GROOM II

GLIDERS FOR RESEARCH, OCEAN OBSERVATION & MANAGEMENT : INFRASTRUCTURE AND INNOVATION

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Deliverable abstract

GROOM RI is designed to be the RI harnessing advantages of Marine Autonomous Systems (MAS) to support ocean observations, research and innovation. This deliverable analyses the role and position of the GROOM RI, in the European Ocean Observing System (EOOS) framework and the ways through which it can contribute to the EOOS implementation plans. This deliverable describes the future GROOM RI position in the European Marine Research Infrastructure (MRI) landscape with an emphasis on its role in the European Ocean Observing System (EOOS).

The analysis has been based on the following three key questions:

- What is the Marine European Landscape at national, regional and European levels?
- What is the European Ocean Observing System (EOOS) and its mission?
- Where should the GROOM RI be positioned in the above system?

The prominent characteristics of the European landscape is that of a very complex system with many different national/regional/European decision-making levels, formed by the Regional Conventions and the EuroGOOS Regional Ocean Observing Systems (ROOS), infrastructure projects and programmes (national and European), the European Research Infrastructure Consortia (ERICs), the non-governmental advisory bodies, the European directives and policies, the data aggregators and related initiatives and organisations. This deliverable provides an extensive presentation of the multiple actors of this European Ocean Observing landscape.

EOOS, as a coordinating framework designed to align and integrate Europe's Ocean observing capacity, concerns all the European communities and organisations operating, supporting and maintaining ocean observing infrastructures and activities, thus including all the main actors of European ocean observing. This deliverable describes precisely what are the aims of EOOS, its governance and progress, and how it structures the above-mentioned complex landscape.

The diversity of the organisational and funding systems established in each European country create uncertainties in the sustainability of coordinated Marine Autonomous Systems (MAS), limiting MAS uptake to answer the Grand Challenges. GROOM RI, harnessing advantages of Marine Autonomous Systems (MAS), fills a gap in the Marine European Landscape, harmonising and advancing the European effort towards a consolidated RIs' ecosystem, and this deliverable concludes that its contribution towards the EOOS endeavour is of paramount importance.

Deliverable Executive Summary

The GROOM RI aims to form a sustainable marine research network at European level, optimising the coordination of European MAS scientific research, and relying on the established communities like the EuroGOOS Glider Task Team to engage with most MAS operators in Europe (more than 60 entities), GROOM RI provides the right sustainable framework to develop MAS contribution to EOOS.

RIs are key components of the EOOS framework considering that they are key mechanisms of integration and coordination of individual observing systems. In that respect it is important that there are no gaps in the marine RI landscape. Given the growing importance of autonomous vehicles, both underwater and surface, in the multiplatform observation approach, it seems rather inadequate that no RI is dedicated to develop and optimise MAS operation in Europe. The GROOM RI is designed to fill this gap, and together with the other marine RIs, will provide a consolidated MRI landscape capable of pushing EOOS requirements through enhanced capacities, efficient and sustainable operations and provision of services, and breakthrough science and innovation.

Despite the positive characteristics, RIs are not free of problems as participation in most cases is limited, there are overlaps in activities, funding is static and does not follow growth opportunities. Moreover, RIs have developed in silos with small connection with its ecosystem, limiting Europe's contribution to EOOS. In line with EOOS objectives, which are to facilitate: a joint strategic development, stakeholder engagement, innovation and future planning by the European ocean observing community the European Commission launched calls to promote the integration and alignment of the RIs, to improve their scientific competitiveness and technological synergy with industries through co-design and co-development. Based on a consolidated MRI landscape and pursuing collaboration work initiated during GROOM-II, projects such as AMRIT, with the aim to address coordination gaps and consolidate the synergies & integration of services between the marine ERICs and their national operators, have been launched and are expected to have a significant impact towards EOOS but do not address the requirements identified during this project and the need for a GROOM RI.

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ADP	Acoustic Doppler Profilers
Argo	Scientific international programme for ocean observation using a fleet of robots
AUV	Autonomous Underwater Vehicle
BSIMAP	Black Sea Integrated Monitoring and Assessment Programme
CAMPUS	Combining Autonomous observations and Models for Predicting and Understanding Shelf seas
CMRE	Center for Maritime Research and Experimentation
CTD	Conductivity, Temperature and Depth
DBCP	Data Buoy Cooperation Panel
DYMS22	Dynamic Messenger 22
EC	European Commission
EuroArgo	European contribution to the Argo Programme
FAO	Food and Agriculture Organization
GEF	Global Environment Facility
GES	Good Environmental Status
GOOS	Global Ocean Observing System
GROOM RI	GROOM Research Infrastructure
ISFET	Ion-Sensitive Field-Effect Transistor
JRC	The Joint Research Centre
MAP	Mediterranean action plan
MASSMO	Marine Autonomous Systems in Support of Marine Observations
MRU	Marine Reporting Unit
MSFD	Marine Strategy Framework Directive

OSPAR	North-East Atlantic Environment Strategy and the Convention on Biological Diversity
PAH	polycyclic aromatic hydrocarbons
PAR	photosynthetically active radiation
REPMUS	Robotic Experimentation and Prototyping Augmented by Maritime Unmanned Systems)
TRL	Technology Readiness Level
UN	United Nation
UNCLOS	UN Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UVP6	The Underwater Vision Profiler 6
WP	Work Package

1 Introduction

1.1 Background and motivation

Environmental problems are diverse and interlinked, and require integrated understanding and strong cooperation across all subdomains of the Earth system. In this context, environmental Research Infrastructures' (RIs) role in providing data and research products across all subdomains of the Earth system is vital. High-quality multidisciplinary research data, services and expertise are in demand when aiming at solving large-scale environmental challenges and making scientific breakthroughs while mitigating societal risks. Moreover, the close cooperation within environmental RIs is crucial since they share the same challenges in their planning, design and operations.

As stated by NZOC, the Net Zero Oceanographic Capability program from NERC, Marine Autonomous Systems (MAS) are increasingly used by operators for their scientific capacities and open the way for decarbonisation of Ocean Observing, and we can expect MAS to grow from a few tens to a few hundred in the coming decade. While operations of MAS are complex and require a wide set of knowledge, skills and equipment, the facilities of the MAS operations remain scattered in Europe, which poses challenges related to data control and provision of high-quality services. In this respect, the GROOM RI's aim to optimise the coordination of European MAS scientific research, and to form a sustainable marine research network at European level in close collaboration with the other environmental domain Research Infrastructures, will be essential.

Tackling versatile ocean health related challenges and sustainable development of oceans as well as responding to fast altering societal needs will require even firmer cross-RI cooperation inside the marine RI landscape.

The GROOM RI, the European Research Infrastructure for MAS will contribute to three cutting edge application areas: Marine Frontier Science, Ocean Observations and Blue economy. The provision of services to European laboratories and research institutes, will apply to a broad range of Use Cases targeted to Discovery Science to enhance and support Marine Frontier Science in Europe. Furthermore, the GROOM RI will expedite the implementation of EOOS in European Seas, support statutory monitoring, MSFD and other regulatory / covenant frameworks, contributing in that way to Ocean Observing, while at the same time will constitute the European foundation to OceanGliders GOOS program. Eventually the Blue Economy will be invigorated with the contribution and support in emergency situations response, as well as the assessment and monitoring of ecosystem stressors for emerging sectors, like Marine Renewable Energies, for the sustainable use of ocean resources (Figure 1).

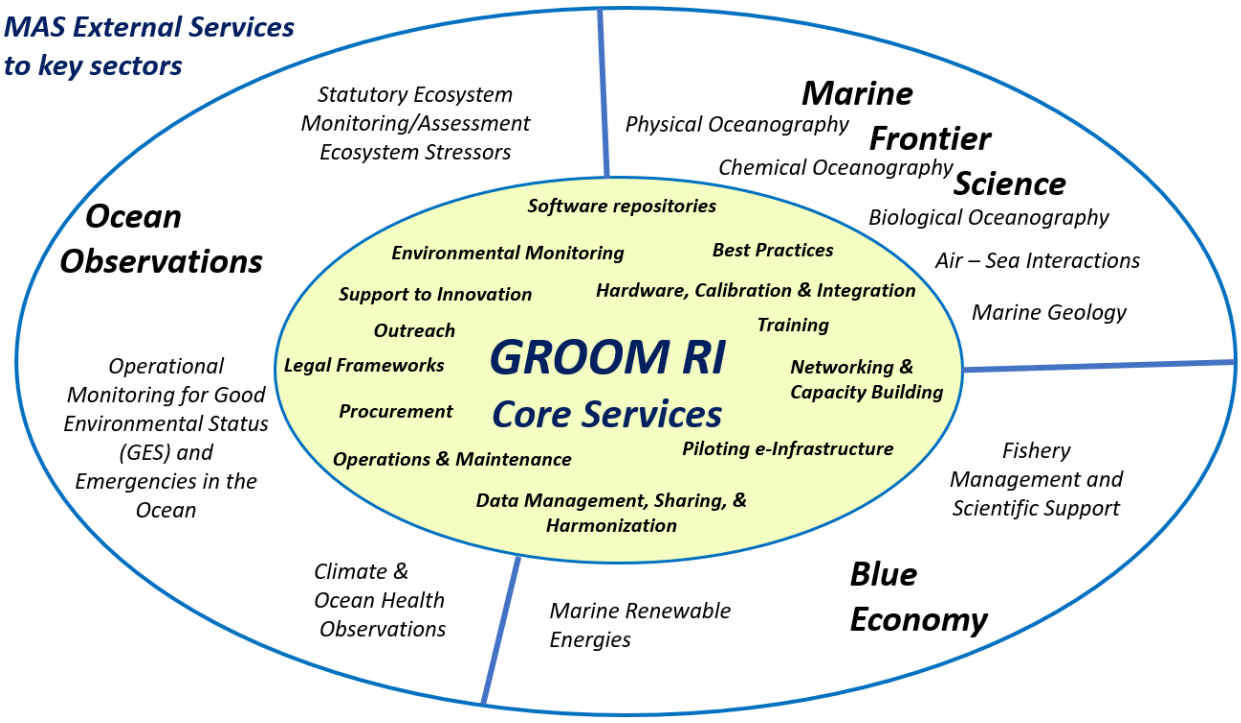

Figure 1 - The GROOM RI, through its organization in terms of core and external services, tackles three major application areas, Marine Frontier Science, Ocean Observations and Blue Economy

1.2 Introduction to the European Marine Landscape

A prominent characteristic in analysing the European Landscape in terms of marine observations, is the high degree of complexity with many different actors with different capacities, operating under different frameworks and responding to a wide range of needs. Attempting to structure this complex system one could identify three main levels (see Table 1), named National, Regional and European which each have a distinct set of characteristics.

The first level, that of National, comprises all observing systems operated by the various European countries. Despite the significant capacity as regards infrastructure, there is little coordination and significant overlap of activities while integration is in most cases a real challenge. At the second level, the Regional, the common marine system challenges have brought interested groups together during the past 20 years, promoting cooperation, knowledge exchange and coordination on specific aspects as for example on data handling, quality assurance and sharing. The role of EuroGOOS with the ROOSs on structuring this important level has been pivotal. Finally, at the third level, the European, there are numerous organisations, projects, initiatives etc. with a wide range of objectives.

Similarly, the European picture in terms of Research Infrastructures (RIs) in the marine and surface water domain is marked by a high degree of fragmentation with actors operating in each country, each of them with overlapping activities and mandates, creating a rather confusing and inefficient landscape. Despite the efforts towards organisation and integration through initiatives such as EuroGOOS, I3 projects (JERICO, FixO3), and the establishment of EU RIs (ERICs), there is significant ground still to be covered.

The GROOM RI aims to support MAS operations in Europe by linking together European facilities, enhancing at the same time the national systems, by optimally coordinating the data value chain and providing efficiently high-quality services. More than 60 entities (institutions and companies) in Europe work with MAS (Figure 2), with most of them coordinated through EuroGOOS. During the design study of the GROOM RI (GROOM II project), 14 facilities (nodes) collaborated, while the framework was set up for all European MAS facilities to be engaged under the GROOM RI umbrella.

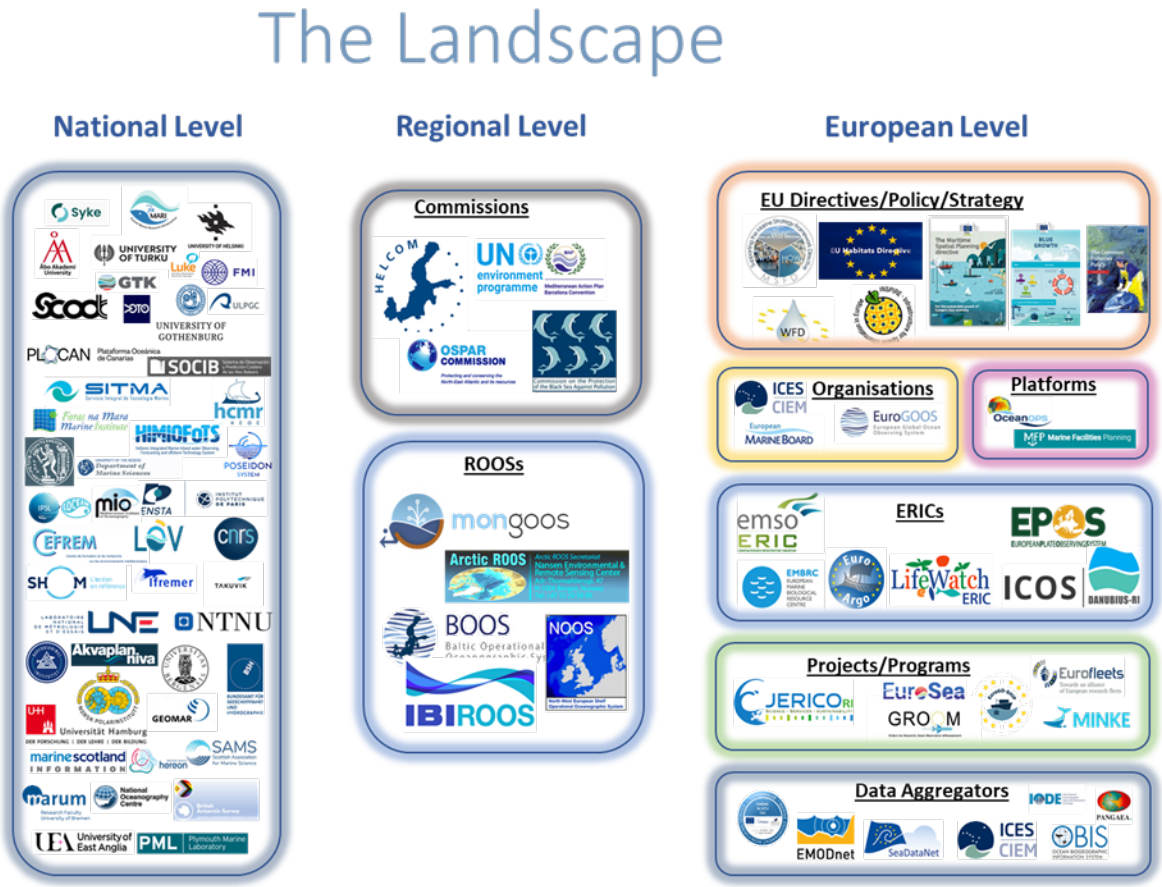

Figure 2 - Illustration of the current landscape of marine observations in Europe at three different levels

2 The Marine Landscape at National Level and MAS Systems at EU countries

Although MAS is a rather recent technology and thus its penetration into the marine observing performing organisations, should be relatively limited, the extensive capabilities it offers, has attracted great interest all around Europe. In the following, we provide a description of the national cases for MAS with the aim to indicate the different national/European decisional levels, in regards to the configuration of the present GROOM II partnership.

Figure 3 - The MAS European Landscape (from ego-network)

2.1 FINLAND

All major components of the Finnish marine research community are gathered under Finnish Marine Research Infrastructure FINMARI. FINMARI represents these components at the National Research Infrastructure roadmap (2021-2024), while comprising central marine science branches; biology, geology, fishery research, ecology, marine chemistry and physical oceanography, geography and remote sensing. Research vessels, gliders, Argo floats, profiling buoys, coastal stations, and Experimental laboratories are included in the entity, while specific partners are participating in EuroArgo, Jerico, EuroFleet, ICOS, SDN European RIs (see Table 1).

FINMARI comprises four Finnish research institutes and three universities, with one of them, the Finnish Meteorological Institute (FMI) to conduct glider missions in the Baltic Sea area.

2.2 SWEDEN

In Sweden, there are four main actors that work with marine autonomous systems, three groups in the University of Gothenburg (UGOT) and the Voice of the Ocean Foundation. They are all collaborating under the umbrella of SCOOT (Swedish Centre for Ocean Observing Technology) funded via EU RDF. SCOOT is a consortium, a cluster with no legal form, that brings together partners which work with autonomous systems, to share expertise and technology. There is no coordination in terms of research infrastructure,

but there is a lot of expertise gained in the last years and available in the SCOOT consortium. Sweden is participating in EMSO, ICOS, EMBRC ERICs and in the GROOM RI projects (Table 1)

2.3 SPAIN

PLOCAN & SOCIB are Singular Scientific and Technical Infrastructures which are co-funded by national and regional government, 50% each, meaning the Spanish Ministry of Science and Innovation (PLOCAN & SOCIB), and the Government of the Canary Islands (PLOCAN) and the Government of the Balearic Islands, respectively (SOCIB), while the University of Las Palmas de Gran Canaria / SITMA has different ways of funding itself.

Spain has a strong presence in the European landscape through these institutes, that is, GROOM RI, Euro-Argo, EMSO, JERICO RI, SEADATANET, EuroFLEETs, DANUBIUS RI, EMBRC, AQUACOSM, Lifewatch, ICOS, Euro-GOOS, EuroGO-SHIP, MINKE, EUMR (Table 1).

2.4 IRELAND

The Irish Glider Network (IGN) established in 2019 is part of EirOOS –Irish Ocean Observing System which is a component of the European Ocean Observing System (EOOS). EirOOS is a multi-platform distributed National Research Infrastructure with the objective to provide ocean and climate monitoring and research platforms to address key national needs and support enhanced Irish participation in European and international research. Ireland is part of the GROOM RI, Euro-Argo, EMSO, JERICO RI, SEADATANET, ICOS, Euro-GOOS, EuroFLEETs, DANUBIUS RI, AQUACOSM, EUMR (table 1).

2.5 GREECE

Glider activity in Greece started in 2017 by HCMR, with the integration of the glider component in the observing network of the Poseidon System. Recently, two more institutes in Greece have implemented gliders in their research, LPCO (Laboratory of Physical and Chemical Oceanography) Aegean University and Remote Sensing Laboratory, NTUA (National Technical University of Athens).

The National Roadmap for Research Infrastructures (2014–2020) (RIs3) was designed and implemented by the General Secretariat for Research and Technology (GSRT) in the framework of the ESFRI roadmaps and describes the national strategic framework for research and innovation in Greece. Among the 28 research infrastructures that were funded in their first phase of implementation between 2017 to 2021, was the national scale RI HIMIOFoTS for the management of the Greek national water resources – HCMR was participating with the Poseidon System and coordinating the effort.

The Greek glider facility is considered part of the National integrated research infrastructure HIMIOFOTS (Hellenic Integrated Marine Inland water Observing, Forecasting and offshore Technology System) (citation 1), which incorporates two distinct components for the management of water resources in Greece: the marine and the surface waters.

Greece is contributing to EuroArgo, EMSO, DANUBIUS – RI, EMBRC and LifewatchERICs, while also participating in GROOM RI, JERICO RI, MINKE and Euro - FLEETS+ infrastructure projects (Table 1).

2.6 FRANCE

Research Infrastructures in France are managed by the Research Ministry. Their funding is dependent on LOLF (Constitutional Bylaw on State Budget Acts - "Loi Organique de Lois de Finances") and they are operated by RPOs (Research Performing Organizations like CNRS, Ifremer, etc).

Back in 2008, the national glider park ("Parc National Glider" PNG hereafter) was founded and managed by the INSU CNRS Technical Division, in order to deploy underwater gliders for the French scientific community. It was installed and operated inside the Mediterranean Ifremer center and part of the CETSM (European Centre of underwater technologies) and it was considered part of FOF (French oceanographic fleet, TGIR – Very Large RI). From 2009 to 2014 glider missions were successfully undertaken by the PNG on behalf of all French scientific communities, while in the next years the situation changed with its final closure in May 2021 and the gliders are now distributed back to the labs they belong to. France is participating in JERICO RI, EuroGO-SHIP, Euro - FLEETs+, MINKE infrastructure projects, as well as EuroArgo, EMSO, ICOS, DANUBIUS, and EMBRC ERICs (Table 1).

2.7 NORWAY

The Norwegian National Facility for Ocean Gliders is based at the University of Bergen's Geophysical Institute. NorGliders aims to maintain and develop ocean glider infrastructure and expertise in Norway. It facilitates vehicle access and coordinates an operation centre comprising a team of pilots distributed among various institutions in Norway.

The Norwegian Research Council supported for the first five years the establishment of the Norwegian National Facility for Ocean Gliders with national funds.

The continuation and sustainability of the infrastructure is then based on research projects. In 2017 the NorGliders acknowledged to be the national facility for ocean gliders, but with no legal status, while it is considered nationally the expert on ocean glider operations, however each institute is developing its own capability – there is no clear national RI. Norway is participating in MINKE and Euro - FLEETs+ infrastructure projects - apart from GROOM RI, as well as ERICs: EuroArgo, EMSO, ICOS and EMBRC (Table 1).

2.8 GERMANY

German Marine research institutions operate a variety of MAS. The entry point for almost all German-wide matters related to scientific and technological aspects of marine science is the "Konsortium Deutsche Meeresforschung (KDM)". KDM is an association after German law (*eingetragener Verein, e.V.*) and provides a high-level coordination across all civil marine research institutions in Germany (see here for a member list[1]). Moreover, representatives from supreme authorities such as the German Weather Service (Deutscher Wetter Dienst; DWD) are ex-officio members of KDM. KDM receives core funding from member fees and from third party projects. It has staff and an office in Berlin and in Brussels. KDM supports the German contribution to the UN Decade, the think tank "Future Forum on the Oceans", and

[1] https://www.deutsche-meeresforschung.de/en/about-us/members/

Strategy Groups (SGs) that assemble German experts from the various KDM institutions on topics of concern. This way, the SGs are national focal points of contact of a respective topic. For MAS operations the SG sustained ocean observing (SG OO) is the point of contact. One major activity of the SG OO is creation and maintenance of a database of German experts categorised by institution, involvement in project, programs, and initiatives. The SG OO is recognized by KDM as a central hub for exchanging information on ocean observing. Examples are the reporting of German ocean observing with "one voice" to the national Global Climate Observing System (national GCOS), recruiting experts for the G7 FSOI initiative, or representing Germanies MAS operators in questionnaires by the GROOM II project. KDM is **not** linked to any processes related to setting up, prioritising (marine) Research Infrastructure in Germany. This is done via **National Research Infrastructure roadmap**[2] and which is overlooked by the German Ministry for Education and Science (BMBF). Moreover, the German Helmholtz Association maintains an **Helmholtz roadmap for Research Infrastructures** (The 2021 Helmholtz Roadmap can be found here[3]).

Germany is contributing to Argo-ERIC, handled by the German Hydrographic Office (BSH) under the Ministry of Traffic and Argo-ERIC is an explicit budget item which serves marine security (and not science). There is involvement in and contribution to other ERICs and AISBL, to ICOS-OCT, Seadatanet through institutions' funding, which is not long-term funding, as well as involvement in infrastructure projects (Table 1).

2.9 UK

Within the National Oceanography Centre (NOC) there are the national marine facilities that support marine science activities all over the UK, providing facilities and means to the UK marine research community as a centralised and cost-effective resource. NOC comprises the Science component, NMEP (National Marine Equipment Pool) and BODC (British Oceanographic Data Centre). The NOC Science component gets funded through national capabilities, while working a lot on science projects with the Plymouth Marine Laboratory and the Scottish Association of Marine Sciences. Glider facilities are provided by NOC, while some other institutes own gliders which they operate alone or in cooperation and support from NOC. The United Kingdom is participating in infrastructure projects, apart from GROOM RI: JERICO RI, EuroGO-SHIP, MINKE, as well as ERICs: EuroArgo, EMSO, ICOS, DANUBIUS, and EMBRC (Table 1).

[2] https://www.research-in-germany.org/en/research-landscape/why-germany/research-infrastructure.html

[3] https://www.helmholtz.de/system/user_upload/Forschung/FIS/21_Helmholtz_FIS_Roadmap_English.pdf

Table 1 - Participation of European Countries operating MAS systems in MRIs and Infrastructure projects/programs

		Finland	Sweden	Spain	Ireland	Greece	France	Norway	Germany	United Kingdom	Italy	Netherlands	Estonia
MAS activity		x	x	x	x	x	x	x	x	x	x	x	x
Infrastructure Projects/Programs	GROOM RI	x	x	x	x	x	x	x	x	x	x		
	JERICO RI	x		x	x	x	x		x	x	x	x	x
	Euro GO - SHIP			x			x		x	x	x		
	Euro – FLEETs +	x		x	x	x	x	x	x		x	x	x
	MINKE	x		x		x	x	x	x	x	x		
ERICs	EuroArgo	x		x	x	x	x	x	x	x	x	x	
	EMSO		x	x	x	x	x	x		x	x		
	ICOS	x	x	x	x		x	x	x	x	x	x	
	DANUBIUS – RI	x		x	x	x	x		x	x	x	x	
	EMBRC		x	x		x	x	x		x	x		
	Lifewatch			x		x					x	x	
Organization	Euro - GOOS	x	x	x	x	x	x	x	x	x	x	x	x

In Table 1 are also presented participations in projects and European infrastructures of countries outside the present GROOM II consortium, which however, were engaged in the framework of the project's work packages.

3 The Marine Landscape at Regional Level

3.1 COMMISSIONS

As mentioned above, organisation and structuring at the regional level has been mainly driven by the need to respond to common challenges – research questions in a region demand common approaches and in most cases interconnected activities beyond the national borders. The same is true for user requirements for services and products. Major initiatives at this important level one are the regional conventions and the EuroGOOS Regional Ocean Observing Systems (ROOSs).

3.1.1 UN Environment Program (UNEP)

The United Nations Environment Programme (UNEP), established in 1972, is the global authority that sets the environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system and serves as an authoritative advocate for the global environment. UNEP's most important regional mechanism is the UNEP Regional Seas Programme established back in 1974. Today, UNEP's Regional Seas Programme consists of three types of Regional Seas Conventions and Action Plans (RSCAPs), across 18 different regions:

- UNEP-administered – These RSCAPs have been established and are directly administered by UNEP who provides Secretariat functions, managing of finances and technical assistance. UNEP administers 5 regional seas conventions and 2 action plans. These are: Caribbean Region, East Asian Seas, Eastern Africa Region, Mediterranean Region (see paragraph 3.1.1.1), North-West Pacific Region, Western Africa Region. The Regional Office for Europe administers the Tehran

Convention (Caspian Sea)

- Non-UNEP administered – These RSCAPs have been established under the auspices of UNEP, but another regional body provides the Secretariat and administrative functions. These are: Black Sea Region (see paragraph 3.1.4), North-East Pacific Region, Red Sea and Gulf of Aden, ROPME Sea Area, South Asian Seas, South-East Pacific Region, Pacific Region
- Independent – These RSCAPs have not been established by UNEP but cooperate with the Regional Seas Programme and attend regular meetings. These are: Arctic Region, Antarctic Region, Baltic Sea (see paragraph 3.1.2), North-East Atlantic Region (see paragraph 3.1.3).

3.1.2 The Convention for the Protection of the Mediterranean Sea Against Pollution (UNEP's Regional Seas Programme)

The Convention for the Protection of the Mediterranean Sea Against Pollution, also known as Barcelona Convention was first adopted in February 1976 in Barcelona and entered into force in 1978. Amended in 1995 and renamed as the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean entered into force in 2004.

The Barcelona Convention and its seven Protocols were adopted in the framework of the Mediterranean Action Plan (MAP) which constitutes the principal regional legally binding Multilateral Environmental Agreement (MEA) in the Mediterranean. The 22 Contracting Parties to the Barcelona Convention are: Albania, Algeria, Bosnia and Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Montenegro, Morocco, Slovenia, Spain, Syrian Arab Republic, Tunisia, Turkey, and the European Union (Figure 4).

Under the Barcelona Convention and its Protocols, the Contracting Parties pledge to take appropriate measures to prevent, abate, combat to the fullest possible extent, eliminate pollution of the Mediterranean Sea Area, and to protect and enhance the marine environment so as to contribute towards its sustainable development. They also pledge to implement the Mediterranean Action Plan to pursue the protection of the marine environment and the natural resources of the Mediterranean, meeting the needs of present and future generations in an equitable manner.

The contracting parties are represented by their competent Ministries and decide on the MAP policies, strategies, budget and programme of work at their ministerial-level meetings held every two years. They designate Focal Points who serve as official conduit for communication to review the progress of work and ensure the implementation of recommendations at the national level.

Figure 4 - Map showing the parties to the Barcelona Convention

3.1.3 HELCOM

Helsinki Commission (HELCOM) is the governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area," also known as the Helsinki Convention that was signed in 1974 by the Baltic Sea coastal states. HELCOM consists of ten members: the nine Baltic Sea countries Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden, and the European Union (Figure 5). The Contracting Parties are represented by a Head of Delegation. In addition to the annual Commission meetings, the Heads of Delegation meet at least twice a year.

A platform for environmental policy making at the regional level, HELCOM works for a healthy Baltic Sea. To help reach its environmental objectives, HELCOM adopted the Baltic Sea Action Plan (BSAP) in 2007. The BSAP is HELCOM's strategic programme of measures and actions to achieve a good status of the Baltic Sea's environment. The Helsinki Convention contains an obligation to protect the Baltic Sea from all sources of pollution from land, air and sea. It also obliges the signatories to take measures to conserve habitats and biological diversity and to ensure the sustainable use of marine resources. The BSAP was updated in 2021, to adjust the current actions and to widen its scope with regard to issues such as climate change, marine litter, disturbance to the seabed and underwater noise. A Science Agenda has been produced to support the implementation of the BSAP and other HELCOM agreements highlighting knowledge needs that must be met within the upcoming 10 years. The Science Agenda aims at communicating HELCOM science needs to funding agencies, to inform and inspire scientists to direct their interest towards closing the knowledge gaps required for HELCOM work, and to increase the interaction between science and policy.

Figure 5 - Contracting Parties and area of interest

3.1.4 OSPAR Commission

The OSPAR Commission, named because of the original Oslo and Paris Conventions, started back in 1972 with the Oslo Convention against dumping and was broadened to cover land-based sources of marine pollution and the offshore industry by the Paris Convention of 1974. OSPAR entered into force on 25 March 1998 and is the mechanism by which 15 Governments (Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom) and the EU cooperate to protect the marine environment of the North-East Atlantic (Figure 7). The Commission is supported by five main committees, some of which are in turn supported by working groups (Figure 6). OSPAR collaborates with UNEP and its Regional Seas Programme to help make the 2030 Agenda a reality and to provide sustainable mechanisms for enhancing cooperation and collaboration on joint programmes, projects and activities, helping governments implement Goal 14 Life Below Water: to conserve and sustainably use the oceans, seas and marine resources for sustainable development.

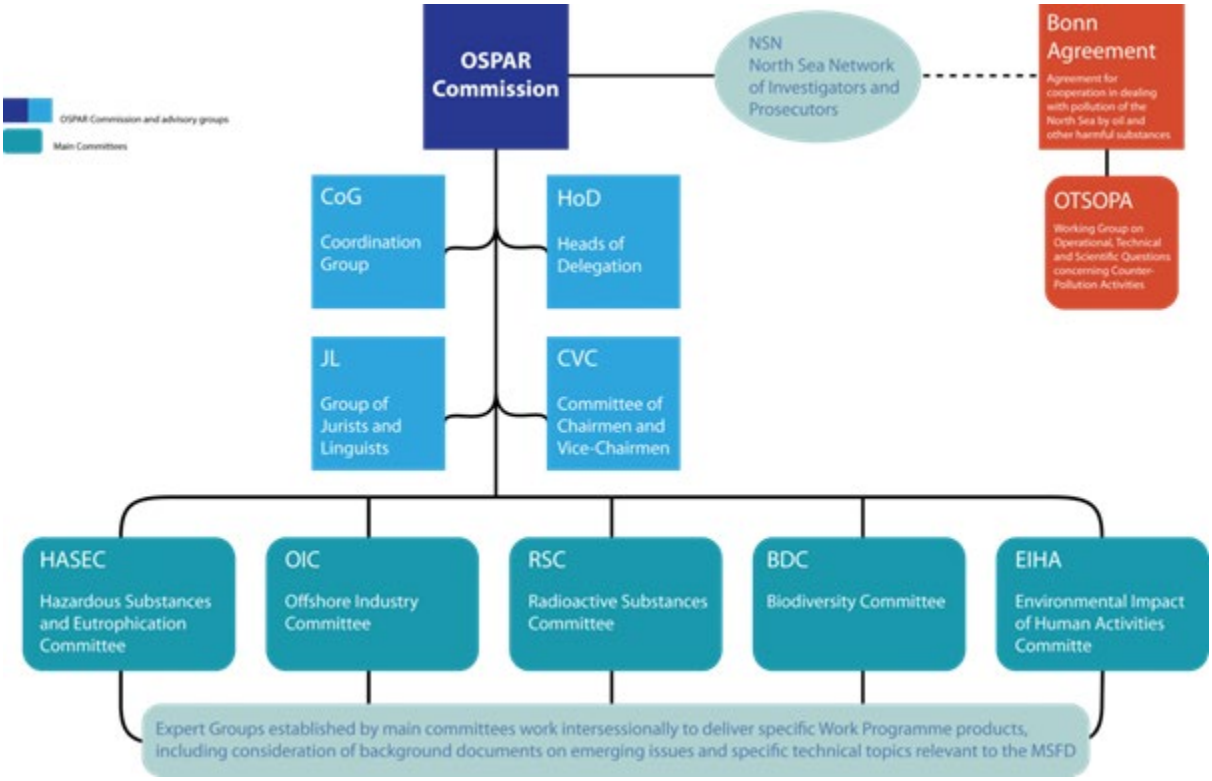

Figure 6 - OSPAR organization scheme

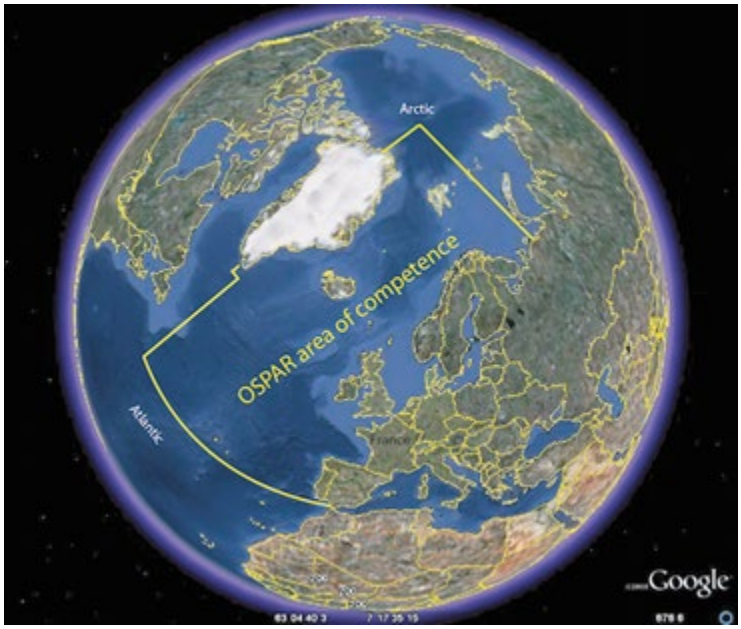

Figure 7 - OSPAR area of competence

3.1.5 Commission on the protection of the Black Sea against pollution

The Convention on the Protection of the Black Sea Against Pollution was signed in Bucharest in April 1992, and ratified in the beginning of 1994 by all six legislative assemblies of the Black Sea countries namely Bulgaria, Georgia, Romania, Russia, Turkey and Ukraine (Figure 8). Also referred to as "Bucharest Convention", its basic objective is to substantiate the general obligation of the Contracting Parties to prevent, reduce and control the pollution in the Black Sea in order to protect and preserve the marine environment. It provides the legal framework for cooperation and concerted actions to fulfil this obligation.

Figure 8 - Commission on the protection of the Black Sea against pollution area of competence

3.2 ROOS

The European Global Ocean Observing System (EuroGOOS) is the European component of the Global Ocean Observing System of the Intergovernmental Oceanographic Commission of UNESCO (IOC GOOS). EuroGOOS, by serving 44 members and supporting five regional systems in Europe, aims to identify priorities, enhance cooperation and promote the benefits of operational oceanography to ensure sustained observations are made in Europe's seas underpinning a suite of fit-for-purpose products and services for marine and maritime end-users.

EuroGOOS supports five Regional Operational Oceanographic Systems (ROOS) in Europe which coordinate and support development and joint service production in European maritime regions.

Five ROOS work within EuroGOOS: in the Arctic (Arctic ROOS), the Baltic (BOOS), the North-West Shelf (NOOS), the Ireland-Biscay-Iberian area (IBIROOS), and the Mediterranean (MonGOOS). EuroGOOS also fosters cooperation in the Black Sea region with Black Sea GOOS.

The objectives, activities, and governance of the ROOS are agreed in MoUs signed between regional EuroGOOS members and non-members. EuroGOOS ensures pan-European representation and interface for ROOS and facilitates cooperation among them. ROOS report to the EuroGOOS General Assembly, while representatives of the EuroGOOS office participate in the ROOS annual meetings.

3.2.1 MONGOOS

The Mediterranean Operational Network for the Global Ocean Observing System (MONGOOS) has been established in 2012 to further develop operational oceanography in the Mediterranean Sea. It includes 34 members from 12 countries. MONGOOS comprises the previous activities of MOON and MEDGOOS. MONGOOS is promoting partnerships and capacity building for GOOS in the Mediterranean Sea and it is creating a continuous working framework with EuroGOOS and GOOS Africa in order to define common roles and activities in the Mediterranean Sea, and foster collaboration with Black Sea GOOS and global ocean GOOS initiatives.

3.2.2 Arctic ROOS

Arctic ROOS is EuroGOOS' Arctic regional system, established in 2007. It includes 20 members from 11 countries. It is an open forum for national agencies, research institutes, universities as well as commercial bodies to inform, share and develop an Arctic Ocean observing system. Arctic ROOS seeks to coordinate activities with the Sustaining Arctic Observing Networks (SAON), the Global Ocean Observing System (GOOS), and other regional Arctic Ocean and sea ice observing networks. The main goals of the Arctic ROOS are to integrate the European oceanographic and sea ice monitoring activities in the Arctic; to foster development of automatic real-time observations; to promote and facilitate dissemination of data via the FAIR principles and to enhance the development of open-source community oceanographic, wave and sea-ice models.

3.2.3 BOOS

The Baltic Operational Oceanographic System (BOOS) was formed by the signature of the BOOS Memorandum of Understanding in 2001, with the aim to promote and develop an operational oceanographic infrastructure including routine collection, interpretation and presentation of in situ and satellite data. BOOS currently includes 20 member organisations from Denmark, Finland, Latvia, Poland, Sweden, Estonia, Germany, Lithuania and Russia.

3.2.4 NOOS

The North West European Shelf Operational Oceanographic System (NOOS) is an operational oceanography system uniting partners from the nine countries bordering the extended European North West Shelf (NWS) and the margin Atlantic Ocean: Belgium, Denmark, France, Germany, Ireland, the Netherlands, Norway, Sweden, and the UK. The partners collaborate to develop and implement ocean observing, monitoring and prediction systems for the NWS area, with delivery of (real-time) operational data products and services.

NOOS aims to develop and implement on-line operational marine data and information services and provide a reliable description of the actual marine condition of the European North West Shelf (NWS) area, including physical, sedimentological, and ecosystem variables. NOOS aims also to provide analysis, forecasts, and model-based products describing the marine conditions, and to collaborate with national and multinational agencies in the NWS area to maximize the efficiency of the ocean observing system, and to optimize the value of the marine information products. Furthermore, among its objectives is to establish a marine database from which time series and statistical analyses can be obtained, including trends and changes in the marine environment, and the economic, environmental, and social impacts.

3.2.5 IBIROOS

The Ireland-Biscay-Iberia Regional Operational Oceanographic System (IBIROOS) aims to set up an operational oceanography organisation operated by participating partners from the 5 countries bordering the Iberia-Biscay Ireland Regional maritime area (France, Ireland, Portugal, Spain and UK), collaborating to develop and implement ocean observing systems for the IBI-ROOS area, with delivery of real time operational data products and services.

4 The Marine Landscape at European Level

4.1 Infrastructure Projects/ Programs

European Infrastructure projects enable RIs to build integrated multi-platform observing systems, reduce overlaps, fill gaps, increase efficiency, enable interoperability, agree on data and metadata standards, and adopt new available technologies. RIs work together and develop common solutions at all stages of their planning, design and operation, guaranteeing their complementarity and interoperability, increasing efficiency and avoiding duplication of effort.

4.1.1 JERICO RI

JERICO-RI is an integrated pan-European multidisciplinary and multiplatform research infrastructure dedicated to a holistic appraisal of coastal marine system changes. JERICO-RI with 40 partners from 19 European Countries, presently connects 9 National RIs. JERICO-RI establishes the framework upon which coastal marine systems are observed, analysed, understood and forecasted. JERICO-RI enables open-access to state-of-the-art and innovative facilities, resources, FAIR data and fit-for-purpose services, fostering international science collaboration. JERICO-RI aims to contribute to a better understanding of the functioning of coastal marine systems and thus to a better assessment of their changes caused by the combined effects of natural and anthropogenic changes. Due to the diversity of scientific/environmental issues and to the range of associated nested spatio-temporal scales, JERICO-RI is enhancing the further implementation of integrated multi-platform technologies: Autonomous fixed platforms; Coastal cabled observatories; HF radars; Coastal profilers and profiling floats; Ferrybox flow-through systems; Gliders, autonomous underwater vehicles.

By doing so it contributes to an efficient management of major ecosystem services and environmental risks, leading to an improved knowledge framework for sustainable development in coastal areas and the emergence of a dynamic coastal blue economy. It aims to be the future coastal component of the European Ocean Observing System (EOOS), and part of the Global Ocean Observing System (GOOS).

JERICO RI was, and still is, supported by: (1) three successive 4-years EC funded projects to start constructing pan-European coastal RI, and a EC funded project (JERICO-DS) dedicated to achieve the design phase of sustained JERICO-RI and start a preparatory one.

4.1.2 EuroFleets +

Eurofleets + has built on the legacy of previous projects, which allowed researchers to access high quality marine research infrastructure on a Pan-European basis for the first time to conduct high quality research. The Eurofleets+ project aims to facilitate open access to an integrated and advanced research vessel fleet, of 27 state-of-the-art, modern research vessels (RVs) (13 Global/Ocean and 14 Regional), 7 Remotely Operated Vehicles (ROVs) and 5 Autonomous, Underwater Vehicles (AUVs), as well as access to the portable telepresence system so that these infrastructures are optimally used for excellent science, leading to high level scientific publications and exploitation by European and international researchers. Ship time is offered to academic and industrial researchers to perform ship-based research across the entire North Atlantic, Mediterranean, Black Sea, North Sea, Baltic Sea, Pacific Southern Ocean and Ross Sea with additional global locations based on specific vessel schedules.

The main specific objectives of the Eurofleets+ project can be summarized as follow:

- Provide efficient, single-point, transnational access to an impressive fleet of research vessels and specialised infrastructure for European and international research communities and to facilitate interdisciplinary research groups to access European and global seas and oceans to conduct excellent research.

- Develop tools and equipment to meet the evolving changes of marine research and to increase the likelihood of new innovative products, processes and services.

- Provide comprehensive training and exchange programmes for user communities and professional staff and increase ocean literacy.

- Establish dialogue with stakeholders from key user communities and develop a strategic roadmap and long-term sustainability plan for advanced and user-oriented transnational access.

4.1.3 EuroGO-SHIP

EuroGO-SHIP, started back in December 2022, is a 4-years HORIZON Europe funded project, which brings together 14 European partners with technical skills in making observations at sea and FAIR data management, as well as leadership in international efforts towards development of best practices around hydrographic research. EuroGO-SHIP will scope, innovate and deliver new services to enhance European hydrographic observations taken from ships, as key research infrastructures contributing to the wider ocean observing system. The project engages and consults with key stakeholders to qualify existing needs of hydrography data originators and end users working with them towards strengthening European capabilities. The proposed new services and access opportunities based on the network needs presented at OceanOBS are:

• shared facilities such as training, best practices, access to capability and access to equipment through a European Marine Equipment Pool (EMEP)

• data curation to ensure fit for purpose data systems and metadata for both real-time and delayed mode quality-controlled data

• secondary quality control to increase consistency and add uncertainty estimates to observations.

These will be refined by broad consultation with data originators, governments, funders and end-users. In addition, pilot activities will both provide immediate support to the networks and help to refine a statement of requirements. These requirements will be compared to the set of services already available within the European RI Landscape and on the basis of this a new structure for supporting European Hydrography proposed.

4.1.4 MINKE

MINKE (Metrology for Integrated Marine Management and Knowledge-Transfer Network), started back in April 2021, brings together 22 organisations from Europe and South America in a 4-years INFRAIA project. MINKE's scope is to integrate key European marine metrology research infrastructures, to coordinate their use and development and propose an innovative framework of "quality of oceanographic data" for the different European actors in charge of monitoring and managing the marine ecosystems. MINKE addresses data quality with focus on all data quality dimensions, with a special emphasis on those related to meteorological factors. The project proposes a new vision in the design of marine monitoring networks, integrating two dimensions of data quality, namely accuracy and completeness, as the driving components of quality in data acquisition.

This new vision will be framed in a quintuple helix model of innovation, incorporating all the elements involved in the monitoring network design:

● the context (ocean health), identifying the Essential Ocean variables (EOVs) as the key parameters to monitor

● the civil society (NGO, Makers community, Social media and Citizen Science platforms) as the key actors to ensure data completeness

● the academia researching new methods to ensure the accuracy and the global quality of the final products, developing tools for integrating the information of top-qualified oceanographic instruments and low-cost instrumentation.

● the industry improving the performance of the observations with new instrumentation, data-transmission systems and cost-effective technologies

● the governments that provide the legal and socio-economic frameworks to develop the proposed network.

MINKE, through the different Integration Activities (Networking, Transnational-Virtual Access and Joint Research), aims to lay the groundwork for creating the necessary synergies among the different involved actors in the quintuple helix model of innovation.

4.2 ERICs

The European Research Infrastructure Consortium (ERIC) is a specific legal form that facilitates the establishment and operation of Research Infrastructures with European interest. The ERIC allows the establishment and operation of new or existing Research Infrastructures on a non-economic basis.

4.2.1 EMSO ERIC

The European Multidisciplinary Seafloor and Water Column Observatory (EMSO) was created in 2006 and included by European Strategy Forum on Research Infrastructures (ESFRI) (ESFRI, 2018) in its roadmap among the essential European large-scale research infrastructures. In 2016, EMSO obtained the status of ERIC and published its Statutes in the EU Official Journal. EMSO is a structure of Regional Facilities of 8 European countries, strategically distributed at key locations around Europe, from the Nordic Seas to North East Atlantic through the Mediterranean to the Black Sea. The observatories are equipped with multiple sensors, located along the water column and the seafloor. EMSO ERIC aims at promoting excellent science through the coordination of a distributed infrastructure of fourteen regional facilities including fixed point multi-sensors platforms, serving marine science researchers and technology engineers, policymakers, industry and the general public. Some regional facilities also utilise ocean gliders in support of their fixed-point platforms.

EMSO ERIC supports multidisciplinary research (marine ecosystems, climate change and geo-hazard) in order to achieve sustainable management and protection of marine resources and to understand the complex interactions among the geosphere, biosphere, hydrosphere and atmosphere. The EMSO ERIC vision is to be a world leader in marine science and technology, launching a new type of large-scale infrastructure that delivers high-quality data with unprecedented resolution to address the Earth-Ocean system challenges of the 21st century.

4.2.2 EMBRC

The European Marine Biological Resource Centre (EMBRC) is a European distributed 'research infrastructure' with more than 40 partners from 9 countries that provides a single access entry point to a comprehensive portfolio of services and research platforms, marine ecosystems, biological resources, E-infrastructure and metadata. EMBRC was integrated into the European Strategy Forum for Research Infrastructures (ESFRI) roadmap in 2008 and was granted a Preparatory Phase contract under the 7th European Framework Programme for Research and Development (FP7). In 2018, EMBRC obtained the status of ERIC and published its Statutes in the EU Official Journal.

The EMBRC-ERIC's mission is: to promote and deliver on new scientific discoveries and deepen knowledge of marine organisms and ecosystems; to promote the use of marine experimental models in mainstream science and raise the profile of marine biological sciences; to promote the sustainable utilization of marine biological resources; to promote the European blue bio-economy.

EMBRC
EUROPEAN
MARINE
BIOLOGICAL
RESOURCE
CENTRE

4.2.3 EuroArgo

The Euro-Argo research infrastructure organizes and federates European contributions to the Argo network and it is part of the European ESFRI roadmap on large research infrastructures. The Euro-Argo ERIC (and its governance structure was set up by the Commission Implementing Decision (2014/261/EU) of May 5, 2014, with 9 funding members. The Research Infrastructure is made up of a central office based in France (Ifremer, Brest) and distributed national facilities. The distributed national facilities operate with direct national resources. As part of the Euro-Argo Research Infrastructure, they agree to a multi-annual commitment of resources (in particular in terms of floats to be deployed and for the data system), and to coordinate their activities through the Euro-Argo ERIC. The Euro Argo ERIC delegates some of its activities to the national facilities who have the relevant expertise (e.g. data management and quality control, float deployment), and according to their areas of responsibility. At present, the Euro-Argo ERIC involves 13 countries: 11 members, 1 observer and 2 candidates. Argo raw data are collected in Data Assembly Centres (DAC) where they are converted into standard exchange formats and are delivered to the GTS and GDACs (Global Data Centres) within 24 hours located in Monterrey (US GODAE/FNMOC/USA) and Brest (Coriolis/ Infremer/ France). A synchronization between the 2 GDACs centres occurs daily.

4.2.4 EPOS

The European Plate Observing System - European Research Infrastructure Consortium (EPOS -ERIC) is an integrated research infrastructure which is currently joined by 19 member-countries and 1 observer-country. It was created to facilitate the integrated use of high-quality multidisciplinary data produced by national monitoring networks, with the aim of developing new tools able to provide scholars of the dynamics of the Earth the fundamental answers to questions regarding geo-hazards and geo-resources. EPOS mission is to establish and underpin a sustainable and long-term access to solid Earth science data and services integrating diverse European Research Infrastructures under a common federated framework. By improving and facilitating the access, use, and re-use of multidisciplinary solid Earth science data, data products, services as well as physical access to facilities, EPOS is developing a federated and sustainable research platform to provide coordinated access to harmonized and quality-controlled data from diverse Earth science disciplines, together with tools for their use in analysis and modelling. EPOS fosters worldwide interoperability in Earth sciences and provides services to a broad community of users. Data and service provision are integrated within the Thematic Cores Services (Seismology, Near-Fault Observatories, GNSS Data and Products, Volcano Observations, Satellite Data, Geomagnetic Observations, Anthropogenic Hazards, geological Information and modelling, Multi-Scale laboratories and Tsunami) and made interoperable with the central hub of the Integrated Core Services (ICS-C), the novel e-infrastructure for promoting FAIR (Findable, Accessible, Interoperable, and Reusable) data management.

4.2.5 ICOS

The Integrated Carbon Observation System, ICOS, is a European-wide greenhouse gas research infrastructure, distributing information from ICOS RI to user communities and establishes integrated data and analysis from GHG observation systems. ICOS data is based on the measurements from over 140 stations across 13 European countries. ICOS mission is to produce standardised, high-precision and long-term observations and facilitate research to understand the carbon cycle and to provide necessary information on greenhouse gases. ICOS promotes technological developments and demonstrations related to greenhouse gases by linking research, education and innovation. With these high-precision data, ICOS supports policy- and decision-making to combat climate change and its impacts. The network of ICOS ocean stations monitor greenhouse gases in the Atlantic and the Nordic, Baltic and Mediterranean Seas. The data collected at the ocean stations are processed and quality controlled by the Ocean Thematic Centre, which coordinates the network of ocean stations.

4.2.6 DANUBIUS – RI

The International Centre for Advanced Studies on River-Sea Systems (DANUBIUS-RI) with 26 partners from 12 countries (24 members and 2 ERICs), is a distributed research infrastructure (RI) that serves as a one-stop shop providing access to a range of experts, infrastructure, services and river-sea (RS) systems across Europe. It provides a platform for interdisciplinary research, access to centres of excellence and harmonized data and, thus, enable knowledge transfer through direct discourse between disciplines, scientists and policy-makers and through development and support for education and training programmes.

4.2.7 LifeWatch ERIC

LifeWatch ERIC is the European Research Infrastructure Consortium supplying e-Science research facilities to scientists and adding knowledge and deeding understanding on biodiversity organisations and ecosystem functions and services in order to support society in addressing key planetary challenges. LifeWatch ERIC is a distributed research infrastructure consortium composed of eight European Union Member States. LifeWatch ERIC's members operate from national nodes, known as Distributed Centres, while its Common Facilities are located in three Member States: Spain (Statutory Seat & ICT-Core), Italy (Service Centre) and the Netherlands (vLab & Innovations Centre).

LifeWatch ERIC was established as a European Research Infrastructure Consortium by the European Commission in 2017.

4.3 ORGANISATIONS

In the marine science field, there are three independent, autonomous, non-governmental advisory bodies at the European level. These organizations transfer knowledge between the scientific community and stakeholders, promoting Europe's marine research and technology leadership. They aim to provide a strategic forum to develop marine research foresight, initiate state-of-the-art analyses, and translate these into clear policy recommendations to European decision-makers.

4.3.1 ICES CIEM

The International Council for the Exploration of the Sea (ICES) is a global intergovernmental marine science organization with more than 5000 experts from 700 institutes and organizations from 20 member-countries, working together to meet societal needs for impartial evidence on the state and sustainable use of our seas and oceans. ICES mission is to advance and share scientific understanding of marine ecosystems and the services they provide and to use this knowledge to generate state-of-the-art advice for meeting conservation, management, and sustainable goals. Through strategic partnerships ICES work extends from the Atlantic Ocean to the Arctic, the Mediterranean Sea, the Black Sea, and the North Pacific Ocean.

To accomplish this, science cooperation agreements are signed with more than 20 global and regional organizations including: UN Intergovernmental Oceanographic Commission (IOC); Food and Agriculture Organization (FAO); Arctic Monitoring and Assessment Programme (AMAP); International Arctic Science Committee (IASC); BONUS programme (science for a better future of the Baltic Sea region); General Fisheries Commission in the Mediterranean (GFCM); Mediterranean Science Commission (CIESM);

In addition, contracts and agreements are signed with public authorities and commissions to which ICES provides advice for, including: European Commission (EC); Helsinki Commission (HELCOM); North Atlantic Salmon Commission (NASCO); North East Atlantic Fisheries Commission (NEAFC); OSPAR Commission (OSPAR).

Furthermore, a strategic planning framework has been established specifically for the cooperation with the North Pacific Marine Science Organization (PICES), the sister organization in the North Pacific. Finally, ICES CIEM holds an official observer status to the United Nations General Assembly, the Arctic Council, and the SeaDataNet.

4.3.2 European Marine Board

The European Marine Board (EMB) is a partnership of major national marine research institutes, funding organisations and national networks of universities which aims to facilitate cooperation and coordination in marine science both in Europe and internationally. EMB traces its origins to the European Committee for Ocean and Polar Sciences (ECOPS), a forum of leading European marine scientists back in 1989. Its current name was officially given in 2013 and at present EMB has 32 members from 18 Countries. The European Marine Board provides a pan-European platform for its member organizations to develop common priorities, advance marine research, and bridge the gap between science and policy in order to meet future marine science challenges and opportunities. The European Marine Board undertakes a wide spectrum of strategic activities, bridging the gap between research, policy, industry and society. EMB engages in several foresight activities by establishing working groups (the Blue Carbon, the Navigating the Future VI, the Deep Sea and Ocean Health, the Coastal Resilience, the Marine Habitat Mapping and the Ocean Oxygen); producing strategic foresight papers; organizing forums and conferences and by participating in EU projects. EMB also participates in marine science policy facilitation and communication.

4.3.3 EuroGOOS

EuroGOOS is an association of agencies and research organizations, founded in 1994, to further the goals of GOOS, and in particular the development of Operational Oceanography in the European Sea areas and adjacent oceans. EuroGOOS now has 44 members in 18 European countries. Since 2013, EuroGOOS is registered as an international non-profit association under the Belgian law (AISBL) and its headquarters are in Brussels. EuroGOOS operates in five regional areas where operational systems have been set up: the Arctic (Arctic ROOS), the Baltic (BOOS), the North West Shelf (NOOS), the Ireland- Iberian area (IBIROOS) and the Mediterranean (MonGOOS). EuroGOOS Working Groups develop strategies, priorities and standards to establish a concerted European approach to the development of operational oceanography. These strategies are actively promoted towards the European and national operational and funding agencies aiming to maximize their impact.

EuroGOOS Task Teams are operational networks of observing platforms, promoting synergy and technological collaboration among European ocean observing infrastructures. Task Teams are important operational components of the European Ocean Observing System (EOOS) framework.

To this end, six Task Teams have been established, namely: the FerryBox, the Tide Gauge, the Gliders, the High Frequency Radar, the Argo, and the Fixed Platforms Task Team. Task Team members exchange open source tools, collaborate in areas of common interest, and jointly make European data available to the EuroGOOS ROOS regional data portals, which in turn are feeding data to pan-European portals, e.g. EMODnet and Copernicus Marine Environment Monitoring Service, CMEMS.

4.4 EU Directives/ Policy/ Strategy

The sustainable use of ocean, seas, and coasts are threatened by marine littering, pollution, climate change, and overexploitation. Research and innovation are critical to better monitor, understand, protect, preserve, and harness the ocean and seas. European Union strategy supports research and innovation in oceans and seas and adapts specific directives summarized below.

4.4.1 MSFD

The Marine Strategy Framework Directive (MSFD) is European legislation, adopted in 2008, to protect the marine ecosystem and biodiversity on which health and marine-related economic and social activities depend. To this end and in order to help the EU countries in achieving a good environmental status (GES), MSFD sets out 11 qualitative descriptors and concrete measures at international level. The Directive enshrines in a legislative framework the ecosystem approach to the management of human activities having an impact on the marine environment, integrating the concepts of environmental protection and sustainable use. In order to achieve its goal, the Directive establishes European marine regions and sub-regions on the basis of geographical and environmental criteria. The Directive lists four European marine regions – the Baltic Sea, the North-east Atlantic Ocean, the Mediterranean Sea and the Black Sea – located within the geographical boundaries of the existing Regional Sea Conventions. Cooperation between the Member States of one marine region and with neighbouring countries which share the same marine waters, is already taking place through these Regional Sea Conventions. The MSFD sets an obligation to review the Directive by 2023 and, where appropriate, propose any necessary amendments.

4.4.2 WFD

The Water Framework Directive is European legislation, adopted in 2000, which sets out rules to pause deterioration in the status of EU water bodies and achieve good status for Europe's rivers, lakes and groundwater. The key objectives of the WFD are set out in Article 4 of the Directive. It requires Member States to use their River Basin Management Plans (RBMPs) and Programmes of Measures (PoMs) to protect and, where necessary, restore water bodies in order to reach good status, and to prevent deterioration. Good status means both good chemical and good ecological status. The Water Framework Directive (WFD) is the primary legislation. It is supported by two so-called daughter directives on the quality and quantity of groundwater and on the quality of surface water. The WFD contains provisions regarding the deadlines for meeting the objectives of the Directive, as well as provisions on exemptions.

4.4.3 EU Habitats Directive

The EU Habitats Directive, formally known as Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora, was adopted by the European Community in May 1992. The aim of this Directive is to ensure biodiversity through the conservation of natural habitats and of wild fauna and flora in the territories of the Member States. Under this legislation, a coherent European ecological network of special areas of conservation was set up with the title “Natura 2000”. Under this legislation, EU countries must introduce appropriate conservation objectives and measures and they must do everything possible to guarantee the conservation of habitats in these areas and avoid their deterioration and any significant disturbance to species listed in the Directive. Systems of strict protection must also be established for animal and plant species particularly threatened.

4.4.4 INSPIRE

The INSPIRE Directive, a unique example of a legislative “regional” approach, was adopted in May 2007, with the aim to establish an infrastructure for spatial information in Europe to support Community environmental policies, and policies or activities which may have an impact on the environment. Based on the infrastructures for spatial information operated by the EU Member states, addresses 34 spatial data themes needed for environmental applications. To ensure that the spatial data infrastructures of the Member States are compatible and usable in a community and transboundary context, the Directive requires that common Implementing Rules (IR) are adopted in a number of specific areas (Metadata, Data Specifications, Network Services, Data and Service Sharing and Monitoring and Reporting). These IRs are adopted as Commission Decisions or Regulations, and are binding in their entirety.

4.4.5 The Maritime Spatial Planning directive

The Maritime Spatial Planning Directive is the common framework for maritime spatial planning in the European Union adopted in July 2014. This Directive establishes a framework for maritime spatial planning aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas, and the sustainable use of marine resources. It aims to contribute to the sustainable development of energy sectors at sea, maritime transport, fisheries, and aquaculture sectors, and to the preservation, protection, and improvement of the environment, including resilience to climate change impacts. It has placed the legal requirements on Member States for the development and implementation of Maritime Spatial Plans (MSP) by 2021. Member States remain responsible and competent for designing and determining, within their marine waters, the format and content of such plans, including institutional arrangements and, where applicable, any apportionment of maritime space to different activities and uses respectively.

4.4.6 Blue Growth

Blue Growth is the European Commission’s (DG MARE) long term strategy to support the smart, sustainable and inclusive growth of the marine and maritime sectors and economy. The Blue Growth Strategy is considered to be based on three fundamental axes: (i) Knowledge of the marine environment; (ii) Maritime spatial planning, and (iii) Integrated maritime surveillance. The European Union’s Blue Economy encompasses all sectoral and cross-sectoral economic activities related to the oceans, seas and coasts, including those in the EU’s outermost regions and landlocked countries. This includes the closest

direct and indirect support activities necessary for the sustainable functioning and development of these economic sectors within the single market.

4.4.7 The Common Fisheries Policy

The Common Fisheries Policy (CFP) is the European Union's fisheries policy created to manage the fish stock of the European Union as a whole. It sets rules for the member states for sustainably managing fishing fleets and conserving fish stocks, as well as encouraging the fishing industry through various market interventions. The CFP was a precursor of the European Green Deal and its related strategies. In turn, the European Green Deal strengthened the CFP approach, emphasising the triple contribution of fisheries and aquaculture to the economy and employment of coastal regions, food security in the EU and the protection of the marine environment. The CFP is guided by the principle of good governance. The regional approach introduced by the 2013 CFP reform allows Member States to cooperate in regional groups and design regional conservation measures through joint recommendations. In addition, the CFP reinforces stakeholder cooperation through the involvement of Advisory Councils.

4.5 DATA AGGREGATORS

The Marine Data Management within the European Landscape relies on three main components namely: SeaDataNet, EMODnet and Copernicus CMEMS as presented in Figure 9.

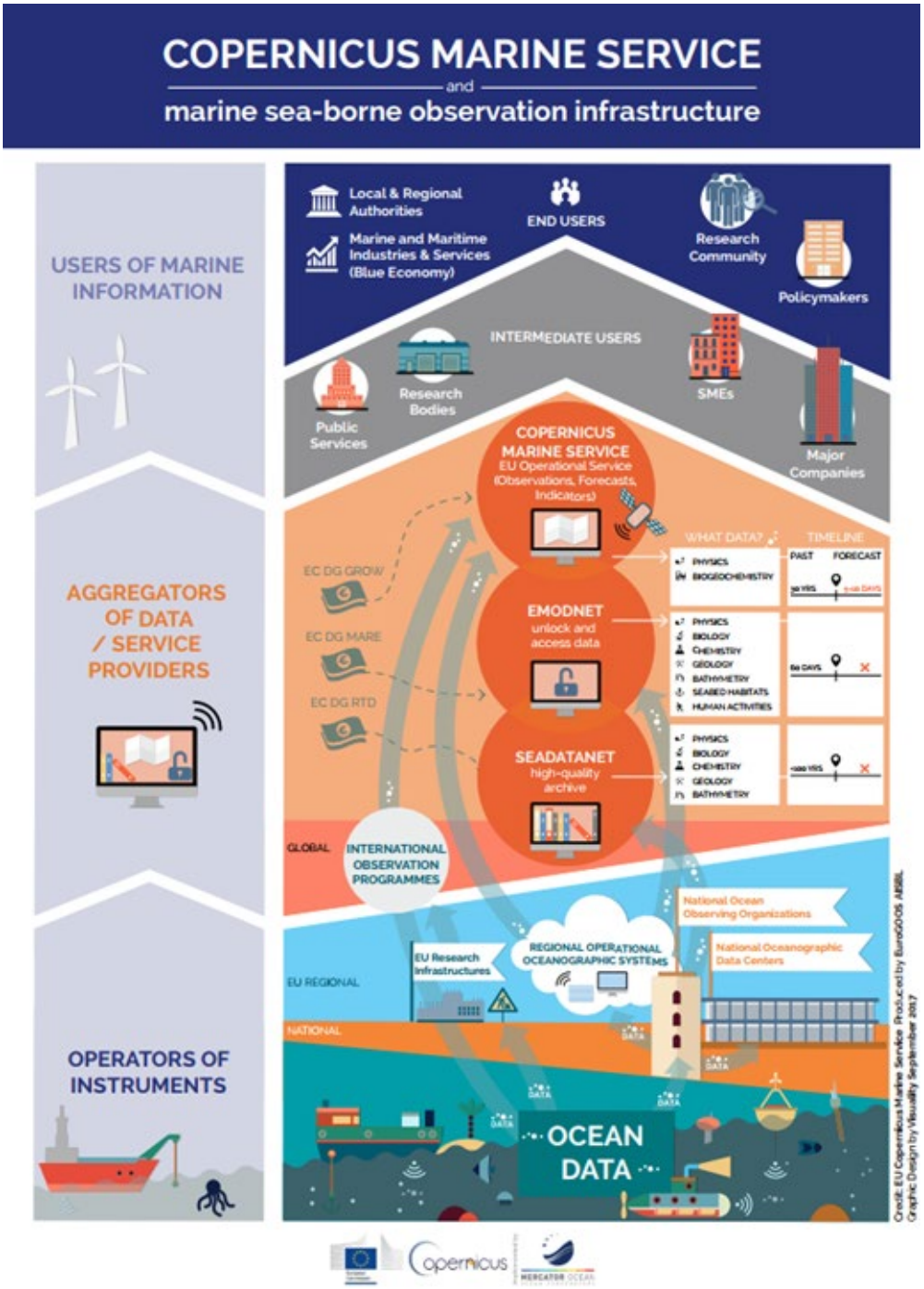

Figure 9 - EU Copernicus Marine Service, produced by EuroGOOS AISBL, September 2017

4.5.1 SeaDataNet

SeaDataNet is a distributed Marine Data Infrastructure for the management of large and diverse sets of data (for physics, geophysics, meteorology, chemistry, biology, geology and bathymetry) deriving from 34 countries (> 1.000 organisations) bordering the European seas. Professional data centres, active in data collection, constitute the Pan-European network providing on-line integrated databases of standardized quality. The on-line access to in-situ data, meta-data and products is provided through a unique portal interconnecting the interoperable node platforms constituted by the SeaDataNet data centres. The development and adoption of common communication standards and adapted technology ensure the platform's interoperability and the INSPIRE compliance. The quality, compatibility and coherence of the data issuing from so many sources, is assured by the adoption of standardized methodologies for data checking, by dedicating part of the activities to training and preparation of synthesized regional and global statistical products from the most comprehensive in-situ data sets made available by the SeaDataNet partners. To this end, SeaDataNet provides: free set of tools to be used by each data centre; capacity building by training workshops for the uptake of standards and tools by the data centres in order to achieve standardisation; Pan-European services for harmonised discovery, access, visualization of data and data products; common SeaDataNet Data Policy and License.

4.5.2 EMODNET

The European Marine Observation and Data Network (EMODnet), developed in three major phases since 2009, consists of more than 120 organisations assembling marine data, products and metadata to make these fragmented resources more available to public and private users relying on quality-assured, standardised and harmonised marine data which are interoperable and free of restrictions on use. EMODnet is supported by the European Union's integrated maritime policy and benefits all marine data users, including policy makers, scientists, private industry and the public. EMODnet provides access to European marine data from seven discipline-based themes (bathymetry, biology, chemistry, geology, human activities, physics, and seabed habitats), for each of which there is a gateway to a range of data archives managed by local, national, regional and international organizations.

4.5.3 COPERNICUS

Copernicus, the European Union's Earth Observation Programme, is aiming to constantly provide information on the state and health of the Earth by observing, collecting, storing and analysing data and providing products to enable effective decisions to be made. Copernicus, brought together by 8 stakeholders in the European Union, brings information based on data from a constellation of 6 families of satellites and dozens of third-party satellites operating alone or combined with sensors placed on the seas, land or in the air. Copernicus then stores the data and provides a large amount of reliable and up-to-date information on the status of the environment. The data are analysed to generate indicators useful for researchers and end users providing information on past, present and future trends. Copernicus contributes not only to European scientific and technical excellence but is part of a public service framework, allowing full, free and open access to all data collected. Scientists, policy makers, entrepreneurs and ordinary citizens can use these data. Copernicus also provides information on essential interrelated themes incorporating six sets of services namely: atmosphere monitoring, marine environment monitoring, land monitoring, climate change, emergency management and security.

4.6 World Ocean data Centres

4.6.1 PANGAEA

PANGAEA is an open access library for projects, institutions and individual scientists to use or archive and publish georeferenced observational and experimental data and metadata. PANGAEA ensures that hosting institutions follow the FAIRness principles (citability, comprehensive metadata descriptions, interoperability and high degree of harmonization). Most of the data are freely available and can be used under the terms of the licence mentioned on the data set description. Each dataset can be identified, shared, published and cited by using a Digital Object Identifier (DOI Name). The World Data Center PANGAEA is a member of the World Data System (WDS) of the International Science Council (ISC). It is further hosting the World Radiation Monitoring Center (WRMC) of the Baseline Surface Radiation Network (BSRN) and as such accredited as a "Data Collection and Processing Centre" (DCPC) of the World Meteorological Organisation (WMO) Information System (WIS).

4.6.2 ICES CIEM

The International Council for the Exploration of the Sea (ICES) is an intergovernmental marine science organization, meeting societal needs for impartial evidence on the state and sustainable use of our seas and oceans (more information can be found in paragraph 4.3.1 since ICES has a double role: organization and data centre)). At the core of the ICES strategic vision, the Transparent Assessment Framework (TAF), aims to make data, methods and results from ICES assessments easy to find, explore and re-run. ICES Data Centre manages, preserves, analyses and interprets a number of large dataset collections related to the marine environment. ICES CIEM develops services and tools to enable visualization and easy access to these data for a broad range of users.

4.6.3 OBIS

OBIS, with more than 20 nodes around the world which connect 500 institutions from 56 countries, is a global open-access data and information clearing-house on marine biodiversity for science, conservation and sustainable development. OBIS mission is to build and maintain a global alliance that collaborates with scientific communities to facilitate free and open access to, and application of, biodiversity and biogeographic data and information on marine life. OBIS delivers over 45 million observations of nearly 120 000 marine species, from Bacteria to Whales, from the surface to 10 900 metres depth, and from the Tropics to the Poles. With this, OBIS provides a global platform for international collaboration between national and regional marine biodiversity and ecosystem monitoring programmes, enhancing Member States and global contributions to inter alia, the Global Ocean Observing System (GOOS) and the Global Earth Observing System of Systems (GEOSS).

4.6.4 IODE

The "Intergovernmental Oceanographic Commission" (IOC) of UNESCO, established in 1961, the programme "International Oceanographic Data and Information Exchange" (IODE). The main purpose of IODE is to facilitate the exchange of oceanographic data (mostly on physical and biological oceanographic data (Boxes 2 and 3), less on hydrographic, chemical and geological data) and information between participating Member States, and thus enhance marine research, exploitation and development. During the past 50 years, IOC Member States have established over 80 oceanographic data centres in as many countries. This network has been able to collect, control the quality of, and archive millions of ocean observations, and makes these available to Member States.

4.7 Monitoring Platforms

4.7.1 OceanOPS

OceanOPS is the International Center of Excellence for Coordination and Monitoring of Meteo-Oceanographic Observing Systems that are part of the Global Ocean Observing System (GOOS). Based in Brest, France, OceanOPS, depends both on the UNESCO Intergovernmental Oceanographic Commission and the World Meteorological Organization and represents the operational center of GOOS. OceanOPS coordinates and optimizes the performance of over 100,000 observations a day from a global network of weather-oceanographic observing devices including international Argo deployment, drifting and fixed buoys, OceanGLIDERS piloted profilers, weather-oceanographic vessels and research vessels, marine animals equipped with oceanographic sensors, tide gauges. Furthermore, ensures centralization, archiving and open access to metadata. Develops web tools to monitor the state of the observation network and its evolution. Assists in the implementation and coordinates deployments / recoveries of instruments. Helps the development of international cooperation. And, communicates about the status and value of GOOS.

4.7.2 Marine Facilities planning

Marine Facilities Planning is a platform allowing scientists to apply to use marine facilities from the NERC, NIOZ, GEOMAR, CSIC, IMR, GU and SYKE. Marine Facilities Planning platform is a joint NIOZ, NERC and Maas Software Engineering project that could be made available to other organisations as well.

5 The European Ocean Observing System (EOOS)

The European Ocean Observing System (EOOS) is a forum for communities and stakeholders to come together -without compromising their own governance systems or agendas- with the ultimate goal of better coordinating Europe's Ocean observing capacity.

5.1 EOOS PROGRESS

The European Ocean Observing System (EOOS) is a forum for communities and stakeholders to come together -without compromising their own governance systems or agendas- with the ultimate goal of better coordinating Europe's Ocean observing capacity.

The EOOS process started back in 2007 during the development of the European Integrated Maritime Policy – the ocean science and observations communities made a clear call to the policymakers that for an integrated maritime policy an integrated European ocean observation is critical. Since 2015, the European Marine Board (EMB) and EuroGOOS have been working in partnership to advance EOOS from a concept to a concrete initiative designed to align, integrate and promote Europe's complex and fragmented ocean observing capacity, guided by an EOOS Steering Group. Building on the European ocean observing community's powerful desire to work together, EOOS connects the diverse European organizations, networks, initiatives, and projects dedicated to ocean observing.

EOOS's vision is to develop a truly integrated and sustained European ocean observing capacity by having

the European ocean observing community and networks working seamlessly together in order to deliver the essential ocean information needed to users for the sustainable use of our ocean's resources.

EOOS's mission is to coordinate and integrate European communities and organisations operating, supporting and maintaining ocean observing infrastructures and activities, fostering collaboration and innovation.

By bringing together the main actors of ocean observing, from local to pan-European scale, EOOS facilitates dialogue and collaboration to improve integration and coordination of in situ ocean observing in Europe.

These actors include:

- Observing networks and agencies
- National operators/implementers
- Research infrastructures
- Data aggregators
- Ocean coordinating networks
- Ocean observing funders

By helping to secure long-term financial investment from multiple stakeholders to create infrastructures that support more sustainable ocean management, EOOS maximizes the value and benefits of European ocean observations. This will lead to improved knowledge and the production of goods and services to benefit society.

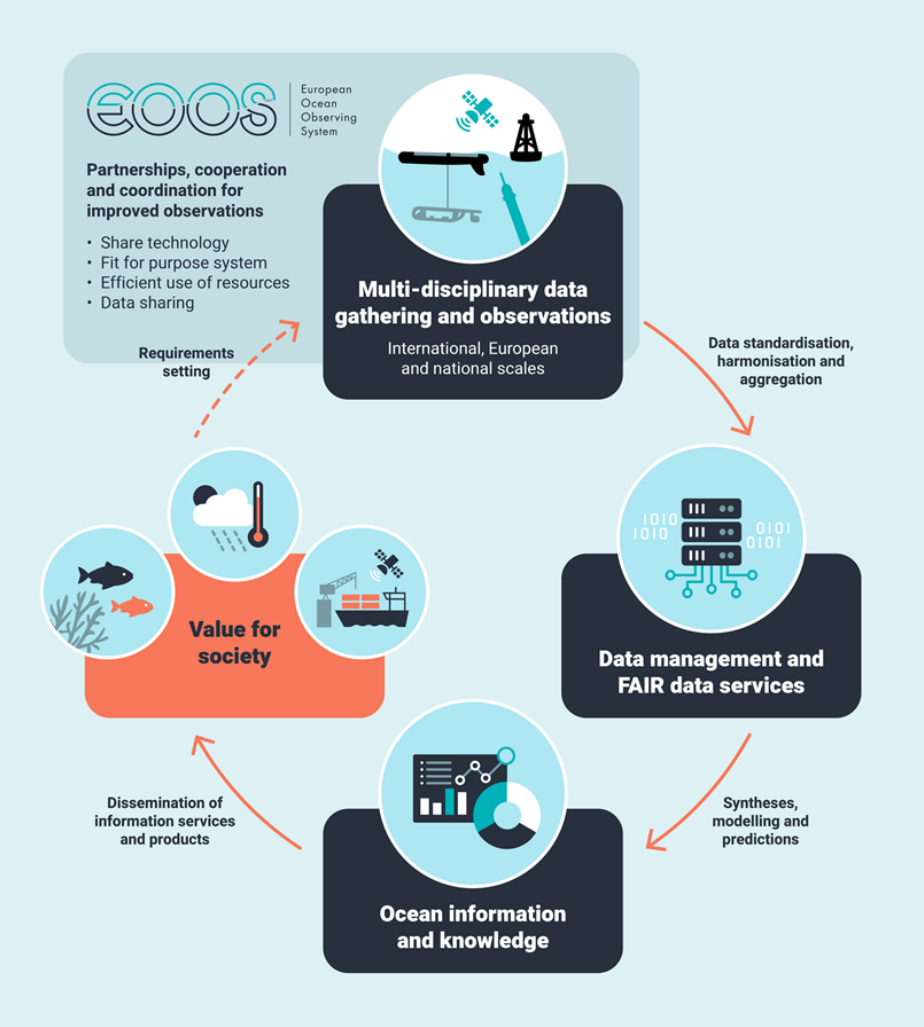

Figure 10 - The European Ocean Observing System (EOOS) framework

EOOS is an integral part of the global ocean and wider earth observing system incorporated into the Global Ocean Observing System (GOOS) and the Global Earth Observation System of Systems (GEOSS). GOOS was created in March 1991 by the Intergovernmental Oceanographic Commission (IOC) of UNESCO in response to calls from the Second World Climate Conference in Geneva, 1990. Since 1991, GOOS has been leading the development of a truly global ocean observing system that delivers the essential information needed for our sustainable development, safety, wellbeing, and prosperity. GOOS is currently led by the Intergovernmental Oceanographic Commission (IOC) of UNESCO and co-sponsored by the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP), and the International Science Council (ISC).

Although initially, GOOS was focused on building a system to support climate science and be the observational backbone for operational forecast systems, in 2011, GOOS began implementing the Framework for Ocean Observing. This is a guide for multiple stakeholders that reflects concerns about ocean health and the demand from nations for information to manage their global economies.

GOOS's mission is to lead the ocean observing community and create partnerships to grow an integrated, responsive, and sustained observing system that serves users as effectively as possible. The GOOS ocean observing community is made up of local, national, and regional ocean observing systems and programs, principal investigators, scientists and technicians making long-term observations within national programs and global ocean observing networks, and many individuals. The core principles are to: implement through user-driven design; maintain sustained observations; ensure regular evaluation; and set global standards and best practices.

By 2030, GOOS's vision is to have a global ocean observing system truly responsive to the needs of end-users, able to mitigate mounting pressures on the ocean and enable resilient and sustainable blue economies.

The glider component of the integrated GOOS is OceanGliders. Started in 2016, OceanGliders is organized in Task Teams (TTs), chaired by recognized specialists in their domains and fully open to engage broader communities. Six TTs are currently identified, namely: Boundary currents, Storms, Water transformation, Ocean health and ecosystems, Best practices, and Data management. It is piloted by the OceanGliders Science/Steering Team (OGST) providing scientific leadership to promote ocean sub-surface gliders as a tool for sustained ocean observations globally, responding to integrated requirements of the GOOS (also incorporating GCOS requirements), and reporting to the WMO/IOC JCOMM OCG (Observation Coordination Group). The OGST oversees the development and implementation of a global-scale glider array for observing key regions of the ocean on the long term, based on national and regional glider projects.

Since 2020, the Scientific Committee on Oceanic Research (SCOR) Working Group is working towards the harmonization of the observational strategies of several dozen OceanObs'19 community papers to create a unified vision for an Observing Air-Sea Interaction Strategy (OASIS). Global coverage of air-sea fluxes will be achieved through consolidation and expansion of the existing networks and introduction of new sustainable ocean technologies, such as autonomous surface vehicles and a new generation of chemical, biological and physical sensors.

5.2 EUROSEA

EuroSea is a European Union Innovation Action funded through the European Commission research funding programme Horizon 2020 under a call supporting the G7 Future of Seas and Oceans Flagship Initiative. EuroSea brings together 55 organizations from 16 countries (oceanographic institutes, met offices, hydrographic agencies, universities, associations, panels and private companies) working across the European Seas (Baltic Sea, North Sea, Mediterranean Sea and Black Sea) and the Atlantic Ocean. Through EuroSea, these organizations improve the coordination of Europe's Ocean observing and forecasting and deliver information and solutions to support decision making in the areas of climate, ocean health and maritime activities. EuroSea's vision is to conduct research and innovation towards a user-focused, truly interdisciplinary, and responsive European ocean observing and forecasting system, that delivers the essential information needed for human wellbeing and safety, sustainable development and blue economy in a changing world. EuroSea's mission is to use a co-design approach to significantly

improve European ocean observing and forecasting services and products by building the community needed for a system that delivers services and products on the ocean, ocean climate, marine ecosystems and their vulnerability to human impacts.

5.3 EOOS GOVERNANCE

EOOS has a flexible and adaptable governmental scheme with stakeholders at its core and an alliance of voluntary partners spanning the public and private sectors. This bottom-up governance model, in which nations are integrally involved, is designed to evolve over time.

EOOS is mainly staffed by EuroGOOS, EMB and JPI Oceans (Joint Programming Initiative Healthy and Productive Seas and Oceans) members. Since 2019 the EOOS governance (Figure 11) includes:

- Steering Group: top level of the EOOS governance approving all decisions; was established in early 2016; is co-chaired by EMB and EuroGOOS; meets on average twice a year, and it is advised by the other EOOS committees. The mandate for Steering Group membership is four years.

- Advisory Committee: advise the Steering Group to bring together broader stakeholders; is a permanent structure since 2019; members are selected by the EOOS Steering Committee and is co-chaired by EMB and EuroGOOS.

- Resources Forum: represent the ministries and funding organizations (including private funders) coordinating/conducting/funding ocean observing activities in Europe; it is chaired by the Executive Director of JPI Oceans while the JPI Oceans Secretariat supports the Resource Forum in close collaboration with the Secretariat of EuroGOOS.

- Operations Committees: represent the diversity of ocean observing implementers at national,regional and pan-European levels; established in 2000 builds on and supports the Global Ocean Observing System (GOOS), through the GOOS National Focal Points for Europe as the principal liaison point to each nation to establish a two-way dialogue between the national implementers of ocean observing, EOOS and GOOS.

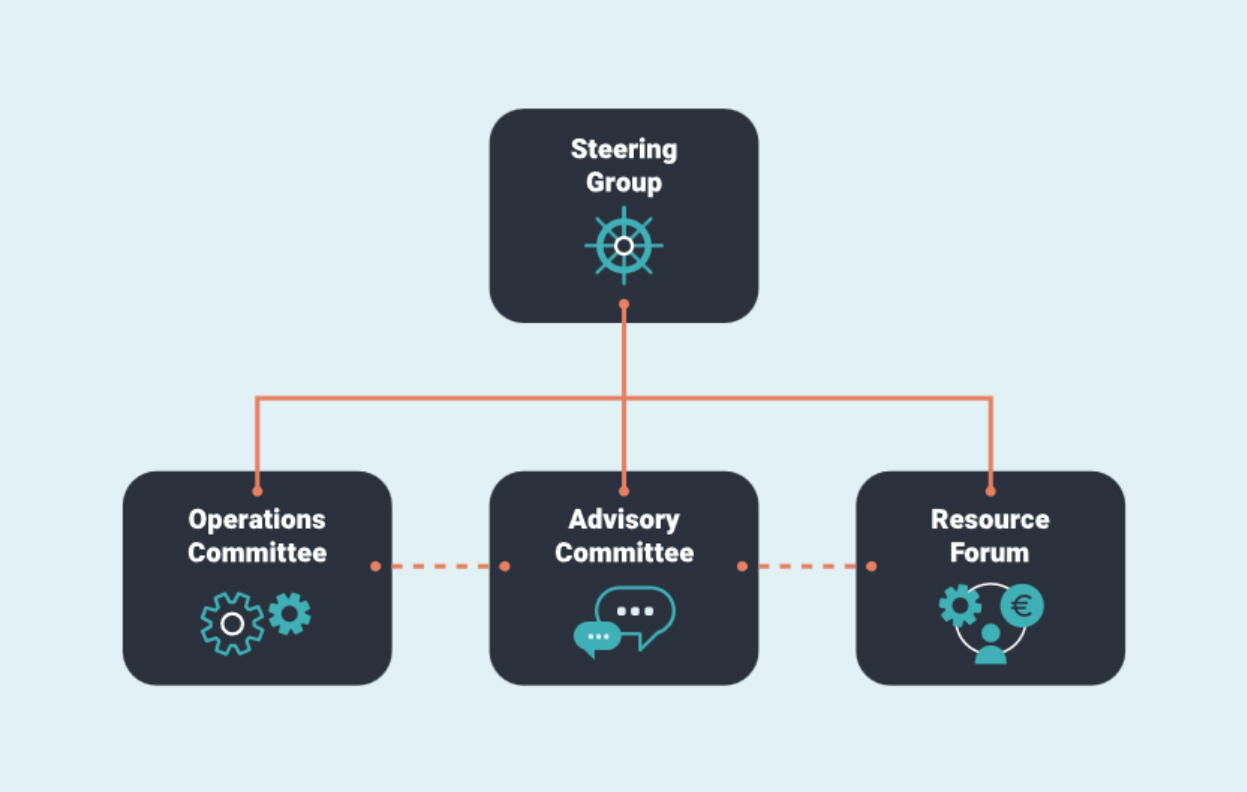

Figure 11 - Schematic diagram of the EOOS Governance model

5.4 EOOS Strategy and Implementation Plan

Europe's capability in ocean observing and marine monitoring is large and widespread. It expands from operational oceanography to research-driven observing platforms, and from policy driven environmental monitoring of European waters for assessments, e.g., MSFD, to industry-driven coastal and offshore monitoring for marine and maritime economic activities, the stakeholder communities and observing infrastructures are diverse and span all marine environments.

The EOOS Strategy 2023-2027 provides direction to advance EOOS from a well-structured multi-actor network towards a platform for coordinating and operationalising user-driven ocean observing. A complementary Roadmap for Implementation provides details of the approaches that EOOS plans to apply within the scope of this five-year strategy. EOOS ultimate goal is to strengthen coordination and dialogue between systems and networks. EOOS adds value by providing a central focal point for strategy, stakeholder engagement and innovation across Europe's diverse ocean observation and monitoring communities.

EOOS work is underpinned by the Framework for Ocean Observing and aligned with the global ocean observing community.

EOOS scope is to add value to existing initiatives and approaches, promoting greater alignment and coordination both with existing partnerships and identifying new connections.

EOOS implementation plan (2023 – 2027) focuses on six areas. For each area, the plan includes tasks outlining concrete activities for implementing the EOOS framework:

1. Co-designing EOOS in collaboration with stakeholders
2. Understanding user and stakeholder needs and priorities
3. Improving the visibility of ocean observing activities
4. Promoting best practices and open data sharing
5. Fostering innovation in ocean observing
6. Advancing the transition to a well-connected, coordinated ocean observing system
7. Communicating the value of ocean observing

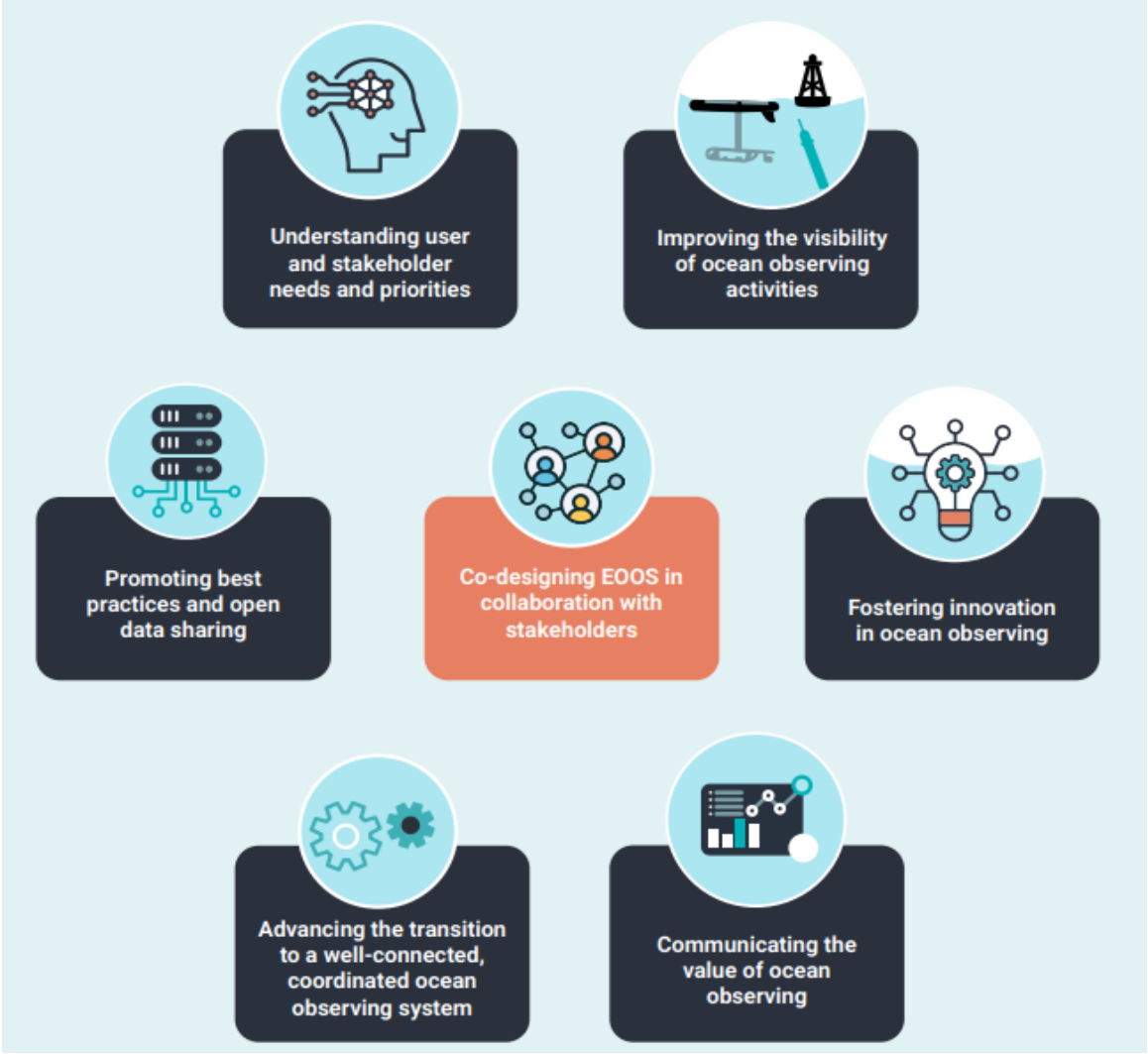

Figure 12 - EOOS Implementation Activities of interconnected objectives

6 The European Strategy Forum on Research Infrastructures (ESFRI)

The European Strategy Forum on Research Infrastructures (ESFRI) Roadmap is a continuous process that regularly identifies projects expected to move towards implementation of new Research Infrastructures or significant upgrade of existing Research Infrastructures. The importance of the Environment domain Research Infrastructures in helping to tackle global environmental issues is addressed in the landscape analysis in the latest ESFRI Roadmap (2021):

"Environmental Research Infrastructures are key to provide systematic and coherent datasets needed for research addressing climate, natural resources, health, food security, biodiversity, and sustainable use of the marine, freshwater and soils. However, they do not only cater to the scientific community but support the environmental monitoring activities conducted by agencies across Europe and serve as test-beds for development of technology and methodology."

The current landscape of the Environment domain Research Infrastructures is illustrated in Figure 13.

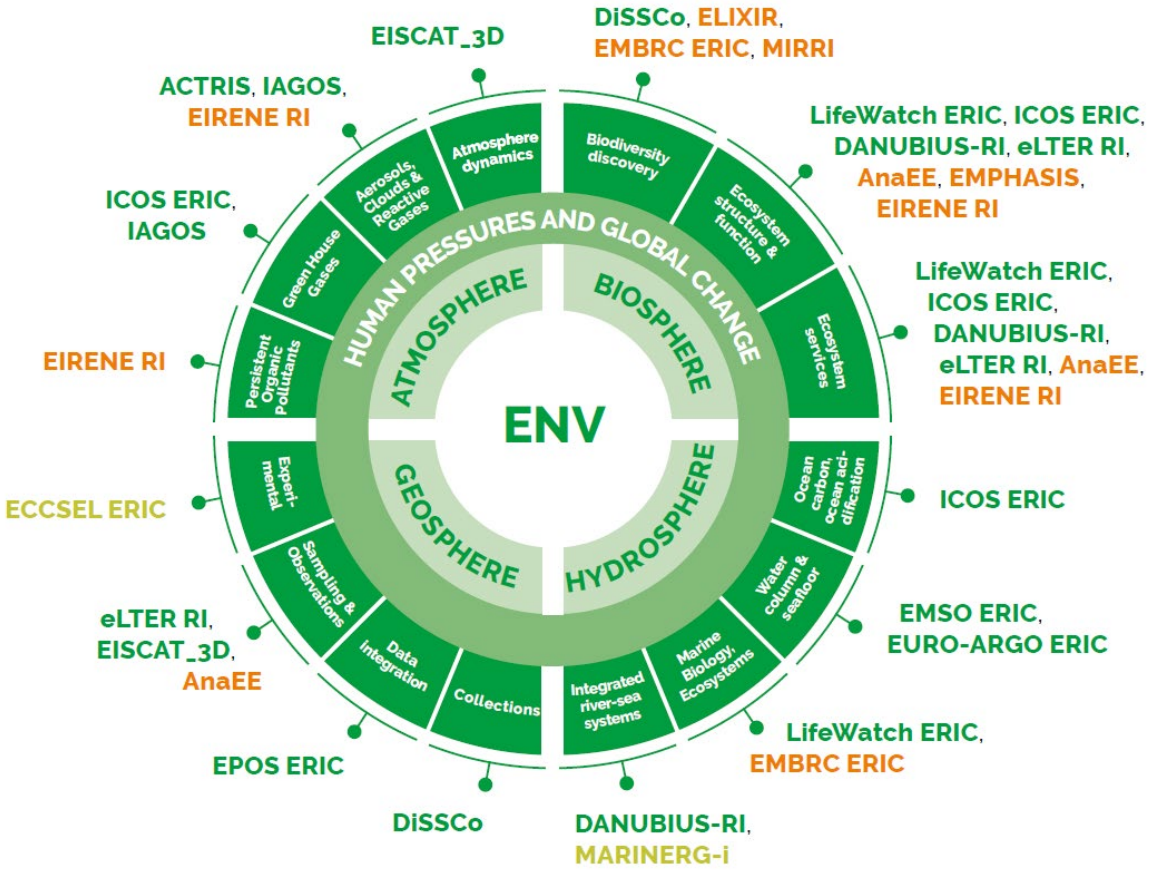

Figure 13 - The landscape of the environmental domain Research Infrastructures described in the latest ESFRI Roadmap (2021)

7 The ENVRI Community and the BEERi

The ENVRI community is a community of Environmental Research Infrastructures, projects, networks and other stakeholders interested in environmental Research Infrastructures (https://envri.eu/). It is a common forum for the environmental research infrastructures to work together, share knowledge and develop joint solutions within four domains: ocean, atmosphere, solid earth and ecosystem/biodiversity.

The ENVRI community has long roots. It has developed and widened within several EU funded projects (Figure 14). The community was established in the ENVRI project that focused on common operations of environmental Research Infrastructures. The follow-up project ENVRIplus was dedicated to finding common solutions to shared information technology and data related challenges by utilising multi-disciplinary expertise. The latest project supporting the cluster activity was the ENVRI-FAIR project that focused on ensuring provision of environmental data, tools and other services that are open and following FAIR principles. In these ENVRI cooperation initiatives, the overarching goal has been to move from separated domains towards an integrated conduct that allows for a system science approach with multidisciplinary services to tackle environmental challenges and establish products for various societal needs.

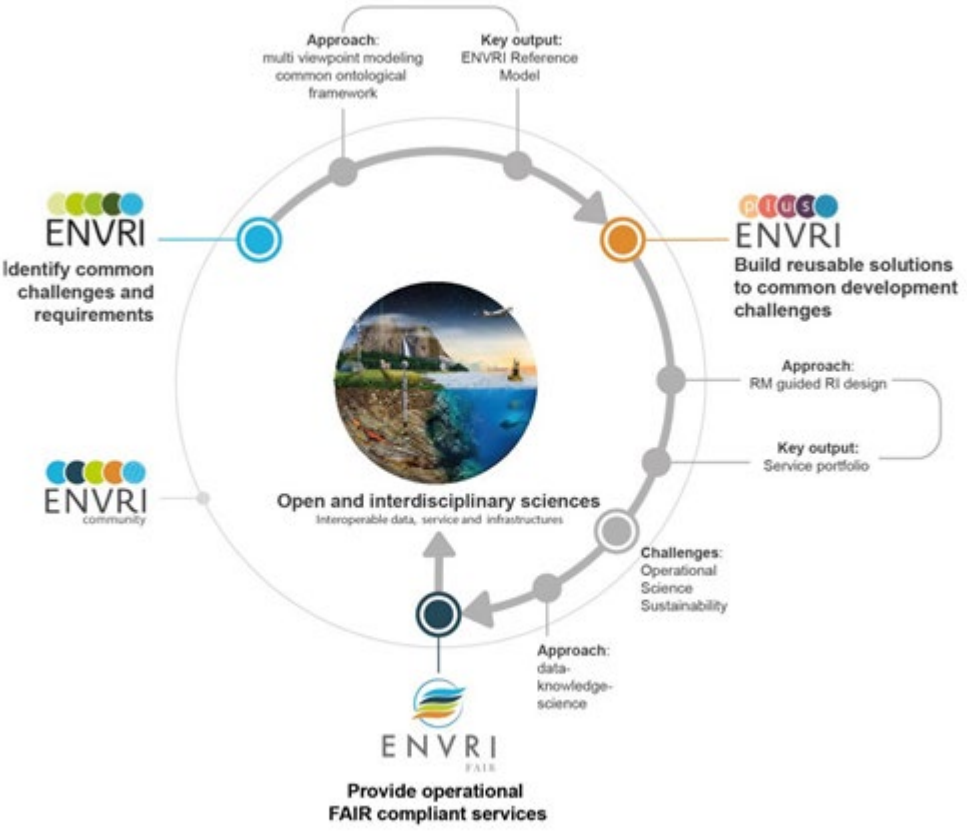

Figure 14 - ENVRI community has developed and widened through several EU funded cluster projects since 2011

Currently, the ENVRI Community brings together 26 Environmental Research Infrastructures in Europe (see Figure 14). GROOM RI became a member of the ENVRI community in June 2021, when it was accepted as a member of the BEERi (Board of European Environmental Research Infrastructures). BEERi works on common strategies, positions, policies and participations, and consists of RI directors or coordinators from the environmental domain research infrastructures in Europe. BEERi was established at the beginning of the ENVRIplus project in 2015 and has continued its activities regularly since then. BEERi's main focus is working on common messages towards the European Commission and ESFRI on behalf of the cluster of environmental Research Infrastructures.

Being part of ENVRI Community helps the involved Research infrastructures with their specific implementation needs (through learning from other RIs and sharing knowledge on lessons learned), supports stakeholder engagement and gives wider visibility and stronger voice for the RIs in the environmental field.

Figure 15 - Environmental Research Infrastructures cooperating in the ENVRI Community

8 The Glider European Research Infrastructure (GROOM RI)

8.1 The advancement of GLIDER activity in Europe and the GROOM RI in the grand European scheme

The first glider network was launched in Europe in October 2005 with the composition of the EGO initiative ("European Gliding Observatories") by several scientific teams aiming to support the advancement of glider activity in Europe, to share operational efforts as a community, and support the dissemination of glider data in global databases (like Coriolis Data Center) in real-time and delayed mode. In the meantime, membership was expanded to the world wide level and the EGO initiative now stands for ("Everyone's Gliding Observatories"). The EGO initiative has been the keystone for glider advancement in Europe, offering the ground for supporting important actions that contributed to the enhancement and establishment of sustained glider observations in ocean research. Some of the landmarks are as follows.

The OceanGliders program started in September 2016 at the 7th EGO conference to support coordination and enhancement of the global glider activity, contributing to the international efforts of the Global Ocean Observation System (GOOS) for Climate, Ocean Health, and Operational Services.

Since the EuroGOOS establishment in 1995, many platform-oriented projects (EuroSea WP3 tasks, Eurofleets, EuroGO-SHIP) and RIs (ARGO, EMSO, as well as network oriented (JericoRI) have been developed in Europe in order to embrace and enhance coordination within the integrated ocean observation initiative of EuroGOOS. Furthermore, in early 2016 the European Marine Board (EMB) and EuroGOOS who have been working in partnership to advance EOOS from a concept to a concrete initiative, are establishing EOOS Steering Group to coordinate and integrate European communities and organizations operating, supporting and maintaining ocean observing infrastructures and activities. Later on, an EOOS Strategy and Implementation plan was developed in 2018 for the communities actively involved, while the EOOS Advisory Committee was also set up in 2018 (figure 16).

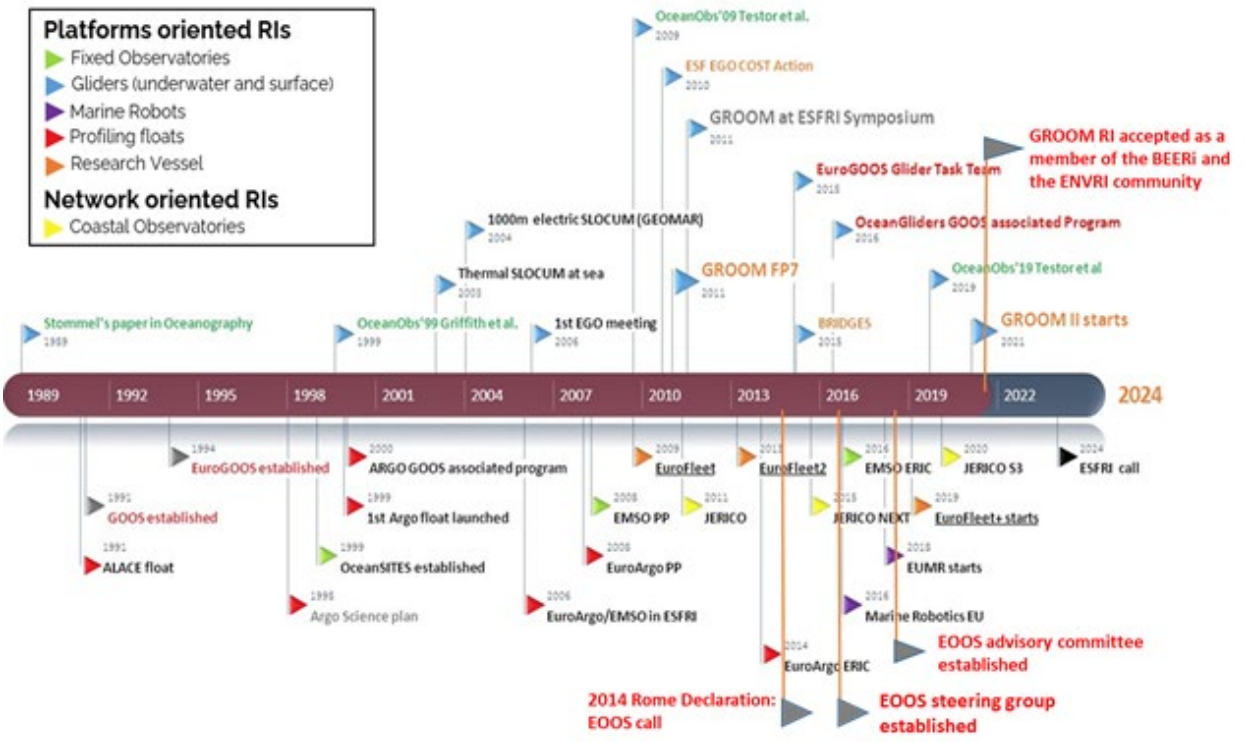

Figure 16 - Landmarks of glider activity advancement through the years (up) in the framework of the marine landscape shaping in Europe with emphasis in the EOOS landmarks (down)

In that framework, glider activity in Europe has been advanced since middle 2000s (1st EGO meeting) achieving important milestones: the launch of the GROOM FP7 design study project in October 2011 laid the foundation for the European glider research infrastructure, which continued with the GROOM II Horizon project started in 2020. This project aims to deliver the European Research Infrastructure for Marine Autonomous Systems (MAS) integrating national infrastructures in order to provide high-quality ocean observation data and services to the community and stakeholders. During the project's implementation, in June 2021, GROOM RI became a member of the ENVRI community. More landmarks which provided a boost in ocean glider related activities and sustained observations was the setup of glider groups coordination in Europe through the establishment of the EuroGOOS Glider Task Team in 2015, and beyond with the launch of the OceanGliders GOOS associated Program (figure 17). In that way, several levels of coordination were offered to facilitate scientific and technological exchanges between glider operators and users, in academia and industry (figure 17).

Figure 17 - The glider component in the grand scheme of marine landscape

8.2 GROOM RI INTEGRATION AND CONTRIBUTION TO EOOS

In the present marine integrated landscape of the ERA (European Research Area) (figure 18), the glider component has developed the solid links inside all the coordinating frameworks built in Europe since the early '90s, when GOOS and EuroGOOS were first established. OceanGliders program in GOOS, EuroGOOS Glider Task Team, and eventually the GROOM RI to bond and enforce the national systems in the framework of EOOS, while also contributing to the ENVRI/BEERi community (figure 18). All the above initiatives are formed and supported by national entities or scientific groups that are cooperating and coordinating at different levels and aspects of interaction. EOOS on the other hand, is the coordinating framework designed to align and integrate Europe's ocean observing capacity, and as such brings together the main actors of ocean observing, from local to pan-European scale, to facilitate dialogue and collaboration and improve integration and coordination of all in situ ocean observing in Europe (figure 18).

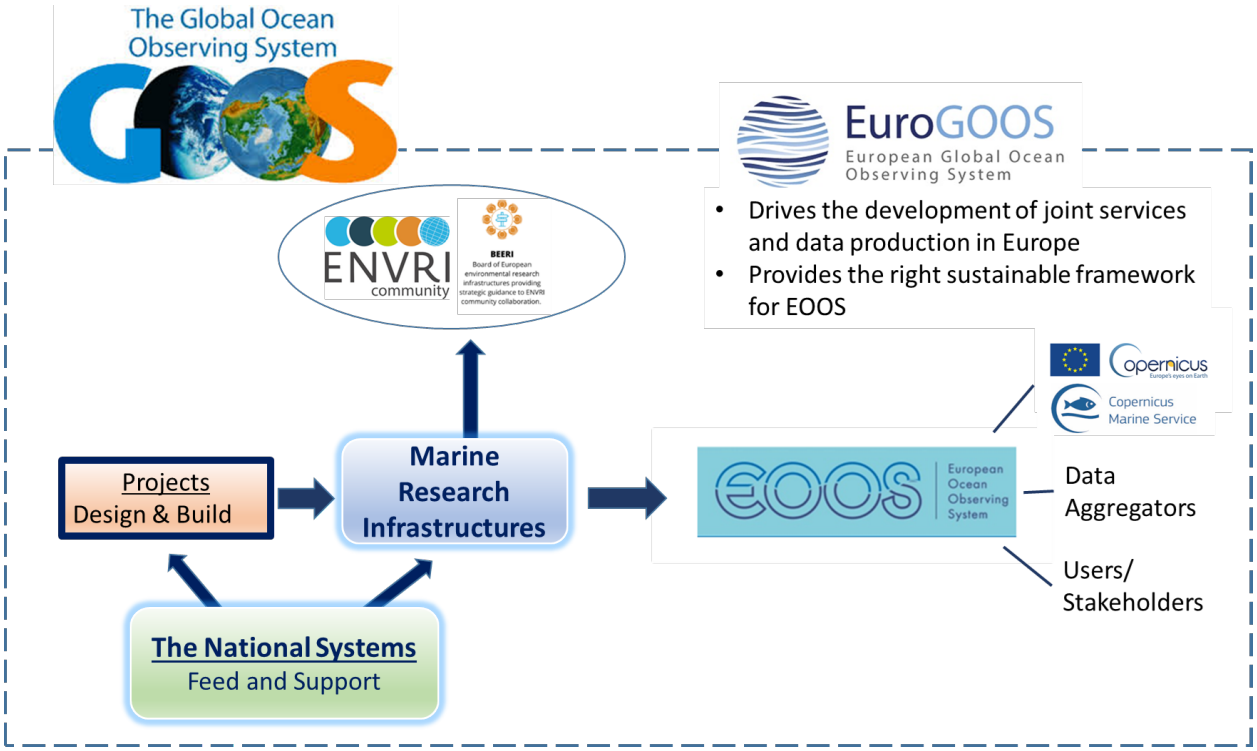

Figure 18 - The marine ERA

OceanGliders, the glider component of the integrated Global Ocean Observing System brings marine scientists and engineers deploying gliders from all over the world to observe on the long-term physical, biogeochemical, biological ocean processes and phenomena that are relevant for societal applications, and contribute to the GOOS through real-time and delayed mode data dissemination. OceanGliders shares best practices, requirements, efforts and scientific knowledge needed for glider operations, data collection and analysis. It also monitors global glider activity and supports the dissemination of glider data in regional and global databases, in real-time and delayed modes, and facilitates data access to wider communities.

EuroGOOS Glider Task Team is a highly functioning user group community that advances and optimises European underwater glider activities to support EuroGOOS strategy and EU initiative on Ocean Observations and technological development. It acts as an expert group to provide high level information to stakeholders and promote the importance of ocean observations under the framework of EOOS. The EuroGOOS Glider Task Team is composed of members of European glider groups, from every region (ROOS).

EOOS is developed in the context of the Framework for Ocean Observing of the Global Ocean Observing System (GOOS). The EOOS Framework benefits from the platform provided by EuroGOOS as the GOOS Regional Alliance for Europe, with dedicated resources for coordination of European ocean observing (EOOS strategy 2023 – 2027). The EOOS framework coordinates and aims at integrating the contributions of the main actors of all in situ ocean observing in Europe. These actors include representatives of observing networks and agencies, national operators/implementers, research infrastructures, data aggregators, ocean coordinating networks and ocean observing funders among others (figure 19).

Figure 19 - EOOS actors – building a fit to purpose ocean observing system in Europe

The main objective of EOOS is to ensure long-term sustainability to integrate European ocean observation capabilities. EOOS is a system based primarily on significant investment made by European countries in ocean observation complemented by EU funds to generate pan-European added value, and with the RIs as an essential component (EOOS implementation plan 2018 - 2022). European marine RIs are developing an active long-term participation of their Member States in the development of EOOS as part of an integrated observation system while they are also aiming to strengthen collaboration by joining forces and favouring their synergies towards integrated multidisciplinary and cross domain research on ocean observing systems. These RIs deliver relevant scientific results, support and contribute to address global societal challenges, and foster innovation. Their data support new operational services within global and European observing systems (GOOS and EuroGOOS), and EU data aggregators (e.g., Copernicus, CMEMS, EMODnet), or other European entities like Joint Programming Initiatives (JPIs, 2022). By bringing together the marine RIs under a joint strategy, it favours alignment to the EOOS objective, leading to defragmentation of the observing landscape and thus act as essential pillars of a coordinated European ocean observation effort (Dañobeitia, 2023).

European Research infrastructures are fundamental contributors and members of the EOOS Operations Committee, which is representing the ocean observing implementers at national, regional and pan-European levels. The committee builds on the experience provided by EuroGOOS, relevant European Research Infrastructures and earth observation agencies, research vessel operators and network of marine stations, as well as the EuroGOOS Regional Operational Oceanographic Systems (ROOS), and task teams. It also builds on and supports the Global Ocean Observing System (GOOS), through the GOOS National Focal Points for Europe as the principal liaison point to each nation to establish a two-way dialogue between the national implementers of ocean observing, EOOS and GOOS.

In this context, three ESFRI landmarks (ICOS ERIC, EURO-ARGO ERIC and EMSO ERIC) and European MRI

projects (JERICO RI, Eurofleets+, GROOM RI, and later EUMR, MINKE and EuroGO-SHIP, all ENVRI members) acknowledged the fact of fragmentation in the marine landscape, have constituted the AMRIT consortium. AMRIT (Advance Marine Research Infrastructures Together) is a HORIZON-INFRA-2023-DEV project — "Developing, consolidating and optimising the European research infrastructures landscape, maintaining global leadership". As the EOOS Framework coordinates and works towards integrating the contributions of the ERICs, the MRI projects and the multiple organisations which operate, support and maintain ocean observing and monitoring infrastructures, the main objective of the AMRIT project is to develop the maximum synergistic functioning of MRIs for sea operations and data collection to build up the EOOS.

The GROOM Research Infrastructure integrates national infrastructures for Marine Autonomous Systems (MAS) to provide access to platforms and services to the broadest range of scientific and industrial users, as well as other ocean observing RIs. It maintains a unique centralized provision of cyber-infrastructure, data and knowledge for the optimized use of MAS to study climate and marine environments, and to support operational services and the blue economy. 14 partners are part of the GROOM II project, while the framework was set up for all European MAS facilities to be engaged under the GROOM RI with more than 60 entities (institutions and companies) in Europe working with MAS – most of them coordinated through EuroGOOS.

The GROOM RI works in parallel and harmonises efforts with the EuroGOOS Glider Task Team. Furthermore, EuroGOOS provides the right sustainable framework within ERICs, MRI projects and marine organisations from all Member States, that they can all contribute to EOOS; EuroGOOS supports 5 ROOSs to coordinate and drive the development and joint service production in Europe, whereas constitutes the legal entity representing the European component of the Global Ocean Observing System (GOOS) and being strongly engaged in building the EOOS Framework.

Within this framework, the GROOM RI, as an active and vital component of the EOOS consolidation, is enhancing the coordination of the national MAS operators and implementers by joining forces, and developing the bonds and synergies to be "stronger together" and fulfil EOOS framework of integration and objectives.

Uniting the European MAS community under a Research Infrastructure, is supporting EOOS strategy objective 1 to collaboratively design and work towards a sustained multiplatform, multi-network and multi-thematic EOOS that meets the specific needs of users. In addition, the GROOM RI will advance, inside its framework, dialogue and collaboration with authorities, funders and policymakers at national, regional and European levels regarding MAS related activities, research and operations, thus proactively contributing to EOOS Strategy Objective 3 to implement recommendations towards a sustained EOOS.

The GROOM RI is proactively contributing to the Objective 2 of the EOOS Strategy 2023-2027: "Engage with European providers of services and products derived from ocean observations to improve collaboration across the marine knowledge value chain". The GROOM RI has defined Marine Autonomous Systems (MAS) Services and Products for public and private needs by identifying five key sectors to focus and develop services and products:

- Fishery Management and Scientific Support,
- Marine Renewable Energies,
- Climate Observations,

- Statutory Ecosystem Monitoring/Assessment Ecosystem Stressors,
- Operational Monitoring for Good Environmental Status (GES) and Emergencies in the Ocean.

Furthermore, the GROOM RI is able to encounter and respond to several use cases:

- UC1 - Contribution to Discovery Science,
- UC2 - Contribution to the GOOS, GCOS, EOOS and other international initiatives like the UN Ocean Decade,
- UC3 - Contribution to the regulatory Monitoring of marine systems,
- UC4 - Contribution to Operational Oceanography/Ocean Forecasting,
- UC5 - Contribution in response to emergency situations,
- UC6 - RI role as a technology Assessment Centre.

Moreover, building UC2, the GROOM RI will draw parallels with EuroArgo through the EOOS and effectively support the coordinated connection of open/deep ocean sustained observations (Argo, EMSO, OceanSites, GO-SHIP) with coastal observations filling data gaps through GTS and (G)DACs. The GROOM RI together with the other marine research infrastructures in a consolidated landscape of EOOS, with enhanced capacities, efficient and sustainable operations and provision of services, will enforce Europe with disruptive research and breakthrough science and innovation through cutting-edge, interconnected and sustainable Research Infrastructures.

8.3 THE GROOM RI IN THE OCEAN OBSERVING VALUE CHAIN

Ocean scientists are increasingly called to provide data and impartial scientific information to support all levels of governance and management. This challenge requires more and better-coordinated efforts in observing and understanding the ocean and coastal seas around the globe. Achieving this, will allow ocean scientists to meet the challenge of delivering ocean information for societal benefit. Till today, largely independent observing systems have evolved to meet the needs of particular disciplines and end users. Integrating efforts across the different scientific disciplines (physical, chemical, and biological), is critical because: 1) many of the world's problems today are in nature interdisciplinary, and 2) the limited resources available for ocean observing systems require strong cooperation and leveraging.

To this end, in 2009, during the OceanObs'09 Conference, more than 600 representatives of ocean observation programs and the ocean science and ocean services communities from 36 countries met in Venice. The conference was sponsored by a number of international and national coordinating and implementing agencies. The assembly made significant progress in building bridges between research and operational observing efforts; between open-ocean and coastal observing; among various ocean science disciplines; and among groups that focus on particular ocean phenomena and observing platforms.

The Conference's international sponsors assigned a Task Team to produce an integrated framework for sustained ocean observing to recommend a way forward for ocean observations in the next decade. The Task Team's objective was to use lessons learned from the successes of existing ocean observing efforts and outline a Framework that can guide the ocean observing community as a whole to establish an integrated and sustained global observing system – one that includes ocean physics, biogeochemistry, and ocean biology and ecosystems, and addresses the variables to be measured, the approach to measuring them, and how

their data and products will be managed and made widely available to modelling efforts and a wide range of users. Achieving this step-change in ocean observing will require internationally accepted processes and expanded collaboration. The Framework for Ocean Observing (FOO) was published in 2012 (Figure 20) and adopted by GOOS as a foundational document that same year (Figure 21). The FOO provides guidelines for the setting of requirements, assessing technology readiness, and assessing the usefulness of data and products for users.

Figure 20 - The FOO Value Chain

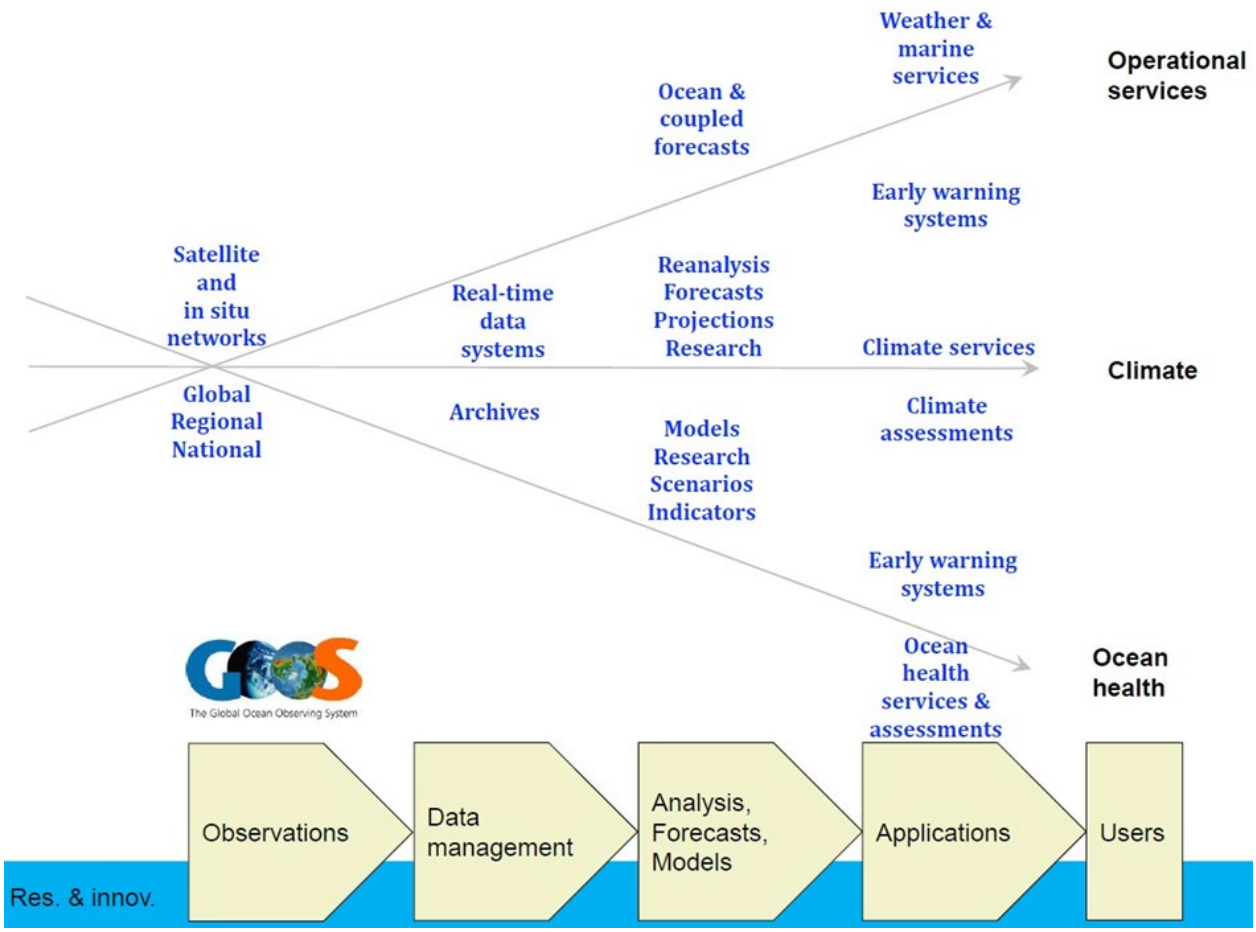

Figure 21 - The Ocean Observing value chain as presented by GOOS

Marine robots are widely used for ocean observation, marine research, & increasingly by private companies. This sector is quickly growing thanks to the rapid evolution of marine robotics & sensing technologies and the increasing demand of services - both in numbers & variety. The operation of these vehicles relies on a network of research infrastructures (RIs) distributed all around Europe.

GROOM II project successfully set up the bases of designing the GROOM RI, a European Marine Research Infrastructure (MRI) that will transform individual fragmented research infrastructures into a sustained organisation offering a first-class service to the global population. Within the framework of the 3-year project the overall organisation of an infrastructure dedicated to ocean research and innovation and maritime services supporting Blue Growth, has been defined.

It is widely accepted that in the European MRI landscape, RIs either exploit a single observation platform (fixed platforms for EMSO ERIC, profiling floats for EURO-ARGO ERIC, research vessels for Eurofleets+ and EuroGO-SHIP, autonomous vehicles for GROOM RI), or are thematic in focus, relying on a multi-platform approach (ICOS-OTC for assessing CO2 emissions and JERICO RI for 'holistic appraisal of coastal marine system changes'). In addition, the MINKE MRI project is transverse, building an innovative 'ocean data quality' framework based on accuracy and completeness to support the observation of EOVs.

Ocean knowledge and data are essential elements recognized by the European Commission to promote a new approach for a sustainable Blue Economy. Better knowledge of the ocean and its ecosystems, together with free access to data, will enable them to properly support industry, public authorities and civil society in their decisions. Towards this endeavour, the role of marine RIs such as GROOM RI is pivotal both for the knowledge triangle as well as for an efficient ocean observation value chain. From an analysis of the role of marine RIs in Europe (Danobeitia et. al. (2023), they have a significant role in strengthening safety and protection at sea and mitigate the multiple risks related to severe changes due to climate change, sea-level rise, geo-hazards, anthropogenic pollution, and loss of biodiversity among other stressors for the benefit of future generations. They provide high-quality, sensitive environmental sustained services that can equally contribute to support thematic actions of regional and/or global impact (e.g., global changes, loss of biodiversity, environmental risks) for a wide variety of operational, public, societal and industrial stakeholders. Finally, they are an essential element of the earth's observing system, complementary to satellites and models and fundamental in the development of the Digital Twins of the Oceans (DTO).

At the same time with the above characteristics and values, marine RIs face significant challenges hampering them from reaching full potential both at individual level but also as an integrated system. Thus, acknowledging the need for collaboration in terms of harmonising practices, methods etc of field operations and data, the ENVRI community was established as mentioned in Section 7 above with targeted activities such as ENVRI-FAIR project tackling specific issues (data in this specific case). Parallel to this, there have been/are significant efforts outside the ENVRI framework to develop collaborations, to bridge gaps, eliminate overlaps and increase efficiency through synergies. Successful examples of collaboration of different RIs in ocean observing campaigns as well as in data handling and sharing (e.g. shared data management methodologies, best practices, etc.) can be found in AtlantOS and EuroSea H2020 projects. However, substantial developments remain necessary to be more efficient and cost-effective and need to be based on a structured approach toward a today's missing formal and optimised organisation. As emphasised by the EMSO ERIC strategy and its third major objective 'actions towards the establishment of cooperation frameworks and creation of tools to facilitate the communication between MRIs', the collaborations established in the framework of European projects are the groundwork for taking the next steps today.

These collaborations have made it possible to evaluate how the lack of coordination, information sharing and integration obstructs the overall potential of the MRIs:

● major ocean observation gaps remain, whereas duplication of efforts and costs limit the ability to reach a critical mass and efficiently allocate resources to sea operators for data collection;

● there is little focus on standardisation, integration and interoperability across the observing platforms and sensors to facilitate operations at sea and data collection, which also limits the ability to respond to future challenge and new technologies;

● the fragmentation between coastal MRIs and those in the open ocean result in a gap in the transition zones;

● achieving the targeted reduction of the carbon emissions of operations at sea needs massive efforts to eliminate overlaps and optimise global planning of operations, in addition to the progressive transition to greener maritime technologies.

These issues are also addressed in Activity 3 in the 'EOOS Strategy 2023-2027 and Roadmap for Implementation' that emphasises the need to improve the visibility of ocean observing activities. To enable the planning and implementation of multi-platform, multi-network, and multi-thematic observation programmes, and to avoid duplication of limited effort, it is essential to understand the timing, location and focus of ocean observing activities among operators.

The challenge today is to build and establish the appropriate synergistic mechanisms which will allow these MRIs to:

1. better support research with an improved flux of ocean data;

2. function as truly integrated components of EOOS and, ultimately, GOOS;

3. better support the Copernicus Marine Service.

To this end, the 4-year project, AMRIT, has been proposed and successfully granted by the EU (HORIZON-INFRA-2023-DEV-01) with the ambition to meet this challenge with the overall objective of developing maximum synergies between MRIs. he 3 ERICs (EMSO ERIC, EURO-ARGO ERIC, and ICOS ERIC) and pan-European MRIs, Eurofleets+, EuroGO-SHIP, GROOM RI, JERICO RI, and MINKE,will work towards a seamless integration of MRI operations in order to tap their full potential to observe and monitor the ocean and marine ecosystems, from coasts to the open ocean, from surface to the seabed, and from physical to biogeochemical and ice variables. By better exploiting the complementarity of the various platforms to observe EOVs and preventing unnecessary duplication of costs and efforts, the project will contribute to increased sustainability, efficiency, and performance of MRIs with enhanced operational and financial optimization. This in turn will contribute to enhanced observing capacity needed to provide the data and information to support ocean/marine monitoring and implementation of EU policies, directives, and objectives. However, for all objectives and aims behind AMRIT and any other similar project, it is fundamentally important that a well designed and structured RI ecosystem is in place. An ecosystem whose components are sustainable with clear strategies defined principally by user requirements and with efficient connecting mechanisms with stakeholders. Although today the MRI landscape is characterised to some extent of complexity with some overlaps in terms of mission and vision, there are also gaps that need to be filled which is what GROOM RI is aiming at. Putting users at the centre, fulfilling their requirements, becomes possible only if the EU RI system

is integrated and harmonised but mostly is complete and GROOM RI is contributing to this by filling a well defined gap.

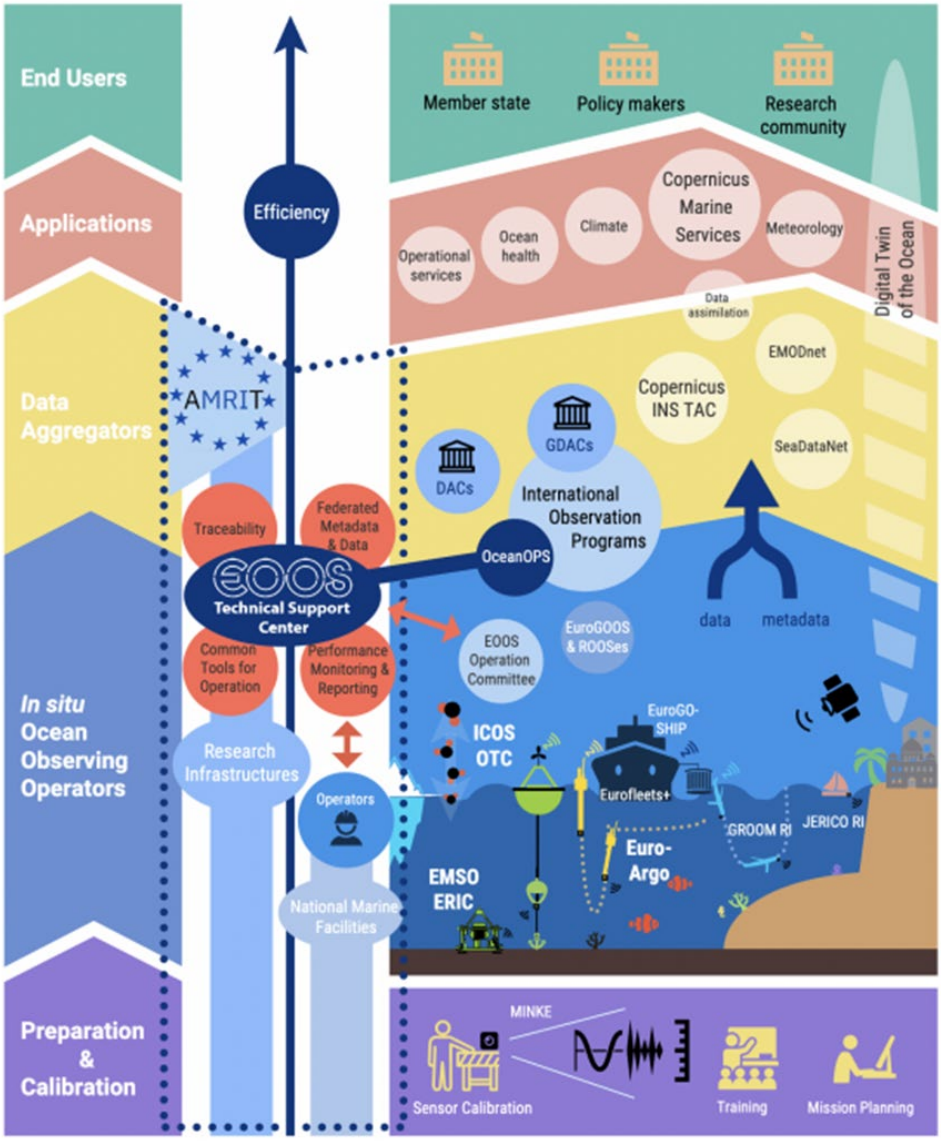

Figure 22 - Goal of the AMRIT project and its positioning in the ocean observing value chain

This sketch is derived from Figure 1 of 'Copernicus Marine Service requirements for the evolution of the Copernicus inSitu Component' Version 2, March 2021 report. It schematises the overall concept of AMRIT and how AMRIT will integrate tools and services for an optimised ocean observing value chain.

9 Conclusions

With both the growing needs of ocean data and knowledge, and the urge to decrease carbon emissions, MAS represent the perfect tool to upscale while also initiating the decarbonisation of Ocean Observation. NZOC report states that *"Decarbonisation may act as a short-term accelerator of increased use of autonomy in marine research, but should not be seen as a long-term driver, the rationale being that all shipping will necessarily move to lower carbon fuels over time. […]The strongest scientific driver behind upscaling of marine autonomy is, however, linked to carbon: the basis of life, the cornerstone of the global economy and at the heart of the climate crisis. For these reasons it is increasingly important to better understand the oceans, however the global ocean is and will remain severely under sampled unless we change the way we interact with it. Autonomy offers a realistic route to alter and enhance our approach."* (Upscaling Autonomy Working Group). There is now a crucial need to integrate MAS activities in the landscape of European ocean observing systems and align such activities with those of the present MRIs.

As stated in the introduction, the landscape of marine observations in Europe is characterised as particularly complex with many different actors with different capacities, operating under different frameworks and responding to a wide range of needs. Although during the last 20 years there have been significant efforts towards organisation and structuration of the system at various levels, the present situation is far from ideal with many challenges creating a pressing need for action. Towards this need, although the EuroGOOS ROOSs have proved a very efficient mechanism for integration at regional level, in terms of coordination the impact is limited due to a number of reasons such as the absence of a legal framework, the voluntary participation, the in-kind contribution etc. This particular gap is filled by the European RIs which provide the legal framework under which individual systems are organised in a common integrated and coordinated network.

RIs provide advanced scientific equipment or instrument suites; resources and services to research communities to conduct high-level research, foster innovation in their fields, and enable cutting-edge research. RIs are long-term structures with a clear governance, and to some extent with secure funding from the respective member states. The infrastructures promote knowledge, dissemination and education for a diversity of stakeholders and services, both in the public and industrial sectors and can be single-site, distributed, or virtual. RIs are at the core of knowledge, and thus play a vital role in the advancement of knowledge and technology, industry and their exploitation.

Despite the positive characteristics, RIs and in particular those operating under the ERIC status, are not free of problems as participation in most cases is limited, there are overlaps in activities, funding is static and does not follow growth opportunities, while each RI seems to operate in silos with small connection with its ecosystem. Recently, the European Commission launched calls to promote the integration of the RIs in local, regional and global innovation systems, to improve their scientific competitiveness and technological synergy with industries through co-design and co-development. Projects such as AMRIT with the aim to address coordination gaps and consolidate the synergies & integration of services between the marine ERICs (EuroArgo, EMSO, ICOS), the projects (EF+, EuroGO-SHIP, GROOM RI, JERICO RI, MINKE) and their national operators, are expected to have a significant impact. It is important to note that the development of the foreseen EOOS Technical Support Center in this project - a federation of existing and new services to support planning, execution and reporting of operations at sea with a focus on the metadata of physical and biogeochemical EOVs, from the sensors to the data delivery to end users, and

feedback to the operators - is a long-term development which goes well beyond the project life-time. Focused on metadata only, it will certainly not be able to support all the various activities of the individual ERICs and projects.

Taking a closer look at the marine RI landscape in Europe, a prominent characteristic is the wide variability in terms of the drivers around which these are established. Thus, there are platform specific RIs such as GROOM, EMSO, Argo and Research Vessels, as well as thematic ones focusing on a specific process such as ICOS or on a part of the marine ecosystem as with JERICO which looks at the coastal ocean. Platform specific RIs are connected with the corresponding GOOS OCG Networks[4] offering harmonisation and coordination beyond EU borders.

At the time when MAS are considered by other MRIs such as EMSO (study the oceanic variability around the sites), ICOS (to extend observational coverage), EuroArgo and JERICO RI (fill the observational gap between the open sea and the coast), as possible assets for their activities, we really need to converge on a solution that will avoid the duplication of MAS components in each RI. This would be overly disastrous. The above-mentioned needs definitely force us to optimize the use of MAS. We advocate here that it must be done through better coordination and top-down approaches because in-kind/projects contributions and bottom-up approaches have clearly reached their limits today. The necessary efforts to integrate MAS activities in Europe are such that funding to support the national efforts must be secured and certainly extended, while the workload is distributed among the MAS actors in a convenient framework to avoid duplication. This is particularly true for supporting the activities involving the emerging surface vehicles because of their capacities and diversity. These activities are expanding as technology provides new capabilities and opportunities.

Adequate ocean observation underpins Europe's ambitions for sustainable development, protection of the marine environment, and preservation of its resources and services. Europe needs strong and connected ocean observing capacities. The European Ocean Observing System (EOOS) aim is to combine, coordinate and develop ocean observing capabilities at all levels across Europe as the backbone for our understanding of ocean processes. Effective coordination and collaboration are key to EOOS as it aims to meet the growing needs of users. EOOS will be a central focal point for strategy, stakeholder engagement and innovation across Europe's diverse ocean observation and monitoring communities.

To achieve a sustained EOOS that is able to meet users' needs, the EOOS Framework has been developed. The EOOS Framework takes a broad and inclusive perspective of the observations and stakeholders within its scope. It strengthens coordination and dialogue between all those planning, resourcing, managing, implementing, and aggregating ocean observations at European, regional, national and sub- national levels.

To achieve an optimised and sustained EOOS a consolidated European ocean observing community is crucial. The EOOS Framework facilitates joint strategic development, stakeholder engagement, innovation and future planning by the European ocean observing community. It connects previously fragmented European ocean observing components and removes barriers to improve information sharing, facilitate dialogue and advance collaboration. The improved integration and coordination at national, regional and pan-European scales enabled by the EOOS Framework strengthens ocean observing in Europe and

[4] https://goosocean.org/who-we-are/observations-coordination-group/global-ocean-observing-networks/

enhances Europe's role in ocean observing globally.

RIs are key components of the EOOS framework considering that they are mechanisms of integration and coordination of individual observing systems. In that respect it is important that there are no gaps in the marine RIs landscape, fulfilling all possible user requirements.

The GROOM RI is coming to fill this gap left in the marine RIs landscape, in regards to marine autonomous systems, harmonising and advancing the European effort towards an RIs' ecosystem that fulfils user requirements, promoting excellent science and state of the art research. The GROOM RI will strengthen the position of users (and their diverse and targeting applications) and their relation with manufacturers in order to steer developments and meet EOOS challenges. It will design and support marine sustained observations in coordination with other RIs towards EOOS vision, mission and objectives, while also taking the role of a European "OCG network" for MAS, supporting other MRIs to operate gliders and MAS.

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