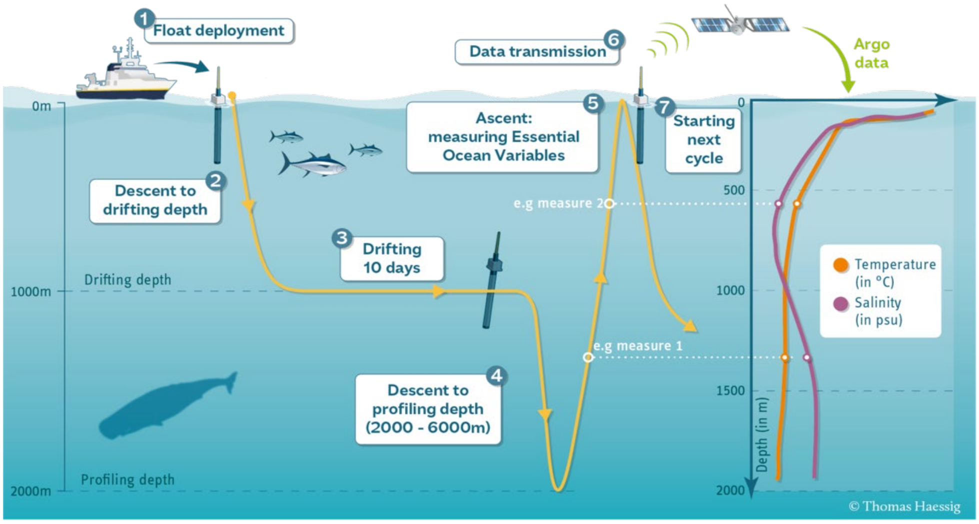

Figure 1. ARGO float cycle[1]

Each float freely drifts with the currents at 1000 m during 9 days. On the tenth day, it is programmed to descend to 2000 m and then slowly ascend to the surface measuring pressure, temperature and salinity (through conductivity) in the entire ocean column. Data is transmitted via satellite (using Argos or Iridium satellite system) when the float reaches the surface. Once the data transmission is completed (within a few minutes using Iridium, Argos-3 and 4), the float dives again at 1000m depth for the next cycle.

In the framework of the Argo program, 12 European countries gathered in 2008 in the Euro-Argo project with a common aim to contribute sustainably to 1/4th of the Argo global array. After a 3-year successful preparatory phase, the Euro-Argo ERIC was established in 2014 and is now able to take up this challenge. The Euro-Argo is also responding to specific European interests for marginal seas, high-latitudes, biogeochemical measurements (BGC Argo including Oxygen, Nitrate, Chlorophyll, pH, suspended particles and downwelling irradiance measurements), depths greater than 2000 m (Deep Argo including measurements down to 6000 m) and float recoveries. The core Argo mission, including temperature and salinity measurements down to 2000 m, is planned to be extended to OneArgo, which is an integrated global, full depth (Deep Argo) and multidisciplinary (Core and BGC Argo) ocean observing array. This extension represents a great challenge in terms of technology, implementation, financing and human resources as Deep and BGC Argo floats are more expensive and complex to process.

Euro-Argo also plays an active role in Argo data management. All data collected by Argo floats can be obtained in near real-time via the two Argo Global Data Assembly Centres (GDACs), the GDAC Coriolis in Brest (France) and the US-Godae GDAC in Monterey (California, USA) (Akazawa et al., 2023). Data are also distributed on the Global Telecommunication System (GTS) in Binary Universal Form for the Representation of meteorological data (BUFR) format.

Two levels of Quality Control (QC) and adjustment procedures exist. The first level is the real-time system that performs a set of automatic checks and adjustments. The second level is the delayed-mode system that consists of evaluation and adjustment of the data by scientific experts (Wong et al., 2022). The DM evaluation is performed both at float level throughout its lifetime and at oceanic basin level. Euro-Argo members lead

[1] https://www.euro-argo.eu/About-us/Euro-Argo-in-brief

and contribute to three of the five Argo Regional Centres (ARCs): the Atlantic ARC (A-ARC), the Mediterranean and Black Sea ARC (MedArgo) and the Southern Ocean ARC (SOARC). The primary aim of these ARCs is to assess the homogeneity of the fleet measurements (and associated calibrated values) at the basin-scale level. They also encourage participation and collaboration between countries working in the same ocean region and provide data products to users.

Each Argo data file stores position information (including the date and time: *JULD* and the horizontal position: *LATITUDE*, *LONGITUDE*, in most cases provided by the Global Positioning System - GPS) and CTD sensor measurements (including the depth *PRES*, the temperature *TEMP*, the salinity *PSAL* and in some cases the conductivity *CNDC*). The CTD sensor measurements are stored in two variables <PARAM> and <PARAM> ADJUSTED. The variable <PARAM> stores the raw data telemetered directly from the float, without any post-deployment adjustment. The <PARAM> ADJUSTED stores the data that have been adjusted, either in real-time or in delayed mode. Sometimes, no adjusted values are available. Each of these variables (for both position information and CTD measurements) have an associated QC flag. In addition, when available, ADJUSTED_ERROR provides the uncertainty of the adjusted values (Wong et al., 2022).

Table 1. Argo Network characteristics at international and European Level (Argo is an international Program with several Argo Regional Centres and National Programs and float sites)

ARGO	**International and European Level**
Data Management	
Oversight & coord.	Argo Steering Team (AST), which provides scientific leadership and oversees the development and implementation of the global array https://argo.ucsd.edu/organization/argo-steering-team International Argo Data Management Team (ADMT), which provides information and oversees developments with respect to data: http://www.argodatamgt.org European Argo coordination (Euro-Argo ERIC): http://euro-argo.eu
Data Type	Near-real-time (NRT) & Delayed-mode (DM)
Components/programmes	1. Core Argo 2. Deep Argo 3. BGC Argo 4. Regional enhancement
Readiness data management system	1. Core Argo: mature, TRL = 9 2. Deep Argo: pilot, TRL = 6 3. BGC Argo: pilot, TRL =6 4. Regional enhancement, mature, TRL = 9
Data centre/repository	GDAC FR Coriolis: http://www.coriolis.eu.org GDAC USA GODAE: http://www.usgodae.org/argo/argo.html
Data delivery (pathway)	Automated For NRT: from float to GDAC and GTS via satellite coms For DM: Distributed to NODCs for DM QC real-time files updated and overwritten at GDACs after 1 year
Data QC	NRT: Automated in data centre DM: Scientific assessment and calibration by country/NODC
Metadata readiness level	1. Core Argo: mature, TRL = 9 2. Deep Argo: pilot, TRL = 5 3. BGC Argo: pilot, TRL =5

	4. Regional enhancement, mature, TRL = 9
Timeless/latency	NRT: 90% of data are available on the GTS (BUFR format) and GDACs (netCDF format) within 24 hours DM: 1 year after data collection
Products/users	NRT: Assimilated into global models to improve ocean forecast DM: Gridded Argo products: https://argo.ucsd.edu/data/argo-data-products/
Links	
Background info	Argo Review: http://www.nature.com/nclimate/journal/v6/n2/full/nclimate2872.html WMO news : https://public.wmo.int/en/media/news/argo-ocean-floats-achieve-2-million-profiles-20-years-support-new-research-ocean-heat
Standards & best practices (doc & links)	Citable snapshots of the global Argo data sets: http://www.argodatamgt.org/Access-to-data/Argo-DOI-Digital-Object-Identifier
Data references	Argo data user manual v3.1, July 2014: dx.doi.org/10.13155/29825 Acknowledging Argo data use: https://argo.ucsd.edu/data/acknowledging-argo/
Products & visualisation	- Argo Data Viewers, including the Argo Marine Atlas: https://argo.ucsd.edu/data/data-visualizations/ - Real time monitoring: https://www.ocean-ops.org/board?t=argo https://fleetmonitoring.euro-argo.eu/ - Float recovery tool: https://floatrecovery.euro-argo.eu
Access to data/product	GDAC Coriolis (France) : ftp://ftp.ifremer.fr/ifremer/argo GDACD US-Godae (USA) : ftp://usgodae.org/pub/outgoing/argo Argo data selection: https://dataselection.euro-argo.eu/ CORA product (including gridded field): https://doi.org/10.17882/46219 ISAS gridded products: https://doi.org/10.17882/52367

4.2. Glider network

Ocean gliders are Autonomous Underwater Vehicles (AUV) that travel in the seawater typically in a saw tooth pattern from the surface to 500 to 1000 m depth. They are deployed for days-to months and travelling 3 to 6 km in the horizontal plane at a speed of about 1 km/h in every dive cycle (i.e. 20 km/day) (Figure 2). Thanks to satellite piloting, it is possible to redefine the route of the glider mission at any time, this is the big difference with Argo floats.

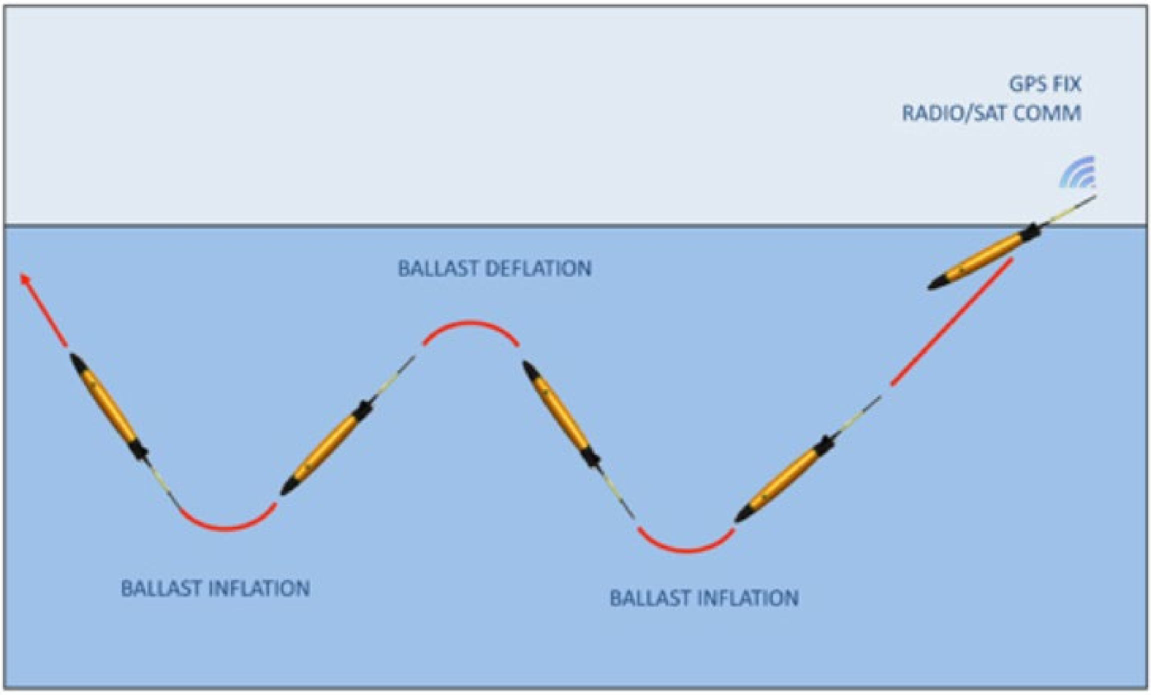

Figure 2. Schematic of a saw tooth path of a glider (Claustre, Beguery, & Pla, 2014)

Gliders are used for measuring physical and biogeochemical oceanographic parameters such as temperature, salinity, oxygen, chlorophyll and dissolved organic matter fluorescence backscattering and turbulence microstructure measurements at high resolution and along predefined transects. They are remotely controlled and can be operated for months and over thousands of km before they have to be fished out.

Gliders also allow data acquisition in severe weather conditions. Data is transmitted in near real-time via satellite when gliders are at surface.

Unlike many other ocean observation networks, it was in Europe that the first grouping of several teams of oceanographers, interested in developing the use of gliders for observing the oceans, began, in the form of the Everyone's Gliding Observatories (EGO) initiative. EGO started with members from France, Germany, Italy, Norway, Spain and the United Kingdom and have been funded by both European and national agencies to operate gliders for various purposes and at different sites[2]. Then, colleagues from Australia, Canada, South Africa and USA, from academia or industry, have joined this open community. EGO data management was based on what has been designed for the Argo and OceanSITES data managements. In 2016, on the occasion of the 7th EGO conference, the OceanGliders program replaced the EGO initiative. The OceanGliders Data Management Task Team proposes to develop a strategy and implementation plan for glider international coordination and governance in order to allow true interoperability of ocean glider data and metadata regardless of the location of the data centre or model of glider used. OceanGliders programme is now officially considered by the WMO/IOC Joint Commission for Oceanography and Marine Meteorology (JCOMM) as the glider component of the GOOS and is engaging in the global system through interactions with the WMO/IOC JCOMM Observations Coordination Group (OCG) and the GOOS expert panels, the Ocean

[2] https://sextant.ifremer.fr/record/589bfa51-2219-4cc8-a19e-83f3c3f27bb4/

Observations Physics and Climate Panel (OOPC), the International Ocean Carbon Coordination Project (IOCCP) and the Biology and Ecosystems Panel[3] [4].

For gliders, two GDACs were identified, the GDAC Coriolis in Brest (France)[5] and the US IOOS Glider in Silver Spring (Maryland, USA)[6].

Data are evaluated using QC tests and the results of these tests are recorded by inserting flags in the data record. However, the real-time QC of TS observations taken from sensors attached to gliders can be extremely challenging. For example, gradual calibration changes and long-term system responses, such as sensor drift, most likely cannot be detected or corrected with real-time automated QC. Drift correction for TS measurements during post-processing is difficult even if a valid post-recovery calibration is obtained. Drift is often caused by biofouling, affecting different systems in different ways—a sensor's response will be affected by the added mass of bio-fouling. It should be noted that this problem is not unique to gliders. Indeed, Argo community has already identified pressure sensor problems with certain groups of profilers (Barker et al. 2011) with thousands of floats impacted.

Gliders transiting water mass gradients in temperature and salinity over short time scales may require additional QC that should be applied prior to the real-time QC tests: a response time lag correction and a thermal lag correction. However, this additional QC is quite controversial. Indeed, the corrections are unique to each specific sensor and may require calibration factors, which explain the complexity associated with obtaining TS data of high accuracy[7].

Table 2. Glider network characteristics at international and European Level (OceanGliders is an international Program, initiated in Europe with the EGO initiative)

Glider	International and European Level
Data Management	
Oversight & coord.	OceanGliders Task Team Data Management https://www.oceangliders.org/ Everyone's Gliding Observatories (EGO): https://www.ego-network.org
Data Type	**Near-real-time (NRT), Delayed-mode (DM) & High-Resolution mode (HR), or recovery mode**
Components/programmes	Glider
Readiness data management system	NTR: Mature, TRL = 9 DM: Pilot, TRL = 5
Data centre/repository	GDAC FR Coriolis: http://www.coriolis.eu.org (for real time) GDAC US IOOS Glider: https://ioos.noaa.gov/data/access-ioos-data/
Data delivery (pathway)	IOOS: https://gliders.ioos.us/ IMOS: https://imos.org.au/ Coriolis: http://www.coriolis.eu.org (for real time)
Data QC	NRT: Automated in GDACs DM: Automated plus scientific oversight by country/NODC
Metadata readiness level	Mature

[3] https://www.seanoe.org/data/00453/56509/
[4] https://www.oceangliders.org/about-us/why-oceangliders/
[5] https://www.coriolis.eu.org/Data-Products/Data-services
[6] https://ioos.noaa.gov/data/access-ioos-data/
[7] Manual-for-QC-of-Glider-Data_05_09_16.pdf (noaa.gov)

Timeless/latency	NRT: Data quality-controlled and disseminated in few hours DM: Some data are quality-controlled and disseminated in delayed mode (some months after) but there is a need to better organize it globally HR : not yet defined
Products/users	Scientific and/or operational objectives To fill the gaps left by the existing observing systems
Links	
Background info	EGO web site: https://www.ego-network.org/dokuwiki/doku.php EGO gliders data processing chain https://www.seanoe.org/data/00343/45402/ OceanGliders program : https://www.oceangliders.org/ Testor et al., 2019, OceanGliders: A Component of the Integrated GOOS, Front. Mar. Sci., 02 October 2019, Sec. Ocean Observation, Volume 6 - 2019 | https://doi.org/10.3389/fmars.2019.00422
Standards & best practices (doc & links)	Good procedures to manage OceanGliders data with Coriolis. V1.3 – January 2020 EGO gliders NetCDF format reference manual: NetCDF conventions Reference tables and files distribution, Version 1.2: http://dx.doi.org/10.25607/OBP-768 EGO community of practices: http://www.ego-network.org Guidelines for the delayed mode scientific correction of glider data, D5.15, Version 4.1 https://repository.oceanbestpractices.org/handle/11329/884 SeaDataNet data management protocols for glider data D9.14, Version 1.2 https://repository.oceanbestpractices.org/handle/11329/2118
Data references	OceanGliders (2023). Ocean gliders: Data and metadata from Global Data Assembly Centre (OceanGliders GDAC). SEANOE. https://doi.org/10.17882/56509 EGO gliders data management team (2023). EGO gliders NetCDF format reference manual. https://doi.org/10.13155/34980
Products & visualisation	GliderMap: ● Python backend ● Javascript frontend (Backbone framework) ● KML export https://gliders.ioos.us/map/
Access to data/product	GDAC FR Coriolis: http://www.coriolis.eu.org GDAC US IOOS Glider: https://ioos.noaa.gov/data/access-ioos-data/

4.3. Autonomous surface vehicle network

An Autonomous Surface Vehicle (ASV) is a robotic vehicle that operates on the sea surface following a pre-programmed trajectory (waypoints) that also displays autonomous functions like obstacle avoidance. ASVs are a form of Unmanned Surface Vehicle (USV), the distinguishing factor between a USV and an ASV is that ASV can function partially without a human remotely operating it, hence they are actually "partially autonomous". The Employing the real-time communication system of ASVs for sending control commands also serve to transfer real-time data to shore.

ASVs are always at the surface, so, they can employ solar or wind power to enhance or completely supply their continuing power needs. Various methods of propulsion exist for ASVs, some ASVs are propelled solely by wind like sailboat, some use current like drifting buoys, some use rechargeable batteries, other use wave-powered or propeller driven, while others are propelled using fuel.

In the scientific field, ASVs are mainly used to carry out missions over long time durations or to map specific regions of the Earth's seafloor, for example in the Seabed 2030 Project[8].

ASV can take different form and can range from a small platform (e.g. drifting buoys) to a large vessel more than 10 meters in length, each manufacturer building its own model (Figure 3).

			
a) Drifting buoys SC40 designed by NKE	b) Autonaut, designed by Autonaut Ltd	c) C-Worker 4 ASV, designed by L3 Harris	d) C-Enduro, designed by L3 ASV

Figure 3. Examples of different ASV

Here are some examples of ASVs particularly used by the marine scientific community:

The Liquid Robotics **Wave Glider®**, powered by wave and solar energy, is an autonomous, unmanned surface vehicle (USV) that can operate individually or in fleets delivering real-time data for up to one year with no fuel. Customer can customize the ocean robot with sensors and payloads that can meet a wide-range of mission requirements.

Ocean Aero has created the world's first and only environmentally powered Autonomous Underwater and Surface Vehicle (AUSV), the **TRITON**, that collects data both above and below the ocean's surface and relays it from anywhere, at any time.

Saildrone are very capable, proven, and trusted platforms available for the collection of high-quality ocean data. It combines wind-powered propulsion technology and solar-powered meteorological and oceanographic sensors to perform autonomous long-range data collection missions in the harshest ocean environments.

The **Sailbuoy** is a long endurance unmanned surface vehicle for the oceans, which can be used from measuring ocean and atmospheric parameters to tracking oil spills or acting as a communication relay station for subsea instrumentation.

[8] https://seabed2030.org/

The **iXblue DriX** is a highly hydrodynamic monohull, which provide exceptional stability and, which cannot capsize. As far as endurance is concerned, DriX can sail for 7 days at 7 knots.

The **AutoNaut** is an Uncrewed Surface Vessel (USV) propelled by the motion of the waves. Renewable energy allows the completion of missions at sea over many weeks. A range of sensors onboard are powered by solar energy to collect valuable oceanic data. AutoNaut is overseen from the safety of shore.

SubSeaSail™ designs and manufactures autonomous, long-duration vessels and unique, low-profile, low-power draw sensors. SubSeaSail vessels and sensors are engineered for simplicity and protected with patents. They offer long-duration unmanned surface vessels (USVs) that are reliable, easy-to-use, and disruptively-economical systems for any number of ocean uses.

A **drifting buoy** (not to be confused with a float) is an oceanographic device floating on the surface to investigate ocean currents by tracking location. They can also measure other parameters like air pressure and temperature, sea surface temperature, salinity, humidity, wave characteristics and wind velocity across all oceans. Drifting buoys are tracked by satellite and GPS and observations are relayed by satellite and used immediately to improve forecasts and therefore increase marine safety[9].

As can be seen above, ASVs are a set of very disparate surface vehicles, with measured parameters and objectives often unique to each vehicle. There is no GDAC for ASV data yet. It is however possible to recover ASV data but you have to be patient and search in many place. Indeed, we have found some Saildrone data on the PMEL ERDDAP, EMODnet ERDDAP and Maracoos ERDDAP, some Ocean Aero's TRITON data on the PMEL ERDDAP, on the University of British Columbia ERDDAP and Oceanscope ERDDAP, and some Liquid Robotics Wave glider data on the Coastwatch ERDDAP… Moreover, as some Saildrones were deployed to the Gulf of Mexico by the National Data Buoy Center (NDBC)[10], it is possible to find some data on the NDBC.

Compared to other types of ASV, drifting buoys are extremely common, very similar to each other and widely used in the scientific community. It would therefore be entirely legitimate to consider them as a network in their own right. As ASV networks are still in their nascent phase and have not yet reached a similar maturity level as drifting buoys, we made the choice, in this document, to consider only drifting buoys in the ASV network.

In USA, the major user of drifters is NOAA's Global Drifter Program. The Global Drifter Program is a branch of NOAA's Global Ocean Monitoring and Observing program and Action Group of the Data Buoy Cooperation Panel (DBCP). The DBCP is an international programme coordinating the use of autonomous and moored data buoys to observe atmospheric and oceanographic conditions over ocean areas where few other measurements are taken. The DBCP programme considers, in fact, moored buoys and drifting buoys in a single program, whereas in the EuroSea project, the choice was made to place the moored buoys in the Eulerian network.

The DBCP network is composed of over 1250 drifting buoys and aims to increase the quantity, quality, global coverage and timeliness of atmospheric and oceanographic data.

[9] https://www.coriolis.eu.org/Observing-the-Ocean/DBCP-E-SURFMAR

[10] https://www.ndbc.noaa.gov/station_page.php?station=42501

Buoy data is generally available in real time to platform operators via telecommunications providers and very quickly distributed on the Global Telecommunications System (GTS) of the WMO. For near-real time and archived data many centres can provide datasets:

- Canada's Integrated Science Data management (ISDM) centre provides an archive of all buoy data on behalf of the DBCP and GOOS. Data coming from the GTS is usually available via the ISDM web site within 2 months of observation,
- The USA National Oceanographic Data centre (NODC) provides an archive of a subset of buoy data and the US National Climate Data Centre (NCDC) provides an archive of surface data,
- Derived Ocean Current Information from the Global Drifter Program is available a few months after observation,
- Coriolis in France provides access to most buoy data on the GTS.

The DBCP has developed and implemented several types of quality control procedures[11]:

- Automated checks on incoming GTS Data: before data is put onto the GTS, Data Processing centres and the operators of buoys ensure that surface observations are validated in real-time, performing a set of tests as described in DBCP Technical Document No. 2[12],
- Regular quality assessments by Quality Control Centres: DBCP members ensure that poor quality data is removed, as quickly as possible, from the GTS, based on feedback on individual data buoys from data users and quality control centres. A well-defined feedback mechanism ensures that any interventions arising from this off-line quality control (e.g., modifications to individual sensor transfer functions) are communicated to buoy operators and processing centres so that modifications can be implemented into the real-time data processing chain in a coordinated and auditable fashion,
- Buoy Monitoring Statistics (Monthly): Several other bodies (ECMWF, national weather and oceanographic agencies, GDC, ISDM, etc.) contribute to regular assessment of data quality for all buoys on the GTS for the previous month.

[11] https://www.ocean-ops.org/dbcp/data/qc.html
[12] https://library.wmo.int/index.php?lvl=notice_display&id=12474#.ZCQFwPbP02w

Table 3. Drifting buoys (ASV) network characteristics at international and European Level (DBCP is an international network with a strong European contribution)

Drifting buoys (ASV)	International and European Level
Data Management	
Oversight & coord.	Data Buoy Cooperation Panel (DBCP)
Data Type	**Near-real-time (NRT) & Delayed-mode (DM)**
Components/programmes	Drifters
Readiness data management system	Drifters: Mature, TRL = 9
Data centre/repository	DPCP GDAC FR: Coriolis: http://www.coriolis.eu.org and various national archives.
Data delivery (pathway)	Automated NRT: WMO Global Telecommunications System (GTS) DM: Marine Climate Data System (MCDS) – under development
Data QC	NRT: Automated in GDACs (validated in real-time before insertion on to the GTS) DM: Manually controlled by several other bodies (national weather and oceanographic agencies…) Sub-surface data are controlled by NOAA / NDBC
Metadata readiness level	N/A
Timeless/latency	NRT: from minutes to an hour DM: N/A
Products/users	NRT and DM: Assimilated into global models to improve ocean forecast or to map Earth's seafloor
Links	
Background info	DBCP program: https://www.ocean-ops.org/DBCP/
Standards & best practices (doc & links)	DBCP Quality control guidelines for GTS buoys: https://www.ocean-ops.org/dbcp/data/qc.html DBCP Standards and best practices : http://www.ocean-ops.org/dbcp/community/standards.html
Data references	Drifter Data Management Team (2017) Drifting buoys GDAC NetCDF data and metadata format. Version 1.0. Plouzane, France, Ifremer/Seanoe, 19pp. DOI: https://doi.org/10.13155/52037 GDAC Drifting Buoys Data Management Team (2018). DBCP drifting buoys DAC data processing chain, version 1.0. SEANOE. https://doi.org/10.17882/51148 Hourly drifter data: https://doi.org/10.25921/x46c-3620 Six-hourly drifter data: https://doi.org/10.25921/7ntx-z961
Products & visualisation	DBCP visualisation tool: http://www.ocean-ops.org/board?t=DBCP
Access to data/product	DBCP access data : https://www.ocean-ops.org/dbcp/data/access.html Copernicus service catalogue : https://www.copernicus.eu/en/accessing-data-where-and-how/copernicus-services-catalogue EMODnet physics catalogue : https://catalogue.emodnet-physics.eu

4.4. Vessel network

Vessel network includes a large quantity of vessels, from Research Vessels (RVs) to ships of opportunity (commercial vessel, fishing boats, ferries…).

Research vessels

Research vessels deliver complete suites of multidisciplinary parameters from the surface to the ocean floor, but with very sparse and intermittent spatial coverage and at very high operational costs. Data collected during research cruises comprise en-route data acquisition systems, human operations (e.g. physical measurements such as CTD/XBT profiles) and the deployment of sensors like ROVs, AUVs or floats. Cruise data is organised by the PI in charge once the campaign has concluded. PIs are then responsible for transferring data and metadata to data centres.

Because cruise data is managed following a variety of different flows and standards, it could have multiple thematic assembly centres. As an example, CO_2 and pH data usually follow a route (and feed SOCAT[13] initiative) while other biogeochemistry (Chl, NOx, FOx) are following other routes (national programmes).

At a national level, it is the National Oceanographic Data Centre (NODC) that manages the data collected within research cruises. NODCs are part of a network coordinated by the Intergovernmental Oceanographic Commission (IOC) and serve as national repositories and dissemination facilities for global marine data.

In Europe, NODCs are networking under the SeaDataNet initiative which implements the data infrastructure for providing integrated databases of standardised quality from in situ (cruise research) data. This data is usually delivered in delayed mode and completes the so-called Cruise Summary Reports (CSR)[14] that are the usual means for reporting on cruises or field experiments at sea. Traditionally, it is the Chief Scientist's obligation to submit a CSR to his/her National Oceanographic Data Centre (NODC) not later than two weeks after the cruise. CSR are available on SeaDataNet[15].

This provides a first level inventory of measurements and samples collected at sea.

Two further key partners in the vessels data management are:

- At international level, it is the International Council for the Exploration of the Sea (ICES), which hosts several databases ranging from temperature, salinity, oxygen, chlorophyll a, nutrients to contaminants, biological effects and biological data,
- At European level, it is EurOcean which is an independent scientific non-governmental organisation aiming at facilitating information exchange and generating value-added products in the field of marine sciences and technologies. EurOcean maintains a Directory of Research Vessels (RV), relying on RV operators providing relevant information.

Moreover, the international Global Ocean Ship-based hydrographic Investigation Program (GO-SHIP) provides a globally coordinated network of about 60 reference sustained hydrographic sections as part of the Global Ocean and Climate Observing Systems (GOOS and GCOS) including physical oceanography, the carbon cycle, marine biochemistry and ecosystems. Global hydrographic surveys have been carried out

[13] The Surface Ocean CO_2 Atlas (SOCAT) is a synthesis activity for quality-controlled, surface ocean fCO_2 (fugacity of carbon dioxide) observations by the international marine carbon research community (>100 contributors).

[14] https://www.seadatanet.org/content/download/7287/file/sdn_csr_backoffice_usermanual_V2.0.pdf

[15] https://csr.seadatanet.org/

approximately every decade since 1969 through research programmes. GO-SHIP data are publicly available without restriction[16]. GO-SHIP has for objective to reach the highest possible data quality by using the 1994 WOCE hydrographic programme manual and the certified reference materials (CRMs), which should be used as frequently as necessary[17]. We can also mention the data publisher Pangaea to find some data from cruise research vessels[18].

Ships of Opportunity

Commercial vessels, but also many other types of ships, make regular transits on the ocean and may offer an excellent opportunity to collect important scientific data relating to physical, chemical and biological oceanography and ecology. The objective is to equip these ships of opportunity or volunteer observing ships with observational equipment and leverage existing routes to gain additional data without the need for dedicated science vessels, allowing for increased coverage, frequency, repeatability, duration and convenience.

The Ship Of Opportunity Program (SOOP) is an international World Meteorological Organisation (WMO)-Intergovernmental Oceanographic (IOC) program that addresses both scientific and operational goals to contribute to efforts of GOOS. The SOOP main mission is the collection of upper ocean temperature profiles and surface measurements (Expendable bathythermograps (XBT), TSG, XCTD, CTD, ADCP, pCO_2 or phytoplankton concentration) from volunteer vessels.

The European component of this Ship of Opportunity Network is EuroGOOS FerryBox Task Team (FB) (Figure 4). FerryBox system is composed with a water inlet positioned at the sea chest or on an extra valve in the hull of the ship. Seawater is pumped into the measuring circuit and directed toward multiple sensors. The FerryBox system can be completed with an additional debubbling unit, which removes air bubbles and coarse sand particles. Basic FerryBox system includes sensors of temperature, salinity, turbidity, chlorophyll-a fluorescence and GPS receiver for position control. Other systems can also include an inline water sampler and additional sensors (oxygen, pH, pCO_2, algal groups or meteorological instruments (air pressure, air temperature and wind)). The FerryBox system is controlled by a computer that logs the data. Data are transmitted to shore via mobile phone connection or satellite communication.

[16] https://www.go-ship.org/DataDirect.html
[17] https://www.go-ship.org/Docs/GOSHIP_Final.pdf
[18] https://www.pangaea.de/

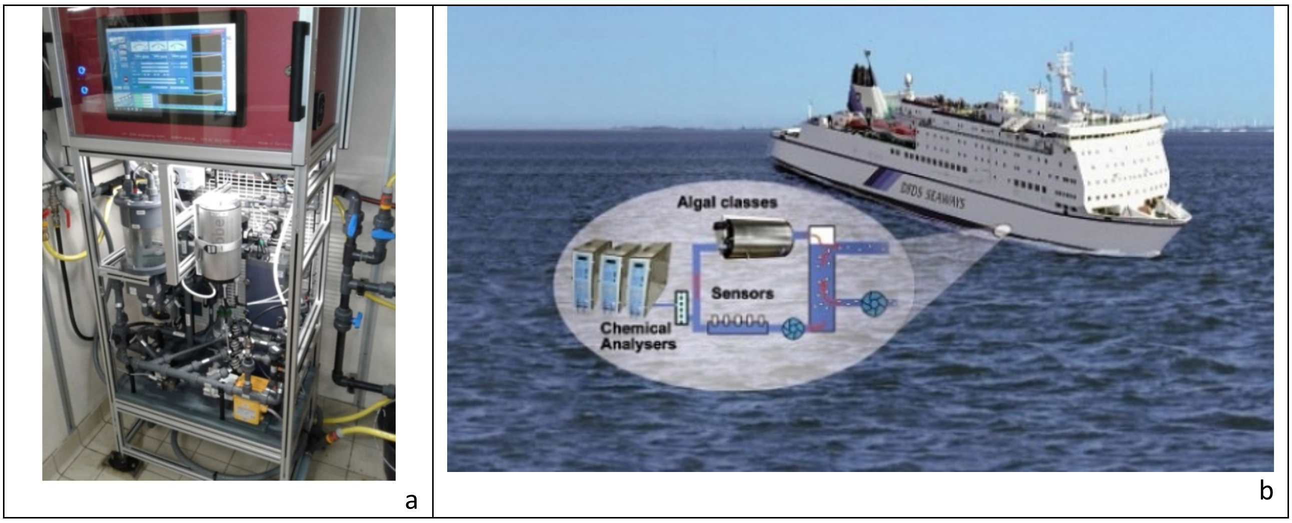

Figure 4. a) FerryBox installed on the Thalassa, Ifremer Vessel. b) FerryBoxes *are used on ships traveling regularly scheduled routes (Picture Hereon*[19]*)*

The number of FerryBoxes installed on ships of opportunity continues to increase in Europe. However, visibility and accessibility of these FB data is not yet at the height of this network. Indeed, data is often available only upon request to the data originator. No GDAC exists for FerryBox data. Some European institutions provide data with a free access:

- All FerryBox data from the Helmholtz-Zentrum Geesthacht Institute and some other institutions are stored in the FerryBox database and can be accessed freely via internet and can be exported in ASCII or NetCDF format[20],
- Some data of temperature, salinity and partly oxygen and chlorophyll-a fluorescence in real-time is also available in free access via the Copernicus Marine Environment Monitoring Service (CMEMS) with no guaranty of the completeness of the aggregated data,
- The Biologic Station of Roscoff (CNRS-UPMC) proposes only graphics and aggregated data for Pont aven and Armorique ferrybox data[21],
- The Norwegian Institute for water Research (NIVA) proposes free access for three Ferrybox routes (Oslo-Kiel, Bergen-Kirkenes, Tromsø-Longyearbyen)[22].

Thanks to the European cooperation via the EuroGOOS FerryBox Task Team, new procedures for data processing and evaluation have been developed. The planned common European database in connection with the EuroGOOS, ROOSes, EMODnet and CMEMS should help to make FerryBox data easily available and visible. This common European FB database will include data quality control which will increase the availability of FB data and then, will support the activities of CMEMS and EMODnet. All data in the database should undergo a real-time QC with agreed standards and flagging scheme of all operators according to the recommendations of the EuroGOOS Data Management Exchange and Quality Working Group (DATAMEQ).

Other types of ship, such as fishing boat or sailing boat, are also used as ships of opportunity.

[19] https://www.hereon.de/institutes/carbon_cycles/coastal_productivity/ferrybox/index.php.en
[20] http://ferrydata.hzg.de/index.cgi?seite=start;cookie=1
[21] http://abims.sb-roscoff.fr/hf/armorique.html?execution=e2s5
[22] https://www.niva.no/en/water-data-on-the-web/ferrybox-ships-of-opportunity

The Global Ocean Surface Underway Data (GOSUD) project[23] is an initiative of the International Oceanographic Data and Information Exchange (IODE) of the IOC programme. The main goal of this project is to assemble in situ observations of the world ocean surface, collected by ships as they traverse their ocean routes. The observations are collected from different categories of platforms such as research vessels, merchant ships but also sailing ships or cruise vessels, from several countries (e.g. France, Japan, USA). The datasets provided by the GOSUD contributors are collected and assembled in the Coriolis database[24]. The GOSUD server provides access to the real-time and delayed mode data through a web selection tool or by file transfer protocol (FTP), ensuring the long-term archive of the datasets.

In France, the multidisciplinary national program RECOPESCA (Réseau de mesure de l'activité de pêche et de données physiques spatialisées) is a collaboration between volunteer fishermen and scientists for the automated collection of geolocated physical and halieutic environmental data in the coastal area. The principle consists of installing sensors on the gear measuring environmental parameters, from the surface to the bottom, and recording detailed data on fishing activity and effort.

In Italy, CNR-IRBIM implemented the "AdriFOOS" observational system, by installing the "Fishery Observing System" (FOOS) on some commercial fishing boats operating in the Adriatic Sea. Their data centre, based in Ancona, receives daily data sets of environmental parameters collected along the water column and close to the sea bottom.

Tara Ocean Foundation expeditions[25] are an example of the use of sailing vessels for data acquisition. The Tara schooner is a floating laboratory that has already made 4 major expeditions, since 2006, in several oceans and seas (e.g., Arctic, Mediterranean, Pacific and a global ocean expedition). The equipment used included flowcams, CTDs, flowcytobots, Underwater Video Profiler (UVP), plankton nets and many other instruments.

[23] http://www.gosud.org
[24] www.coriolis.eu.org
[25] https://oceans.taraexpeditions.org/en/

Table 4. Vessel network characteristics at international and European Level

Vessel network	International Level	European level
Data Management		
Oversight & coord.	The Emerging Fishing Vessel Ocean Observing network (FVON): https://fvon.org/ GOSUD Project: https://www.gosud.org/	EuroGOOS FB Task Team: https://eurogoos.eu/ferrybox-task-team/ Coordination of pioneering programs: e.g. RECOPESCA and AdriFOOS, through EU projects such as JERICO, NEXOS and NAUTILOS
Data Type	**Near-real-time (NRT), fast & Delayed-mode (DM)**	
Components/ Programmes	GOSUD project: https://www.gosud.org/ GO-SHIP project: https://www.go-ship.org/ SOT-SOOP: https://www.ocean-ops.org/sot/programmes.html	EuroGOOS Ferry Box (FB) Task Team (European) RECOPESCA (France) AdriFOOS (Italy)
Readiness data management system	Each program has its own data management system with different levels of maturity, the global management is in development	Each program has its own data management system with different levels of maturity
Data centre/repository	GOSUD datasets are collected and assembled in CORIOLIS https://www.gosud.org/Data-access/Gosud-FTP-Access GO-SHIP : https://www.go-ship.org/DataDirect.html	AdriFOOS : https://www.seanoe.org/data/00618/73008/ Hereon : http://ferrydata.hzg.de/index.cgi?seite=start
Data delivery (pathway)	No specific global distribution yet	No specific European distribution yet
Data QC	Ferry box and fishing ship : NRT: Automated in data centre DM: Automated plus scientific oversight by FB owner	Ferry box and fishing ship : NRT: Automated in data centre DM: Automated plus scientific oversight by FB owner Some programs as AdriFOOS have already developed QC processes and some best practices, which have been accepted at EU level
Metadata readiness level	Pilot	Pilot
Timeless/latency	Near Real Time or Delayed Mode depending on the program	Near Real Time or Delayed Mode depending on the program
Products/users	Surface transects, profiles and bottom data (temperature, salinity) and sometimes chemical (nutrient, pH, CO2, DOC, chlorophyll…) to be used for operational oceanography, fishery biology and other societal uses	Surface transects, profiles and bottom data (temperature, salinity) and sometimes chemical (nutrient, pH, CO2, DOC, chlorophyll…) to be used for operational oceanography, fishery biology and other societal uses

Links		
Background info	Fishing Vessel Ocean Observing network : https://fvon.org/publications/ eMOLT : https://www.emolt.org/ Ocean Data : oceandata.net	EuroGOOS Ferrybox Task Team : https://eurogoos.eu/ferrybox-task-team/ AdriFOOS: https://www.irbim.cnr.it/en/inf-dettagli/adrifoos/ RECOPESCA : https://sextant.ifremer.fr/geonetwork/srv/api/records/14430933-5103-4c32-b812-c3df3d7d579a
Standards & best practices (doc & links)	GOSUD https://www.gosud.org/Standards-and-best-practices/Measuring-Sea-Surface-Salinity-with-thermosalinometers/TSG-DM-QC	JERICO NEXT project : D2.5 Report on Best Practice in the utilization of sensors used for measuring nutrients, biology related optical properties, variables of the marine carbonate system, and for coastal profiling More best practices in development through NEXOS and FVON http://www.nexosproject.eu/sites/default/files/20170117-NXS-WP7_D.7_5_finalv2.pdf
Data references	GOSUD annual reports : https://www.iode.org/index.php?option=com_content&view=article&id=20&Itemid=59 Go-SHIP documents : https://www.go-ship.org/Documents.html#Manuals	JERICO NEXT project: D2.5 Report on Best Practice in the utilization of sensors used for measuring nutrients, biology related optical properties, variables of the marine carbonate system, and for coastal profiling Specifications for a European FerryBox data management system: https://www.jerico-ri.eu/download/jerico-next-deliverables/JERICO-NEXT_Deliverable_5.3_v1.1.pdf
Products & visualisation		
Access to data/product	GOSUD datasets are collected and assembled in CORIOLIS https://www.gosud.org/Data-access/Gosud-FTP-Access GO-SHIP : https://www.go-ship.org/DataDirect.html	RECOPESCA : https://sextant.ifremer.fr/Donnees/Catalogue#/metadata/14430933-5103-4c32-b812-c3df3d7d579a AdriFOOS : https://www.seanoe.org/data/00618/73008/

4.5. Eulerian observatories network

Eulerian observatories are defined as platforms that are fixed at one location and equipped with various sensors in order to make in situ measurements of the properties of the surrounding water or sediment or of the processes occurring there.

Moored buoys

Moored buoys are normally relatively large and expensive platforms. They can vary from a few meters in height and breadth to over 12 meters. Measurements from the mooring include surface variables (wind, air and sea surface temperature, salinity, air pressure) as well as subsurface temperatures down to a depth of 500 plus meters.

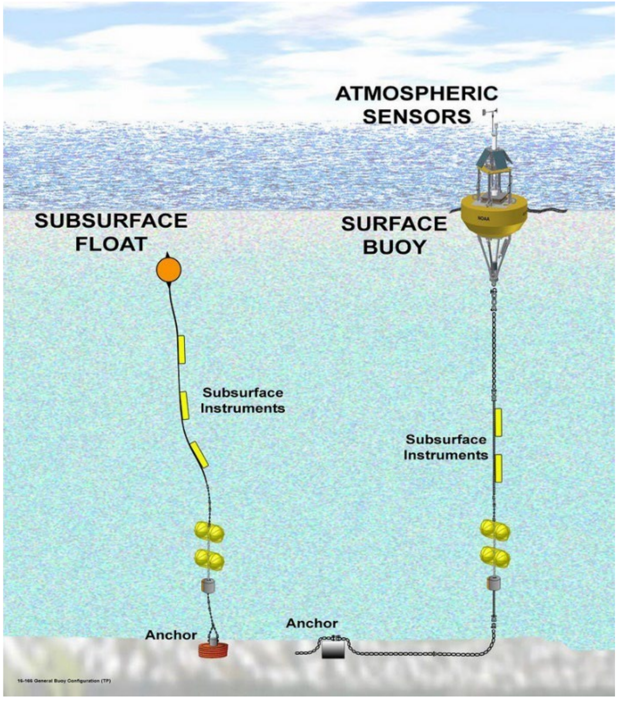

Figure 5. Examples of coastal moorings (Bailey K. et al. (2019)

The Data Buoy Cooperation Panel (DBCP) coordinates also moored data buoys, with a network of over 400 moored buoys. As autonomous buoys, moored buoys measure air pressure, sea surface temperature, ocean current velocity, air temperature, humidity, wave characteristics and wind velocity across all oceans[26].

The International program OceanSITES, initiated as a DBCP action group, has for objective to coordinate a global system of long-term, deepwater reference stations measuring dozens of variables and monitoring the full depth of the ocean, from air-sea interactions down to 5,000 meters. Many countries are contributing to OceanSITES with about 100 sites and 200 platforms. OceanSITES is an established component of GOOS. It provides coordination, integration into a global system and a data management framework enabling the accessibility and dissemination of the data to the community.

[26] https://www.coriolis.eu.org/Observing-the-Ocean/DBCP-E-SURFMAR

These data are served by two Global Data Assembly Centres (GDACS): one at the Coriolis GDAC in Brest (France)[27] and one at the National Data Buoy GDAC Center (NDBC) is the United States[28].

At European level, it is the EuroGOOS Fixed Platforms Task Team which has for objective to integrate the European fixed point observatories, both in the open and coastal ocean. The task team aims to contribute to the development of the European Ocean Observing System (EOOS), component of GOOS.

Data quality and provenance information for both coordinate and data variables is needed. There are 2 possible cases: if the quality control values are constant across all dimensions of a variable, the information may be given as text attributes of that variable; otherwise if they vary along one or more axes, they are provided as a separate numeric flag variable, with at least one dimension that matches the “target” variable[29].

Deep-sea observatory networks

Deep-sea observatories are high-technology platforms equipped with multiple sensors, placed along the water column and on the seafloor. They constantly measure different biogeochemical and physical parameters (temperature, salinity, pH, water circulation, seabed movement…) that address natural hazards, climate change and marine ecosystems. Deep sea observatories provide services to the industry and benefit from technological advances in new sensors and devices, fundamental for oceanic multidisciplinary research.

On an international scale, there is no network for deep sea observatories. However, several deep-sea platforms have already been deployed and are operated. Usually, data from these platforms is not freely accessible.

- The Monterey Accelerated Research System (MARS) observatory is a cabled deep-sea observatory managed by the Monterey Bay Aquarium Research Institute (MBARI) and funded by the National Science Foundation (NSF),
- The ALOHA Cabled Observatory (ACO), the deepest operating ocean observatory on the planet (nearly 3 miles) is managed by the University of Hawaii and supported by NSF,
- The North-East Pacific Time-integrated Undersea Networked Experiments (NEPTUNE) Canada and Victoria Experimental Network Under the Sea (VENUS) are the first multi-node cabled ocean observatories in the world. They are operated by Ocean Networks Canada (ONC). Data are available from the NEPTUNE Canada website and transmitted to a data archival system at the University of Victoria,
- The off Hatsushima Island Observatory in Sagami Bay, central Japan is a cable-connected multi-disciplinary observatory, installed in 1993.

At the European level, it is the consortium of partners, EMSO (European Multidisciplinary Seafloor and water column Observatory), which shares in a common strategic framework scientific facilities (data, instruments, computing and storage capacity). Formally, it is a European Research Infrastructure Consortium (ERIC), legal framework created for pan-European large-scale research infrastructures. EMSO ERIC consists in a system of observatories placed at key sites around the Europe, from North-East to the Atlantic, through the

[27] https://tds0.ifremer.fr/thredds/CORIOLIS-OCEANSITES-GDAC-OBS/CORIOLIS-OCEANSITES-GDAC-OBS.html
[28] https://dods.ndbc.noaa.gov/thredds/catalog/oceansites/catalog.html
[29] http://www.oceansites.org/docs/oceansites_data_format_reference_manual.pdf

Mediterranean, to the Black Sea. EMSO ERIC achieved the Certification of Compliance to ISO 9001:2015 standard for the "Design, coordination, and development of environmental research activities on seafloor and water-column".

EMSO ERIC offers a data portal with free open access of European deep-sea observatories[30].

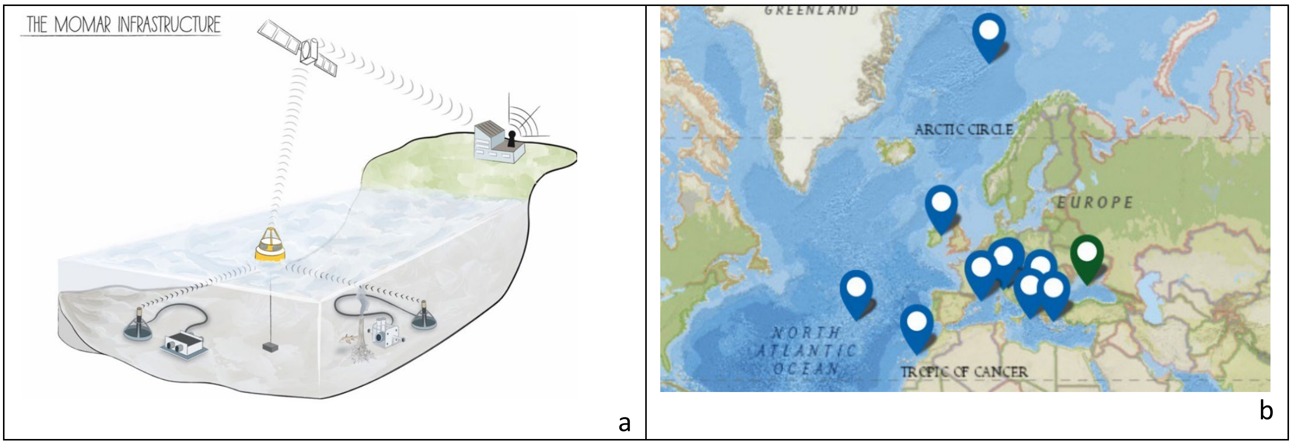

Figure 6. a) Example of deep-sea observatory the Momar infrastructure b) EMSO ERIC platforms

Several data quality control methods for seafloor observatories have been proposed or are under study in the wake of seafloor observatory projects performed worldwide. For NEPTUNE and VENUS observatories, quality control includes both automated (e.g., single-sensor range tests, dual-sensor relational tests, spike detection, and gradient steepness) and manual processes (e.g., regular manual review) to test whether the data meet necessary quality requirement. The Ocean Observatories Initiatives (OOI) applied the system level and human-in-the-loop data quality control methods. At the system level, six automated algorithms, i.e., global range, local range, stuck value, gradient, trend and spike test are proposed to be run on datasets. Daily interactive human-in-the-loop approaches to quality control are performed after automated algorithm tests. To analyse the EMSO data, the Module for Ocean Observatory Data Analysis (MOODA) was developed. The software helps to facilitate EMSO data access and aims to make informative plots as a central part of exploring and understanding data. The code of MOODA includes algorithms to generate the SeaDataNet standard Quality Control flags for the data.

[30] https://data.emso.eu/home

Table 5. Eulerian observatory network characteristics at international and European Level

Eulerian observatory network	International Level	European level
Data Management		
Oversight & coord.	OceanSITES: http://www.oceansites.org/ DBCP: https://www.ocean-ops.org/DBCP/	EuroGOOS Fixed platform Task Team: https://eurogoos.eu/fixed-platforms-task-team/ EMSO ERIC: https://emso.eu/
Data Type	**Near-real-time (NRT) & Delayed-mode (DM)**	
Components/programmes	Fixed moored buoys	1. Fixed moored buoys 2. Deep-sea observatories
Readiness data management system	Mature	1. Fixed moored buoys: Mature 2. Deep-sea observatories: Pilot
Data centre/repository	OceanSITES data access: http://www.oceansites.org/data/index.html DBCP data access : https://www.ocean-ops.org/DBCP/data/access.html	EMSO ERIC : https://data.emso.eu/home
Data delivery (pathway)	-	-
Data QC	NRT : Mature DM : Mature	1. Fixed moored buoys: Mature 2. Deep-sea observatories: mature (based on the OceanSITES User's Manual of the quality control
Metadata readiness level	Mature	1. Fixed moored buoys: Mature 2. Deep-sea observatories: Mature (based on the OceanSITES metadata)
Timeless/latency	-	-
Products/users	-	-
Links		
Background info	DBCP background : https://www.ocean-ops.org/DBCP/overview/background.html OceanSITES : http://www.oceansites.org/	Puillat et al. (2009) Standardization prospective in ESONET NoE and a possible implementation on the ANTARES Site: https://archimer.ifremer.fr/doc/2009/publication-6392.pdf

Standards & best practices (doc & links)	DBCP best practices : https://www.ocean-ops.org/dbcp/community/standards.html OceanSITES data format reference manual endorsed : https://www.oceanbestpractices.org/2021/12/14/oceansites-data-format-reference-manual-endorsed/	Handbook of best practices for open ocean fixed observatories (FIX03 project) : https://repository.oceanbestpractices.org/bitstream/handle/11329/302/Handbook%20of%20best%20practices2017.pdf?sequence=1&isAllowed=y
Data references	OceanSITES : file:///C:/Users/clietard/Downloads/2009-CWP_OO09_OceanSITES_05jul09.pdf OceanSITES publications : https://scholar.google.de/citations?hl=en&view_op=list_works&gmla=AJsN-F5yqTsOxBqb2eea7CKUcjeZB2YuG90bXcm_vUyI9-8noS4Br6NeXKpQUsttpY1wpJKGgoUOJ77esKNgDWvhoYvDVnCepQ&user=ECLfsRkAAAAJ#	EMSO ERIC : https://emso.eu/what-is-emso/ Pearlman J. et al. (2019) Evolving and sustaining ocean best practices and standards for the next decade. Front. Mar.Sci. Vol.6 PIRATA, French contribution to OceanSITES: Bourlès et al. (2019) PIRATA: A sustained observing system for tropical Atlantic climate research and forecasting. Earth and Space Sci., 6, 577-616, doi/10.1029/2018EA000428
Products & visualisation	OceanSITES map : http://www.oceansites.org/network/index.html OceanSITES product : http://www.oceansites.org/tma/index.html	EMSO ERIC facilities : https://data.emso.eu/home
Access to data/product	OceanSITES data products : http://www.oceansites.org/data/ OceanSITES current global time-series map : http://www.oceansites.org/network/index.html	EMSO data portal : https://data.emso.eu/home

4.6. Tide gauge network

Tide gauges are instruments on fixed platforms, located usually along the coastline that measure water level with respect to a local height reference. Their primary objective is to support coastal zone monitoring and management, tide prediction, datum definition, harbour operations and navigation. Additionally, they are used in sea level hazard warning systems for climate monitoring, model validation and assimilation and to detect errors and drifts in satellite altimetry[31].

Established in 1933, the Permanent Service for Mean Sea Level (PSMSL)[32] is responsible for the collection, publication, analysis and interpretation of mean sea level data from the global network of tide gauges (Woodworth and Player, 2003). PSMSL data bank contains over 56000 station-years of monthly and annual mean values of sea level from almost 2000 tide gauge stations around the world[33].

The Global Sea Level Observing System (GLOSS)[34] is the main international programme responsible for collection in real-time, quality-control and tide gauge archiving data. It was established by the UNESCO Intergovernmental Oceanographic Commission (IOC) in 1985 to have a well-designed, high-quality in situ sea level observing network to support a broad research and operational user base. GLOSS contributes to the Global Ocean Observing system (GOOS). The main component of GLOSS is the GLOSS Core Network (GCN), a global set of 290 tide gauge stations located around the world that serves as the backbone of the global in situ sea-level network (Figure 7).

At present nearly 70 nations participate in the GLOSS program, with various tide gauges networks, each with a different focus and each changing over time as research priorities evolve. This makes harmonisation of data between networks particularly difficult.

GLOSS data management is requiring the coordinated participation of an international group of agencies. Several data centres provide complementary data streams while helping to shape the future of the global in situ sea level observing network[35]:

- The British Oceanographic Data Centre (BODC), in collaboration with the Permanent Service for Mean Sea Level (PSMSL), is responsible for delayed mode datasets,
- The Flanders Marine Institute (VLIZ) in Belgium is responsible of real time data[36],
- The University of Hawaii Sea Level Centre (UHSLC) collects, assesses, and distributes fast delivery data, which are used extensively for satellite altimeter monitoring,
- PSMSL collects the monthly time series with all quality control assessments applied and documented, usually obtained by national providers,
- The Coastal water level observatory system (SONEL) is the dedicated centre for Global Navigation Satellite System (GNSS) data at or near tide gauge stations, providing a geocentric reference to the ellipsoid, and vertical land movement information at the tide gauge site (Wöppelman and Marcos, 2016; Wöppelman et al., 2021)

[31] https://www.gloss-sealevel.org/sea-level-monitoring-requirements
[32] https://psmsl.org/data/
[33] https://psmsl.org/about_us/news/2008/egu_2008/EGU2008-A-03459.pdf
[34] https://www.ioc-sealevelmonitoring.org/
[35] https://gloss-sealevel.org/data#.VRFlLfnF_LE
[36] http://www.ioc-sealevelmonitoring.org/list.php

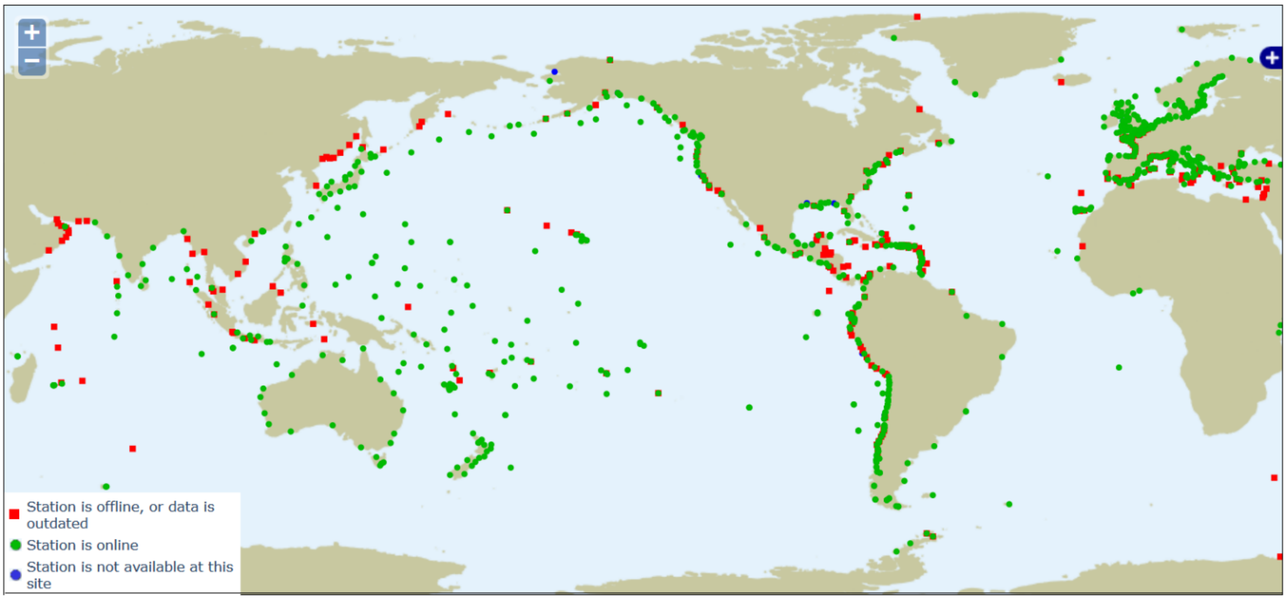

Figure 7. Sea level station monitoring facility from the GLOSS Program[37]

Tide gauge network is particularly old network. In some places, the records can cover several centuries. The way in which data are measured has also changed a lot over the past 3 centuries. Indeed, there are many types of tide gauge capable of measuring sea level with very variable operation. We can cite among others: float tide gauge, acoustic tide gauge, pressure tide gauge and radar tide gauge.

Float gauges are now being replaced with acoustic, pressure or radar systems, but they are still important components of GLOSS and were the source of most of the historical records. The radar tide gauge systems are now something of a GLOSS standard in many areas. Pressure tide gauge is the type of systems used, for example, by the UK national tide gauge network with 45 stations, in real-time for flood warming and in delayed-mode data quality controlled for scientific research (IOC, 2006, 2012).

In addition to the global core network, GLOSS promotes the densification of the tide gauge network according to a fit-for-purpose design able to fulfil regional, national and even local needs. This information is relevant for a better knowledge of the regional variations in mean sea level but also for an adequate monitoring of extreme events. In Europe, the EuroGOOS Tide Gauge Task Team was established in 2015, in order to foster cooperation, exchange knowledge and ensure that best practices, aligned with GLOSS standards, are followed across different institutions operating tide gauge networks in the region, more than 600 and the number is increasing. The task team does not pretend to create a new data portal but to ensure data availability in the existing ones, to identify gaps and duplicities, and to promote research on the use of new technologies, as well as data processing and quality control tools (e.g.: Recommendations for CMEMS on standard NetCDF format for tide gauge data; EuroSea D3.3: New Tide Gauge Data Flow Strategy; Perez Gómez *et al*. (2021): Report EEA/DIS/R0/20/001 Lot 1).

[37] https://www.ioc-sealevelmonitoring.org

As an example of regional collaboration, a recent community paper provides a detailed inventory of existing tide gauges in the Mediterranean and Black Seas, analyzing their adequacy to specific applications and their availability in international data programs (Pérez Gómez et al., 2022).

Table 6. Tide gauge network characteristics at international and European Level

Tide gauge	International Level	European level
Data Management		
Oversight & coord.	Global Sea Level Observing System (GLOSS)	EuroGOOS Tide Gauge Task Team
Data Type		**Near-real-time (NRT) & Delayed-mode (DM)**
Components/programmes	Permanent Service for Mean Sea Level (PSMSL) IOC Sea Level Station Monitoring Facility SONEL GNSS@TG data portal University of Hawaii Sea Level Center British Oceanographic Data Centre	ROOS's and MONGOOS
Readiness data management system	Mature	Mature
Data centre/repository	• PSMSL for monthly time series tide gauge data: https://psmsl.org/data/ • Univ. Hawaii seal level center: https://uhslc.soest.hawaii.edu/datainfo/ (Fast Delivery Centre for hourly values) • British Oceanographic Data Centre (Delayed mode Delivery Centres for hourly values) : • IOC Sea Level station monitoring facility for real-time high frequency (1 min or less) data • SONEL (GNSS data near tide gauges)	No need of a specific data portal, data are already available in GLOSS data portals as well as in the Copernicus Marine Service In Situ TAC or EMODnet. E.g: https://data.marine.copernicus.eu/product/INSITU_GLO_PHY_SSH_DISCRETE_MY_013_053/description
Data delivery (pathway)	• PSMSL for monthly time series tide gauge data: • https://psmsl.org/data/UHSLC for US tide gauge data in fast delivery mode: https://uhslc.soest.hawaii.edu/datainfo/ • BODC for UK tide gauge in DM: https://www.bodc.ac.uk/data/hosted_data_systems/sea_level/uk_tide_gauge_network/ • VLIZ for real time data:http://www.ioc-sealevelmonitoring.org/list.php • SONEL	No need of a specific data portal, data are already available in GLOSS data portals as well as in the Copernicus Marine Service In Situ TAC and EMODnet. https://data.marine.copernicus.eu/product/INSITU_GLO_PHY_SSH_DISCRETE_MY_013_053/description
Data QC	Mature	Mature

Metadata readiness level	Mature	On-going effort to improve metadata through a new metadata on-line tool for the European region, developed in the frame of EuroSea : http://eutgn.marine.ie/geonetwork/srv/spa/catalog.search#/home
Timeless/latency	Fast: within minutes to several hours NRT: within 1 week DM: 1 month to 1 year	Fast: within minutes to several hours NRT: within 1 week DM: 1 month to 1 year
Products/users	fast, NRT : hourly data DM: mean sea level data (high frequency data)	-
Links		
Background info	What is a tide gauge ? https://oceanservice.noaa.gov/facts/tide-gauge.html GLOSS website : http://www.gloss-sealevel.org/	EuroGOOS Tide Gauge Task Team : https://eurogoos.eu/tide-gauge-task-team/
Standards & best practices (doc & links)	• Manual on Sea-level Measurements and Interpretation, Volume V : https://repository.oceanbestpractices.org/handle/11329/306 • Manual for real-time quality control of water level data (IOOS) : https://ioos.noaa.gov/project/qartod/#manuals • ICES Guidelines for Water Level Data: https://repository.oceanbestpractices.org/bitstream/handle/11329/224/Data_Guidelines_TWL_v7_revised_2006.pdf?sequence=1&isAllowed=y • SONEL standard GPS data collection procedure : https://www.sonel.org/Telechargement-de-donnees-GPS-	Same as those for GLOSS, and the following: EuroGOOS Tide Gauge Task Team - Recommendations for CMEMS on standard NetCdf format for tide gauge data: https://eurogoos.eu/download/NetCdf_Recommendations_forCMEMS_EuroGOOS TGTT_October_2017.pdf
Data references	GLOSS publications : https://gloss-sealevel.org/library/publications Woodworth & Player (2003) The Permanent Service for Mean Sea Level: An Update to the 21stCentury. J. of Coastal Res. Vol. 19.	Lyszkowicz A. & Bernatowicz A. (2018). Geocentric changes of the mean sea level of the Baltic Sea from altimeter and tide gauge data Parker A. (2016). The actual measurements at the tide gauges do not support strongly accelerating twentieth-century sea-level rise reconstructions. Nonlinear Engeenering Pérez Gómez et al., 2022. Coastal sea level monitoring in the Mediterranean and Black Seas. Ocean Sci., 18, 997–1053, 2022. https://doi.org/10.5194/os-18-997-2022 Calafat, F. M., Frederikse, T., & Horsburgh, K. (2022). The sources of sea-level changes in the Mediterranean Sea since 1960. Journal of Geophysical Research: Oceans, 127, e2022JC019061. https://doi.org/10.1029/2022JC019061
Products & visualisation	Sea level station catalogue: http://www.ioc-sealevelmonitoring.org/ssc/	Copernicus marine service : https://data.marine.copernicus.eu/products

	PSMSL products : https://psmsl.org/products/ SONEL visualisation map https://www.sonel.org/-Tide-gauges,29-.html SONEL : absolute sea level trends : https://www.sonel.org/-Sea-level-trends-.html?lang=en	EMODnet physics : https://emodnet.ec.europa.eu/geonetwork/emodnet/eng/catalog.search
Access to data/product	PSMSL products : https://psmsl.org/products/ Copernicus marine service : https://data.marine.copernicus.eu/products EMODnet physics : https://emodnet.ec.europa.eu/geonetwork/emodnet/eng/catalog.search	Copernicus marine service : https://data.marine.copernicus.eu/products EMODnet physics : https://emodnet.ec.europa.eu/geonetwork/emodnet/eng/catalog.search

4.7. HF radar network

High Frequency (HF) radar (or simply "HFR") system is a unique technology (figure 8), which measures the speed and direction of ocean surface currents in near real-time in coastal areas, utilising high frequency radio waves. A pair of radar antennas is positioned on shore and can measure surface currents (over 1-2 m in the water column) up to 200 km offshore with a resolution spanning from 500 m to 6 km depending on the radar frequency.

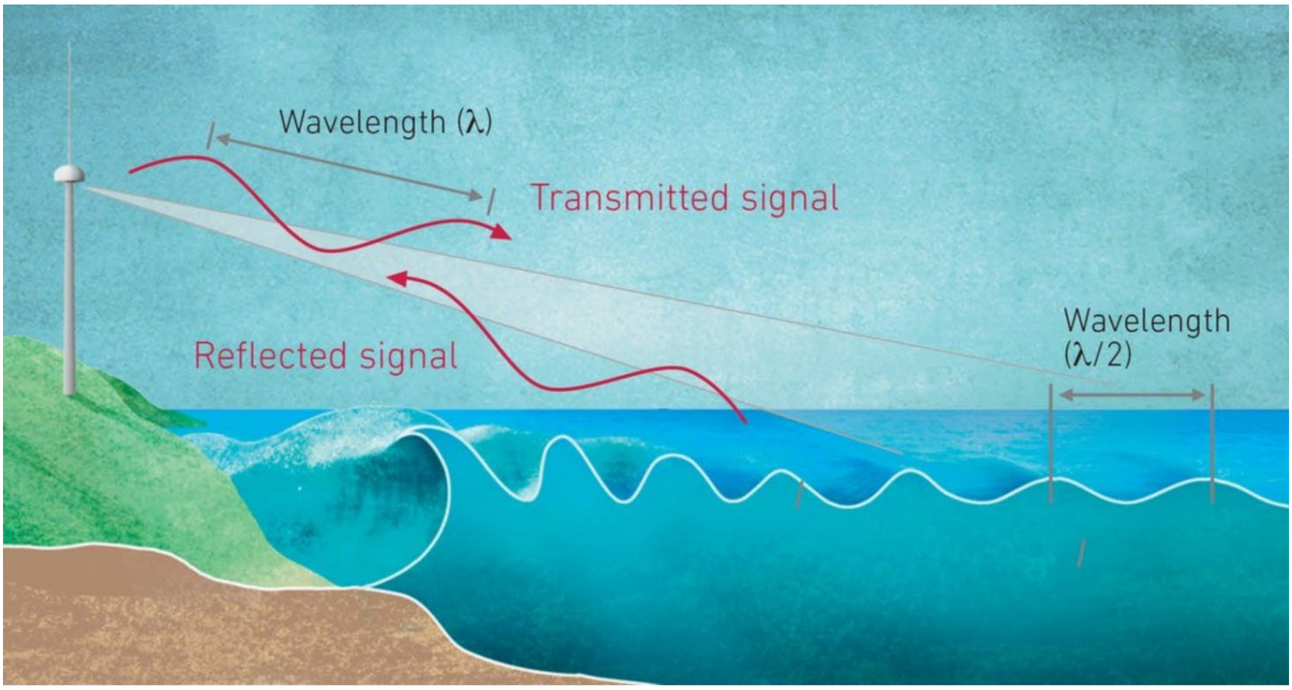

Figure 8. Operating diagram of a HF radar [38]

There are approximately 400 HF radars operating in 36 countries around the globe. The U.S. High Frequency Radar Network (HFRNet) has been in operation for over 13 years, with radar data being ingested from 31 organisations including measurements from Canada and Mexico. HFRNet currently holds a collection from over 150 radar installations totalling millions of records of surface ocean velocity measurements. During the past 10 years in Europe, HFR networks have been showing steady growth with over 60 stations currently deployed and many in the planning stage. In Asia and Oceania countries, more than 110 radar stations are in operation (Roarty et. al., 2019).

Through the Group on the Earth Observation (GEO), a global partnership was established in 2012 in order to connect the many countries operating HF radar. In 2017, the Global HF radar network was recognized by OceanOPS as an observational network of the Global Ocean Observing System (GOOS) to promote HF radar technology and increase data sharing among operators and users (Roarty et al., 2019).

Several radar HF data catalogues are available but not always with open access data, among others:

[38] https://medclic.es/en/instrumentos/radar-costero-hf/

- European and US HF radar data via the European HFR Node (under EuroGOOS coordination) THREDDS server[39],
- European and US HF radar data via the European HFR Node (under EuroGOOS coordination) ERDDAP server[40],
- European HF radar data via the EMODnet THREDDS server[41],
- Mediterranean HF radar data via the MONGOOS HFR Network[42] and CALYPSO HFR Network[43],
- Portugal HF radar data via the Hydrographic Institute HFR Network,
- US HF radar data via the University of California, San Diego server (US IOOS THREDDS Server)[44],
- Australian HF radar catalogue via the AODN portal[45],
- Taiwan HF radar data via the Taiwan Ocean Radar Observing System (TOROS) Network[46].

At European level, since 2015, the EuroGOOS HF radar Task Team has aimed to contribute in the implementation of the EuroGOOS strategy and facilitate data flow towards European Integrators. EMODnet Physics has largely contributed to the development of the European HF radar network and of its node that nowadays hosts the European HF radar registry (unique id, metadata and sensors specifications) and publishes operational data with QC/QF (Quality Flag) in a common data model and format. QC tests are mandatory for radial velocity and for total velocity data. Each QC test will result in a flag related to each data vector which will be inserted in the specific test variable. Data will have a "good data" flag if and only if all QC tests are passed by the data[47].

[39] https://thredds.hfrnode.eu
[40] https://erddap.hfrnode.eu
[41] https://emodnet.ec.europa.eu/en/map-week-%E2%80%93-high-frequency-radar
[42] https://www.mongoos.eu
[43] https://www.calypsosouth.eu/index.php/welcome/open_page/52/0
[44] https://cordc.ucsd.edu/projects/hfrnet/
[45] https://portal.aodn.org.au/search
[46] www.tori.narl.org.tw
[47] https://archimer.ifremer.fr/doc/00617/72915/71948.pdf

Table 7. HF radar network characteristics at international and European Level

HF radar	International Level	European level
Data Management		
Oversight & coord.	Global HF Radar Network: https://rucool.marine.rutgers.edu/geohfr/index.html CORDS: https://cordc.ucsd.edu/	EuroGOOS HFR Task Team and EuroGOOS European HFR Node: https://eurogoos.eu/high-frequency-radar-task-team/ https://www.hfrnode.eu/
Data Type	**Near-real-time (NRT) & Delayed-mode (DM)**	
Components/programmes	Global HF Radar Network https://rucool.marine.rutgers.edu/geohfr/index.html, provides access to metadata and a visualization portal; CORDS	EuroGOOS HFR Task Team and EuroGOOS European HFR Node
Readiness data management system	Mature	Mature
Data centre/repository	No specific global distribution system, links to national and European data centres are provided here: https://rucool.marine.rutgers.edu/geohfr/data.html	EuroGOOS European HFR Node : https://thredds.hfrnode.eu https://erddap.hfrnode.eu
Data delivery (pathway)	No specific global distribution system, links to national and European data centres are provided here: https://rucool.marine.rutgers.edu/geohfr/data.html	NRT and DM data towards Copernicus Marine Service, SeaDataNet and EMODnet Physics
Data QC	Discussion started with Oceanobs but no metadata model exists at global level	Automated at European HFR Node; DM: Automated plus scientific oversight at European HFR Node
Metadata readiness level	Pilot, TRL 5	Mature, TRL 9
Timeless/latency	N/A	NRT within 6 hours; DM within 6 months
Products/users	Sea surface current data for assimilation in forecast models, uses in coast guard activities and societal use	Sea surface current data for scientific community and societal use
Links		
Background info	Roarty H. et al. (2019) The Global High Frequency Radar Network.	https://eurogoos.eu/high-frequency-radar-task-team/ EuroSea D3.4 deliverable on European HFR network governance (https://eurogoos.eu/download/eurosea-european-high-frequency-radar-network-governance/)

		Rubio A. et al. (2017) HF Radar Activity in European Coastal Seas: Next Steps toward a Pan-European HF Radar Network. Lorente, P., et al. (2022): Coastal high-frequency radars in the Mediterranean – Part 1: Status of operations and a framework for future development. Reyes, E., et al. (2022): Coastal high-frequency radars in the Mediterranean – Part 2: Applications in support of science priorities and societal needs.
Standards & best practices (doc & links)	QARTOD manual for HFR : https://repository.oceanbestpractices.org/handle/11329/288.2	Jerico-Next D5.14 deliverable : https://repository.oceanbestpractices.org/handle/11329/1441 Best Practices on High Frequency Radar Deployment and Operation for Ocean Current Measurement : https://repository.oceanbestpractices.org/handle/11329/1262
Data references		Jerico-Next D5.14 deliverable : https://repository.oceanbestpractices.org/handle/11329/1441 SeaDataCloud D9.2 Deliverable : https://repository.oceanbestpractices.org/handle/11329/1511
Products & visualisation	COORDS : https://hfrnet-tds.ucsd.edu/thredds/catalog.html	EuroGOOS European HFR Node : https://thredds.hfrnode.eu https://erddao.hfrnode.eu
Access to data/product	COORDS : https://hfrnet-tds.ucsd.edu/thredds/catalog.html	EuroGOOS European HFR Node : https://thredds.hfrnode.eu https://erddap.hfrnode.eu Copernicus Marine Service SeaDataNet EMODnet Physics

4.8. Augmented observatories (genomics) network

Long-term observation of marine environments and their biodiversity is critical for understanding the functioning of marine ecosystems and evaluating their responses to natural and anthropogenic pressures, as well as for measuring feedback of ecosystem functioning on global biogeochemical cycles and thus climate. Biodiversity observations also contribute to assessing the sustainability of services provided by marine ecosystems, as well as the relevance of environmental and conservation policies. Recent pilot studies have shown that the scope and scale of marine environmental monitoring can be significantly broadened via the integration of 3 novel high-throughput approaches:

- Environmental genomics,
- Automated imaging technologies,
- Automated physico-chemical and biogeochemical sensors.

The resultant “next generation observation” offers the prospect of developing a holistic view of marine ecosystems, which is fundamental in light of increasing awareness of the complex inter-dependency of biotic components of these ecosystems and the fragility of the equilibriums underpinning them. Building upon previous initiatives, notably the Tara-Oceans expeditions that pioneered the deployment of next generation observation over an extremely large spatial scale, the integration of these approaches into existing traditional time-series monitoring programs at fixed study locations will lead to the creation of Augmented Observatories (AOs)[48].

The Augmented observatories is for the moment more a case study or a prototype than a network. The data management proposed and followed by this genomic prototype will then be discussed and applied to other observatories. The important point at this stage is that metadata and information are common to this observatory and the other EuroSea networks when possible or understandable and useful to this observatory when relevant.

Like robotic ASVs (other than drifting buoys, e.g. paragraph 4.3), it is premature, today, to consider augmented observatories as ocean observatory networks.

5. Conclusion

This handbook highlights the difference and complementarities that exists between these eight ocean observing networks. Firstly, each of these networks are working in different ways and using various technologies (e.g. buoys, vessels, gliders…). In addition, each network has its own objectives depending on the theme studied, for example, tide gauges focus on the study of ocean levels while HF radars focus more on the study of speed and direction of ocean currents in coastal areas. Moreover, some of these networks already have an international organisation with established data management plans such as the Argo network or the glider network while other conversely, have a very disparate organisation such as tide gauge networks or the ASV networks where we can list very varied forms of tide gauges and of ASVs.

[48] https://www.sb-roscoff.fr/en/roscoff-marine-station/about-sbr/projects-investing-future/ao-embrc

Despite these differences, all the networks compared have international and European organisations, in one way or in another, which has been enhanced when relevant within the document in terms of data management.

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