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

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Deliverable abstract & Executive Summary

This report analyses the interfacing of a future GROOM RI with European (EOOS) and global coordination programs for Ocean Observing under the umbrella of the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS). The analysis seeks to identify how a GROOM RI can address the needs for data and information flow articulated under GOOS/GCOS to ensure (1) global visibility of GROOM RI members MAS activities and (2) coordination of GROOM RI members MAS activities in global observing initiatives. The analysis sets its focus on GOOS but since GOOS has been established the marine/ocean entry point to WMO, and thus to GCOS, we consider GOOS and GCOS to be equivalent in this context and also interchangeable for this purpose. MAS activities are introduced to GOOS via OceanGliders, a self-organised global coordination group composed of volunteering experts without nations mandate as for many of the GOOS observational networks. Being one of the GOOS Regional Alliance (GOOS RA), EuroGOOS is the accepted organisation to exchange and coordinate regional and European matters with the GOOS.

The position of the GROOM RI as an EU contribution of nations to OceanGliders, the GOOS/GCOS and EOOS will to a large degree depend on how GROOM RI defines its relation to EuroGOOS, in particular to the EuroGOOS Glider Task Team and the EuroGOOS Data Working Group. By its self-description, and accepted by GOOS, the EuroGOOS is the European contribution to GOOS and therefore GCOS. Thus, the engagement with EuroGOOS will define the entry point of GROOM RI into GOOS (GCOS) from an organisational point of view. Note, this does not exclude the possibility that individuals who are part of the future GROOM RI via their institutes or nations (depending on the final structure) may also be active as experts in the various GOOS groups and thus contribute to GOOS/GCOS on an individual basis. Such different roles and entry points should be clearly separated as otherwise they can easily lead to misunderstandings.

One open point for the discussion with EuroGOOS is to what degree it can represent member states. What can be said is that EuroGOOS has no nation mandated representatives but only institutions as members and how comprehensive they represent the respective European nations is unclear. In case of the GROOM RI being an ERIC the nation's commitment and thus mandated representations can be assumed. However, it will be in particular the extent to which the future GROOM RI truly and comprehensively represents national activities in relation to MAS activities, an important characteristic that will determine how efficiently the GROOM RI can fulfil the position of a nation's representation.

To ensure interoperability of data and metadata a dialogue with the respective data groups in GOOS, EMODnet, and EOOS is required. Here again the relation with EuroGOOS is key as other RI have shown, such as EuroArgo or EMSO-ERIC. The data system that is required for the GROOM RI is complex because it is based on the nations and its individual PIs and who carry out and supervise mission-based observations. Attention needs to be paid to the fact that EuroArgo (as Argo) stands for “Array for Real-time Geostrophic Oceanography” and collects data only in real-time. Thus, only to a very limited degree data management for a future GROOM RI can be copied from Argo. In fact, the GROOM RI data system is more to compare with EMSO-ERIC that as well is based on nations/PIs missions (deployments) activities. Consequently, a dialogue with EMSO-ERIC (and comparable activities) on the management is recommended.

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List of Abbreviations

AUV	Autonomous Underwater Vehicle
BP	Best Practices
CMS	Copernicus Marine Services
EMBRC	European Marine Biological Resource Centre
EMODnet	European Marine Observation and Data Network
EMSO	European Multidisciplinary Seafloor and water column Observatory
EOOS	European Ocean Observing System
EO(C)V	Essential Ocean (Climate) Variable
EuroArgo	European Research Infrastructure ERIC for Argo float operations

EuroGOOS	European Global Ocean Observing System
EUROFLEETS	Alliance of European marine research infrastructure
EuroSea	Improving & integrating the European Ocean Observing and Forecasting System
FAIR data	Data which meet principles of findability, accessibility, interoperability, and reusability
FOO	Framework for Ocean Observing
GOOS	Global Ocean Observing System
GCOS	Global Climate Observing System
GROOM RI	GROOM Research Infrastructure
HELCOM	Helsinki Convention on the Protection of the Marine Environment of the Baltic Sea Area
IMOS	Australia's Integrated Marine Observing System
IOC	Intergovernmental Oceanographic Commission
IODE	International Oceanographic Data and Information Exchange programme of IOC
ISC	International Science Council
MAS	Marine Autonomous Systems
MMOP	Marine Meteorology and Oceanography Programme of WMO
MRI	Marine Research Infrastructure
MSFD	EU Marine Strategy Framework Directive
OceanOPS	Metadaten repository and related services for OCG and in turn the GOOS
OSPAR	Oslo and Paris Conventions
PI	Principle Investigator
RA	Regional Alliance
R&D	Research and Development
RSC	Regional Sea Conventions
SOP	Standard Operating Procedures
UG2	Underwater Glider User Group (US expert network on underwater glider)
UNEP	United Nations Environment Programme
TT	Task team
TPOS2020	Tropical Pacific Observing System 2020 Project
WMO	World Meteorological Organization
WP	Work package

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1. Introduction

Measurements acquired with Underwater Glider technology have been identified as an important contribution to global ocean observing because of their unique sampling in space, time and parameter space (Liblik et al. 2016, Testor et al. 2010, 2019). Observational campaigns that make use of glider technology (standing synonym here for marine autonomous systems - MAS) are, and always will be, executed and financed by nations. However, various benefits are generated for nations to integrate MAS observations and operations into international and global programs and initiatives (Testor et al. 2019). Key to an efficient integration is defining how information is exchanged from an individual researcher conducting glider observations to overarching programs and initiatives. Individual researchers cannot represent their interests directly in international initiatives; instead, focus groups must be formed in which interests and needs are consolidated and then communicated to others by group representatives. One such focus group is GROOM RI, and as part of the GROOM II project the themes of a future GROOM RI seek to consolidate and will be synthesised in the Deliverable 1.6 (Final Conceptual Design Report on the GROOM RI.). In brief, the needs include coordination of the participating members of the GROOM RI with European and global groups, (ii) opportunities for infrastructure sharing, (iii) tailored data management solutions, (iv) support and recommended data quality control (incl. Best Practices and SOPs), and (v) training and knowledge transfer activities.

This report seeks to provide recommendations for approaches of a GROOM RI for setting in place structural elements that allow integration of the GROOM RI partners in European and international initiatives, more specifically Global Climate Observing System (GCOS) and the Global Ocean Observing System (GOOS), the GOOS Regional Alliance (GOOS-RA) EuroGOOS and a recent European initiative, that is the European Ocean Observing System (EOOS). The recommendations include aspects of the GROOM RI governance, provision of information and (meta)data flow structures in order to derive recommendations for elements and linkages of a GROOM RI to deliver and receive information with the global systems in order to optimise operations in this context.

Given the current landscape, the most relevant groups for a GROOM RI are the connection with the EuroGOOS Glider Task Team (GTT) and the EuroGOOS Data Management, Exchange, and Quality Working Group (DATAMEQ WG). Furthermore, it is of interest to introduce and analyse how a GROOM RI best links to the OceanGliders that is the global coordination body for underwater glider activities and is an accepted link to GOOS/GCOS via the Observation Coordination Group (OCG) of which it is a member.

The analysis presented here is structured by first providing a brief introduction to the concept of "sustainability" in marine and ocean observing. Next, the different aforementioned groups are introduced, with an emphasis on expectation and established structures to ensure engagement, and data and information exchange. The EOOS is only very briefly introduced as this has been done in detail via the GROOM II D4.2 "*Whitepaper on the GROOM RI position in EOOS*". Appreciating that the GROOM RI operations and services have their base in nations financing of activities, it is ultimately the access to FAIR data, and metadata that will determine the success of the GROOM RI in contributing to the GOOS/GCOS.

1.1 WHAT IS MEANT BY SUSTAINED OBSERVING?

Purposeful observational efforts in the ocean are executed to address specific observing requirements - whether for science or monitoring. To provide the information that address requirements a chain of operations must be executed that ultimately lead to the release of information tailored to the specifics of any requirements. The chain of operations can be "translated" into an observing design which defines the minimal criteria for time, space, and parameter sampling to capture the information (data) needed to address the requirement. The one key aspect that makes observing "sustained" is identifying the users that need data and products in a sustained way (Nowlin et al. 2001, Adams et al. 2000). For the Global Ocean Observing System (GOOS) the characteristics for sustained observations have been defined as follows (Nowlin et al. 2001):

- **Long term:** Once begun, measurements should continue into the foreseeable future. Continuity is sought in the observed quantity, but not necessarily in the measurement method
- **Systematic and relevant to the observing system:** Measurements should be made in a rational fashion, with spatial and temporal sampling, precision, accuracy, and care in calibration tuned to address the products needed by multiple users
- **Sustained:** implies regular review of the measurement techniques to keep up with development of new technologies and thus ensure efficiency related to science, monitoring, and costs. Trade-offs must be subjected to scientific evaluation on a continuing basis to take advantage of new knowledge and technology. Consequences might be that different observational approaches or platforms are getting more efficient via technological progress

In this report we use the above definitions in summary as being observations that contribute to sustained observing.

1.2 COLLECTING DATA THAT ADDRESS SUSTAINED REQUIREMENTS

Key to the collecting of observational data for addressing sustained observing requirements is 1) timely data availability, and 2) knowledge quality of that data. Regarding 1): Timely in this context depends on the application type that is targeted with the data (e.g. daily ocean forecasts require data in more or less real-time while seasonal forecasts or long term climate indicators may consider data collected months or years ago) and may mean hours to years or even decades. Consequently individual data points can serve multiple applications. Regarding 2): A need to specify data quality in the form of a measure of inaccuracy/uncertainty again will ensure that individual data can be used for various applications e.g. a temperature recording intended to be used for deriving a climate indicator may require a higher accuracy than a temperature record to be used for characterising a fish habitat (there may of course be exceptions). How the inaccuracy/uncertainty is estimated is a topic by itself that is linked to Standard Operating Procedures (SOPs) and Best Practices and the GROOM RI has developed and recommends for this reason a Best Practices strategy in Deliverable 6.3 "*Best Practices for Data Management, Operations, Maintenance and Fault Reporting*". Observational data that has not been individually QCd still can undergo secondary quality control procedures for example via a validation against data with known quality, a procedure that for example is applied to Argo float data because the observational devices are not recovered to allow laboratory calibration of sensors in regular intervals. The combination of observation data and measures for uncertainty are also referred to as the Essential Ocean (Climate) Variable (EOV/ECV), more details below.

Sustained sometimes is confused with commitment to long term use of a certain observation technique but the definition used here explicitly refers to the permanent observation of relevant variables and in respect to data products open to all technology and approaches that can provide sufficient sampling (spatial, temporal, parameter). All freely available data, independent of the reason why it was recorded, can potentially contribute to sustained observing. This also, and explicitly, includes time-limited observational efforts e.g. process studies, short term science projects.

At the same time, however, there is the dilemma that sufficient coverage with measurement data (regardless of the measurement technology) must be guaranteed for services and the question is how can this be ensured? Hydrographic services are commissioned to carry out routine measurements in many countries. This is first of all the interest of the nations and within territorial waters. These are augmented by European and multinational needs that partly have found a base via treaties and agreements (e.g. MSFD) and pose commitments of countries to also observe outside their EEZ, share data and information. International obligations are for example formulated in the Regional Seas Programme of the United Nations Environment Programme (UNEP). This program aims to address the degradation of the Ocean and coastal areas via action plans developed under the Regional Sea Conventions (RSC), which bring together Member States and neighbouring countries that share marine waters (e.g. the Barcelona, Bucharest, HELCOM and OSPAR conventions). The aims of these action plans also align with wider initiatives such as the Green Deal, the Ocean Decade, and the Mission. Multinational systems aim for a high degree of interoperability of data and thus agreement on Best Practices and Standards must be achieved.

A particular case of observing is long data time series that can be used to derive climate indicators. Climate indicators rely on some sort of homogenised data available over extended periods of time, however, presumably all climate time series have been initiated via short term/process studies driven solely by scientific interest. Over time such studies developed into seasonal, interannual, and multiannual time series and eventually covered even multidecadal time scales. This transition implies that the observational efforts proved of use to derive data products that address sustained societal requirements (e.g. observational evidence of climate change considered in the IPCC reports). However, because originating from a project based observation the transition to recognized and respectively funded sustained operation does not always take place (e.g. see Weart 2008, chapter: *Money for Keeling: Monitoring CO_2 Levels*).

Regardless of whether the observations are collected for monitoring or scientific purposes, making the data available is crucial for their use as a contribution to sustainable requirements. Here two attributes matter most to characterise the data: (1) Follow FAIR (Findable, Accessible, Interoperable, Reusable; Wilkinson et al. 2016) principles, and (2) augmenting the observations with reproducible uncertainty/heterogeneity estimates (e.g. as defined for use of observational parameter data to derive “Essential Ocean Variable”). Both attributes together allow a potential data use to decide whether or not data is suitable for use in a specific application. This way data serves various observing requirements such as naval applications, marine services (i.e., analyses and forecasts of waves, surface currents, and marine meteorological conditions), and surface observations for general weather prediction, managing the impact of human activities (other than climate e.g. pollution), mitigation of coastal hazards, and ensuring public health (e.g. tsunami early warning, MSFD, OSPAR).

- **MAS observations have been demonstrated a key contribution in multiplatform, cross-disciplinary ocean observing given the unique time/space/parameter sampling for the benefit of many marine applications and thus for sustained observing**

2. Coordination of Global and European Ocean observing

2.1 The ocean observing value chain and the Framework for Ocean Observing (FOO)

Linking requirements for ocean observing with the observing design, the collection and quality control of observational data, the data integration into data products, and finally the dissemination of products to users has been termed Ocean Observing Value Chain (Fig. 1). Probably Fleming (1997) was the first to propose this approach as a design principle for the emerging EuroGOOS at that time. The concept is making use of the value chain that stems from economics (Porter 1985) and illustrates that even in the early days of pan-European (and later global) coordination the link between ocean observing and economy was identified as mandatory. The ocean observing value chain principle was also used by Lindstroem et al. (2012) as a framework for a strategy for the global ocean observing efforts and termed Framework for Ocean Observing (FOO). This activity occurred in the aftermath of the OceanObs09 conference in 2009 in Venice, Italy. The FOO also introduced the concept of “Essential Ocean Variables” (EOVs) being derivatives from observational data and data uncertainties, a concept that was adopted from the World Meteorological Organization (WMO) GCOS Essential Climate Variables (ECV) concept. One important effect of introducing the EOVs was a “unification” of the highly fragmented global community of ocean observers in an operational aspect, and that was conducting observations and agreement on uncertainty estimates in order to provide EOVs to the global systems. Also important was that the FOO considered in its design equally coastal and open ocean observing and thus is applicable to regional, (multi)-national (e.g. EuroGOOS) or global systems (e.g. GOOS).

The FOO is structured in three pillars: Requirements Processes, Coordination of Observational Elements, and Data Management & Information Products (Lindstroem et al. 2012). Assessment of feasibility, capacity, and impact for each of the three pillars was suggested via “readiness levels”, namely concept, pilot, and maturity. A number of examples for where ocean observation value chains are routinely being executed can be found: a prime example is ecosystem-based fisheries management under the auspices and coordination of the International Council for the Exploration of the Seas (ICES), an *intergovernmental* marine science organisation, “meeting societal needs for impartial evidence on the state and sustainable use of our seas and oceans” (ICES website). In fisheries the linkages between economic value, the need for international collaboration and agreements, and fit-for-purpose observing for “science for advice” is as mandatory as it is evident in the operations. A variety of observations and data integration needs are generated through the Common Fisheries Policy (CFP, 2013) of the European Union (EU) that demands for example an end to overfishing. Another example for sustained needs, and thus sustained observations, is motivated by the Marine Strategy Framework Directive (MSFD, 2008; MSFD, 2017a; MSFD, 2017b) that calls for an ensemble of criteria requiring: (1) the preservation of biological diversity with species abundance or demographic characteristics not altered by anthropogenic pressures, (2) a healthy size and age structure of exploited stocks, and (3) marine food webs with species composition, diversity, balance and productivity not affected by stress factors of anthropogenic origin. See also Deliverable D.4.3 "Report on the GROOM RI in contributing to statutory monitoring frameworks and maritime/naval information" for further details. One recent global initiative that is based on a value chain approach is the "Alliance for Hydromet Development" (https://alliancehydromet.org/) that was launched at the COP25 and pays attention in a value-chain content to high-quality weather, climate, hydrological, and related environmental services ('hydromet' services).

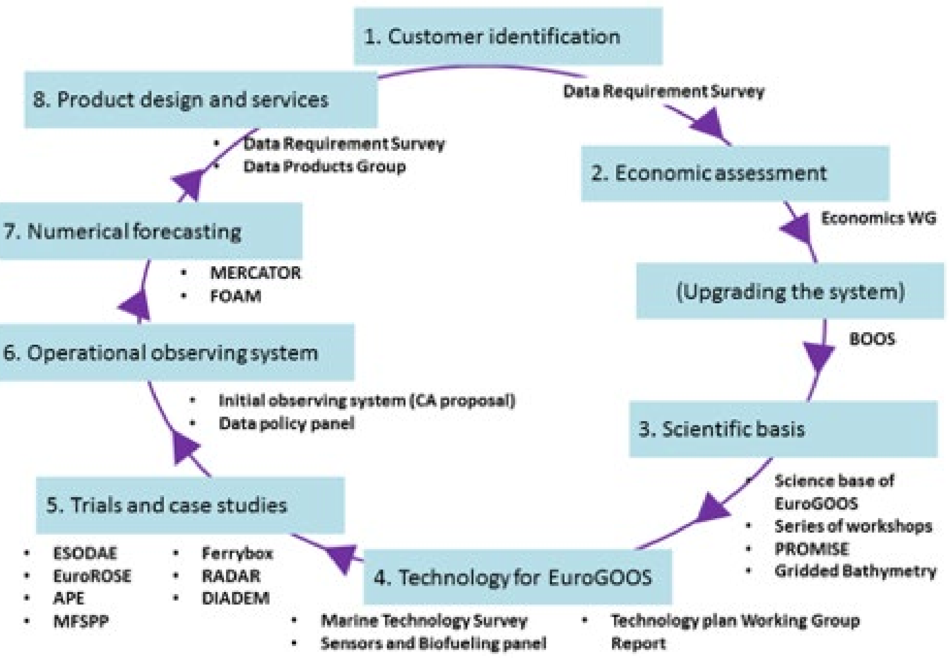

Figure 1 - The ocean observing value chain as proposed for the European Operational Oceanography System EuroGOOS (after Flemming 2001)

2.2 General description of GOOS/GCOS

Global Ocean Observing System (GOOS) seeks to coordinate observations around the global ocean for three application areas initially defined as climate, operational services, and marine ecosystem health (GOOS, 2018a) and later changed to climate, forecast & warnings, and marine ecosystem health. GOOS makes use of a three-tiered governance model (Moltmann et al. 2019): A multinational steering committee was established to provide oversight (tier one). Scientific expert panels were formed to guide system requirements. Pre-existing structures were evolved to create discipline-based panels of volunteers, providing scientific oversight on physics, biogeochemistry, and biology/ecosystems (tier two). Of specific relevance for the integration of nations MAS operations into GOOS is that GOOS is not established with nations mandated membership, such as it is the case for WMO or for example IODE of IOC. Thus, in order to fully represent the MAS operations of nations in GOOS, it is necessary for nations to fully coordinate their MAS activities at national level, including a contact person who then has a voice in global coordination groups such as OceanGliders. Efforts were also made to connect GOOS with observation coordination groups involved in implementation at global and regional scales (tier three): Marine Meteorology and Oceanography Programme (MMOP) of WMO, the Observations Coordination Group (OCG), and the GOOS Regional Alliance Council. Finite lifetime observing system development projects (called GOOS pilot projects) are used as a way of increasing the readiness of the observing system (e.g. TPOS2020). The GOOS Project Office has responsibility for facilitating collaboration between the three tiers. GOOS is co-sponsored by the Intergovernmental Oceanographic Commission (IOC), the World Meteorological Organization (WMO), the United Nations Environment Programme (UNEP) and the International Science Council (ISC).

Global Climate Observing System (GCOS) is a long-term, user-driven operational system capable of providing the comprehensive observations required for: monitoring the climate system, detecting and attributing climate change, assessing impacts of, and supporting adaptation to, climate variability and change, application to national economic development, and research to improve understanding, modelling and prediction of the climate system. GCOS addresses the “total climate system” and that includes physical, chemical and biological properties, and operates across all spheres - atmospheric, oceanic, terrestrial, hydrologic, and cryospheric components. As for GOOS; GCOS is co-sponsored by IOC, WMO, UNEP, and ISC. The ocean part of GCOS is brought in via GOOS and with the MMOP a central instrument for exchange and dialogue.

Tracking of the status of the observational assets that operate under the recognition of GOOS is based on metadata related to the observational efforts and is achieved via OceanOPS. OceanOPS has, according to the GOOS website, five goals: 1) Monitoring to improve the global ocean observing system performance. 2) Leading metadata standardization and integration across the global ocean observing networks. 3) Supporting and enhancing the operations of the GOOS; 4) Enabling new data streams and networks; 5) Shaping the OceanOPS infrastructure for the future.

- **For visibility and global management of nations observations as a contribution to GOOS the seamless integration of nations MAS operations with OceanOPS is mandatory**

2.3 Connecting nations' glider operations to the global coordination via OceanGliders

OceanGliders is a global coordination initiative for underwater gliders. It's major governance element is the "glider science/steering team" (GST) that defines the operations as outlined in OceanGldiers Terms of Reference (ToR)[1]. The OceanGliders ToR expects GST members to be "scientists and technical experts from national or regional projects contributing to the international Glider Program". It goes on with "normally this will be the scientific leader of a national or regional project but more members will be allowed in the case of large contributors". This suggests that inclusion/representation of regional groups covering many (ideally all) nations MAS activities would be ideal. Examples that, at least from their structure, fulfill this role are UG2 (US), IMOS (Australia), or the EuroGOOS Glider Task Team is preferred. OceanGliders has established Task Teams to jointly work on the improvement of glider operations to better address science topics that link to societal needs (sustained observing) under the observing themes: boundary currents, storms, water mass transformation, and ocean health and ecosystems. Two more task teams have been established that address Best Practices and Data management, and provide global coordination activities to arrive at a global framework for harmonisation and interoperability of data. A call for proposals for new task teams was launched in 2023. The OceanGliders Data Management Task Team organises and reports on real time and delayed mode contributions of gliders data at the global level and facilitates data access to the general glider and broader communities. OceanGliders is recognized by GOOS via its OCG as an "emerging OCG network" meaning not all OCG attributes for a global coordination network[2] are fully achieved.

- **The entry point for MAS operations into GOOS/GCOS is via OceanGliders which is an expert group and thus not composed by nations representatives**

2.4 Connecting GROOM RI to EuroGOOS and EOOS

From its 1st strategic document (Woods et al. 1996) EuroGOOS defined itself as "... the European component of GOOS, and consists of an association of national agencies working together to foster European participation in GOOS, and the development of operational oceanography for the benefit of Europe". In 1996 EuroGOOS had 22 member institutions from 14 European countries. EuroGOOS defined the term "operational oceanography" being "an activity of routinely making, disseminating, and interpreting measurements of the seas and oceans and atmosphere so as to: provide continuous forecasts of the future condition of the sea for as far ahead as possible, provide the most usefully accurate description of the present state of the sea including living resources, assemble climatic long term data set which will provide data for description of past states, and time series showing trends and changes." This definition for operational oceanography enabled EuroGOOS addressing

[1] Version from 01. September 2016; Accessed November 2023 *https://www.oceangliders.org/wp-content/uploads/2018/06/OceanGliders-st_tor.pdf*

[2] https://oceanexpert.org/downloadFile/54733 (accessed Feb. 2024)

comprehensively its major guiding question: *How observing is integrated into a dissemination system?* or in other words - as mentioned above - ocean observing was considered as a "value chain" (Flemming 2001; Figure 1). It is interesting to note that for the global GOOS no definition for "operational oceanography" exists any more, but was, in older documents, addressing themes related to short-term forecast & warnings. However, more recently GOOS defines its operations delivering against three specific application areas: climate, forecast & warnings, and ocean health and "operational oceanography" dropped out.

Operational Oceanography

- An activity of routinely making, disseminating, and interpreting measurements of the seas and oceans and atmosphere so as to: provide **continuous forecasts** of the future condition of the sea for as far ahead as possible, provide the most usefully **accurate description of the present state** of the sea including living resources, assemble climatic long term data set which will provide data for **description of past states**, and time series showing trends and changes."

An important part of the EuroGOOS governance was and remains its members being agencies /institutions. Moreover, in 2013 EuroGOOS became an international non-profit organisation (AISBL) and committed to advancing European-scale operational oceanography (see the above definition for the EuroGOOS operational oceanography). Also EuroGOOS is accepted by GOOS being the GOOS RA and advocating for sustained operations to deliver reliable and timely services to society[3]. GOOS defines its vision for RA that they integrate the national needs into regional systems and deliver the benefits of GOOS's strategy, structure, and programmes at a regional, national and finally global level. Within Europe the EuroGOOS can also be considered a nation's entry point into GOOS - although not as a nation but via membership and activities in EuroGOOS. This integration is facilitated by the EuroGOOS governance structure, namely the secretariat, task teams, working groups, and other governance and operational elements, and its ToR. EuroGOOS recognition and acceptance has substantially increased, and in 2023 it had, according to its website, 46 member institutions from 19 countries. Within EuroGOOS, the currently most relevant groups for the coordination and data aspects with a GROOM RI are likely the EuroGOOS Glider Task Team and the EuroGOOS Data Management, Exchange, and Quality Working Group (DATAMEQ WG).

- **Defining the relation between the EuroGOOS Glider Task Team and a GROOM RI will be central for all planning on how the RI connects to nations on the one side and to the other**

[3] See EuroGOOS Article of Association https://eurogoos.eu/download/eurogoos-deed-of-incorporation-june-2023/?wpdmdl=13685&refresh=65b9375df24101706637149 accessed January 2024

European (incl. EOOS) and international initiatives (incl. GOOS OCG) on the other side. For the future GROOM RI to enable nations representation will depend on the organisation type the RI will choose (e.g. AISBL, ERIC)

The representation of European RIs in GOOS via EuroGOOS TT has been successfully implemented by Euro-Argo ERIC being a member of the EuroGOOS Argo TT. Other RIs, namely EMSO (with EMSO ERIC being a member of the EuroGOOS Fixed Platform TT) have not achieved integration into the GOOS relevant OCG networks (DBCP, OceanSITES).

In the context of the European coordination of ocean observing efforts, the European Ocean Observation System (EOOS) (https://www.eoos-ocean.eu/) is a more recent and additional initiative that fills coordination gaps and in particular creates an umbrella across the observation technologies as it has been extensively discussed in D4.2 "Whitepaper on the GROOM RI position in EOOS". In brief, EOOS' Mission is to coordinate and integrate European communities and organisations operating, supporting and maintaining ocean observing infrastructures and activities, fostering collaboration and innovation. Towards this, the EOOS framework 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. 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. By bringing them together under its framework, EOOS is reducing the existing fragmentation of European in situ ocean observing while by aligning and integrating existing ocean observation initiatives, the EOOS Framework aims to help ensure their quality, usefulness, efficiency and value for money. This includes avoiding duplication and finding synergies or complementarities between activities, leveraging the best possible value from Europe's ocean observation capabilities and resources.

The current EOOS strategy is focusing on three main objectives:

- **Unite** the European ocean observing community through the EOOS Framework, to collaboratively design and work towards a sustained multi- platform, multi-network and multi-thematic EOOS that meets the specific needs of users.
- **Engage** with European providers of services and products derived from ocean observations to improve collaboration across the marine knowledge value chain.
- **Advise** governance, funding and policymaking to implement recommendations towards a sustained EOOS.

It is a community-driven initiative following a joint, inclusive approach developed through a federation of partners. Theoretically these partners could also be nations ocean observation coordination groups. The governance of the EOOS Framework is overseen by a Steering Group, together with three further expert bodies: an Advisory Committee, which brings together a broader stakeholder base, a Resources Forum, which represents European ministries and funding agencies responsible for ocean observing, and an Operations Committee, which represents the diversity of the ocean observing implementers at national, regional and pan-European levels. The role of the latter body, the Operations Committee, is pivotal in this endeavour, as it will support the flow of information on ocean observing activities across national, regional and global scales and identify system requirements to meet user needs for sustainable ocean observing. Furthermore, it contributes to the mapping of infrastructure, technology and human capacity to help identify gaps in ocean observing systems at regional and/or European level while identifying shared priorities through the development of a work plan. Research Infrastructure projects like GROOM RI as well as coordination activities such as the EuroGOOS Task Teams (ie. Glider TT) are among the five Operations Committee member categories. As written in the respective EOOS ToR's *representatives of European Ocean Observing Research Infrastructures (ERICs and Projects) will provide perspective and information on opportunities, encouragement and enhancement of existing collaborations, identification of gaps in observational data, technology for their FAIR-compliance transformation and interested communities and stakeholders*, while *EuroGOOS Task Teams will be able to provide advice as implementers of current and future observing requirements in Europe and help support emerging networks of platforms.*

In order to establish GROOM RI as a representative of national MAS operations in Europe, at least two conditions must be met: 1) the countries must agree to this arrangement at national level, 2) the financing model for the GROOM RI must ensure that the basic tasks can be consistently fulfilled and at the same time the annual costs are as low as possible to make membership attractive and defendable at a individual member level (e.g. institutions). In order to achieve 1), a national strategy for MAS operations is useful. To approach 2) it is mandatory to determine the running costs for the basic tasks of the GROOM RI and then, assuming a scenario where all MAS operating institutions in the nations become members, determine the minimum required annual contribution (based on costs) which can then be used as a starting point to determine the fees.

Although finances are not the main focus of this deliverable but of deliverable D3.2 “Financial sustainability at Regional, National and EU levels” it turns out that finances and costs are to be considered when recommending ways to integrate nations MAS operations into the GOOS/GCOS. In general, one can assume that nations may not be in favour of double pay for coordination services and therefore again the EuroGOOS Glider Task Team is to be mentioned. In the current situation, the institutions already pay annual contributions to EuroGOOS and thus also to the EuroGOOS Glider Task Team (and the EuroGOOS DATAWG), and it should therefore not appear that there is a double payment - which would be the case if only GROOM RI tasks would be already being fulfilled by the EuroGOOS Glider TT. Again, the key activity is to precisely define that sharing of workload between the EuroGOOS glider TT and associated bodies with the EuroGOOS, such as the EuroGOOS DATAWG, and the future GROOM RI.

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3. Connecting nations MAS observations to regional & global initiatives (incl. data)

Ultimately, all underwater glider observations (and MAS observations in general) are executed for addressing nations' observing and strategic requirements. If an observation infrastructure such as GROOM RI can demonstrably reduce the cost of observations, it is likely to be recommended for funding as a member at national level. There are numerous reasons why European co-operation on common observation targets is worthwhile, if not necessary. Given the connectivity of the seas and oceans, nations observing interest can in many cases not be addressed from nations alone and there are many examples for how nations have real monetary benefit to incorporate data and data products from other nations in their operations (e.g advice, alerts, planning). Examples include the propagation of heat waves, the magnitude and variability of the global carbon uptake by the ocean, common fisheries policy, or occurence of hazardous events such as oil spills or other pollution events. In Deliverable D.4.3 "GROOM RI CONTRIBUTION TO STATUTORY MONITORING FRAMEWORKS" for example, applications are presented that concern observations that are executed within the framework of national obligations in connection with European framework agreements/directives (e.g. MSFD). The deliverable D4.3 also nicely exemplifies the cross fertilisation between monitoring activities and science applications which also is an important driver for European RIs.

It has been outlined in other deliverables (D5.1 "*Glider services for public and private needs*") which service activities are envisioned within a GROOM RI and that create added value when compared to a situation where nations perform their operations in a self-responsible mode. Other cross nation cutting topics include training and capacity development (see D2.3 "*GERI scientific and technical training and capacity building*"), developing, refining, and agreeing on common operation procedures (D6.3 "*Best Practices for Operations, Maintenance and Fault Reporting*") and data aspect (quality control, metadata/provenance, data standard and formats, see D6.2 "*Data management roadmap for the GERI*") which in turn aim for true interoperable observational data that also is ready to be elevated to Essential Ocean/Climate Variables (EOV/ECV) by adding reproducible uncertainty[4] estimates[5] or more generally measure of heterogeneity (e.g. many ecosystem variables cannot be served with uncertainties in a statistical sense).

Through the coordination and exchange that is achieved in a GROOM RI one important aspect is data and metadata harmonisation and with a primary focus on delayed mode data. Unlike systems such as Argo, and its European branches EuroArgo as well as the EuroGOOS Argo Task team, the MAS operations are done for retrieving delayed mode data. MAS data sets are structured in individual missions, executed by nations PIs with a focus on their needs. Argo stands for "Array for Real-time Geostrophic Oceanography" and originally was designed as an international collaboration effort to collect temperature and salinity profiles data from the upper ocean to intermediate depths in real-time. Argo today is also collecting more than temperature and salinity as documented in the OneArgo

[4] Uncertainty is defined here as the lack of certainty, a state of limited knowledge where it is impossible to exactly describe the existing state, a future outcome, or more than one possible outcome.

[5] A set of possible states or outcomes where probabilities are assigned to each possible state or outcome – this also includes the application of a probability density function to continuous variables

design (Roemmich et al. 2019, Owens et. al. 2022) but the observational technique that makes use of real-time data submission only remains. This is in stark contrast to MAS observations that do have the focus on delayed mode data and consequently various procedures for sensor and data calibration and validation. Consequently, the data system of a GROOM RI is much more complex and is based on the nations and the individual PIs who are active there and who carry out and supervise the missions.

In deliverable D6.2: "Data management roadmap for the GROOM RI" the various aspects of data flows are being depicted in order to illustrate the complex data ecosystem of MAS operations from individual PIs, via their nations into European data systems such as EMODnet and CMS, but also considering the exchange with for example metadata repositories of the GOOS (namely OceanOPS). Key for a truly interoperable data system is knowledge of the respectively used vocabularies (data, metadata), creating and maintaining tools to allow translation between the nations data storage and archiving solution for integration into a federated network of data systems. D6.2: "Data management roadmap for the GROOM RI" set its focus on the GROOM RI internal organisation to address current and future data management needs for various stakeholders (e.g. GOOS and EOOS as examples for the category "informed" stakeholders in D6.2, while "informed" was termed stakeholders that want to stay up to date and will provide feedback/input when necessary.

4. Conclusion and list of Recommendations

In reference to the major objectives that this deliverable should address we conclude:

1. How can a GROOM RI fulfil the requirements of the OceanGliders program of the GOOS/GCOS?

The entry point for MAS operations in GOOS/GCOS is via OceanGliders. OceanGliders is not composed of mandated representatives of nations but is an expert group, as it is the case for other observation networks under the GOOS OCG umbrella. It can be recognised that EuroGOOS defines itself as the European component of GOOS. Consequently, it can be stated that the EuroGOOS Glider Task Team can be considered as the natural entry point for European nations MAS operations into the GOOS. Individual PIs are of course free to participate as experts in OceanGliders, but without a national or even European mandate. Participation at expert level can also be a future GROOM RI.

2. How can a GROOM RI fulfil the requirements EOOS?

The EOOS envisions ot have representatives of European Ocean Observing Research Infrastructures (ERICs and Projects) as contributors in order to provide perspective and information on opportunities, encouragement and enhancement of existing collaborations, identification of gaps in observational data, technology for their FAIR-compliance transformation and interested communities and stakeholders. Further the EOOS ToRs outline their expectations on EuroGOOS Task Teams that they will be able to provide advice as implementers of current and future observing requirements in Europe and help support emerging networks of platforms. Further details on the GROOM RI response to EOOS requirements are outlined in D4.2 (Whitepaper on the GROOM RI position in EOOS)

3. How can the GROOM RI fulfil the data flow standard of GOOS, the EMODNET project, and EOOS?

The GROOM RI will provide an important contribution to data and metadata harmonisation. To ensure interoperability of data and metadata a dialogue with the respective data groups in GOOS; EMODnet, and EOOS is required. Here again the relation with EuroGOOS is key as other RI have shown, such as EuroArgo or EMSO-ERIC. The data system that is required for the GROOM RI is complex because it is based on the nations and its individual PIs and who carry out and supervise mission-based observations. In that regard the system is more to compare with EMSO-ERIC then it is with EuroArgo. EuroArgo (as Argo) stands for "Array for Real-time Geostrophic Oceanography" and collects data only in real-time.

In summary, the position of the future GROOM RI as an EU contribution of nations to OceanGliders, the GOOS/GCOS and EOOS will to a large degree depend on how GROOM RI defines its relation to EuroGOOS, in particular to the EuroGOOS Glider Task Team and the EuroGOOS data Working Group. By its self-description, and accepted by GOOS, the EuroGOOS is the European contribution to GOOS and thus also GCOS. Thus, the engagement with EuroGOOS will define the entry point of GROOM RI into GOOS (GCOS) from an organisational point of view. This does not exclude the possibility that individuals who are part of GROOM RI via their institutes or nations (depending on the final structure) may also be active as experts in the various GOOS groups and thus contribute to GOOS/GCOS on an individual basis. Such different roles and entry points should be clearly separated as otherwise they can easily lead to misunderstandings.
One open point for the discussion with EuroGOOS is to what degree it can represent member states. What can be said is that EuroGOOS has no nation mandated representatives but only institutions as members and how comprehensive they represent the respective European nations is unclear. In case of the GROOM RI being an ERIC the nation's commitment and thus mandated representations can be assumed. However, it will be in particular the extent to which the future GROOM RI truly and comprehensively represents national activities in relation to MAS activities, an important characteristic that will determine how efficiently the GROOM RI can fulfil the position of a nation's representation.

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