

# AtlantOS

European Strategy for  
All-Atlantic Ocean Observing System



**This report is a European contribution to the implementation of the All-Atlantic Ocean Observing System (AtlantOS). This report presents a forward look at the European capability in the Atlantic ocean observing and proposes goals and actions to be achieved by 2025 and 2030.**

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# Contents

Executive Summary	4
1. European strategy for the All-Atlantic Ocean Observing System (AtlantOS)	6
1.1 Why do we need a European strategy for Atlantic ocean observing?	7
1.2 Structure of this strategy	8
2. Meeting user needs: from requirement setting to product delivery	9
2.1 Recurring process of multi-stakeholder consultation for user requirements and co-design	9
2.2 The 'blue' value chain – products driven by user needs	10
2.3 European policy drivers	12
3. Existing and evolving observing networks and systems	13
3.1 Present capabilities and future targets	13
3.2 Role of observing networks and observing systems in the blue value chain	15
3.3 Advancing the observing system through new technology	17
4. Data flow and information integration	18
4.1 FAIR as guiding principles	19
4.2 Information integration – linking observations and modelling	20
5. Capacity development	22
5.1 Enhancing visibility and raising awareness of capability and participation in ocean observing – supporting training and teaching	22
5.2 Improving and promoting research policies to embed ocean observation at national level	24
6. Governance system	26
6.1 AtlantOS governance	26
6.2 European AtlantOS governance	27
6.3 Ethical considerations	28
7. Outlook – financial sustainability	30
8. Summary	32
9. References	35
Annex 1: List of actions	36
Annex 2: Glossary of acronyms and terms	41

# Executive Summary

This strategy presents a forward look at European capability in Atlantic ocean observing, with goals and concrete actions to achieve these by 2025 and 2030. The strategy is aimed at European and international ocean observation stakeholders both within and beyond the AtlantOS network, in particular those involved in the programming and planning of ocean observing activities but also the wider marine science community. It also aims to inform policy makers of the latest developments in ocean observation coordination and provide input to future planning of research agendas and financing of ocean observation coordination in the Atlantic ocean and beyond. Within this strategy, the European capability and strategy for future efforts is assessed and should be seen as European contribution to the international All-Atlantic Ocean Observing System Strategy.

European countries and the EU have already invested significantly in ocean observing infrastructure and technology. There is increasing recognition of the need for effective coordination and governance in ocean observing systems in the global ocean in general, and the Atlantic in particular. This is set to continue as the political interest in the ocean increases and the societal need for the ocean as a resource increases along with the need for sustainable management.

The High-level strategy (AtlantOS) (de Young *et al.*, 2018) has outlined an ambitious vision and an integrated concept for a forward-looking framework and basin-scale partnership to establish a comprehensive ocean observing system for the Atlantic ocean as a whole that shall be sustainable, multi-disciplinary, efficient, and fit-for-purpose.

Europe is prepared to make a substantial contribution to a successful implementation of AtlantOS to meet requirements for products and services expressed by European user communities of which Copernicus (services and satellite missions), Blue Growth, EU Directives, regional conventions and others are important representatives with whom regular consultation will be established.

It is recognized that European institutions already operate platforms, networks, and systems at various maturity levels. The European contribution to AtlantOS will build on these existing observing activities and go beyond the status quo by increasing the level of activity, securing sustainability and especially establish a cross-disciplinary coordination.

Securing a fit-for-purpose observation system means a constant focus on innovation to take on board observations of new essential variables, increase quality, reduction of cost, minimizing effect on environment, etc. Close cooperation with instrument developers and manufactures is therefore an integral part of the of the European contribution to AtlantOS which additionally will raise the competitiveness of European industry.

AtlantOS and the European contribution to it only makes sense if there is open, easy and fast access to the generated data. Europe will therefore ensure that an open data policy is implemented based on the FAIR principles. Europe has over the past decades invested large resources in building marine data management facilities and open access data portals, which will form the basis for the management and handling of the European component of AtlantOS. These data management systems will be under continuous development to meet the requirements from users regarding availability and quality.

The European contributions to AtlantOS will follow internationally agreed standards and best practices, education and training of involved personnel will therefore be a continuously ongoing process fully integrated into the governance structure.

Europe's contribution to AtlantOS will be composed of input from numerous organisations from several European countries. An effective European component of AtlantOS will therefore require a strong and well-organised governance structure that on the one-hand can secure coordination of a multinational, multi-institutional and multi-disciplinary effort and on the other hand can contribute substantially

to the overall AtlantOS governance. The governance of Europe’s contribution to AtlantOS will be a special activity of the European Ocean Observing System (EOOS) and it is recommended that the EOOS office should include a separate group to handle the daily coordination and management tasks related to the European AtlantOS component. EOOS will additionally be a mechanism for Europe to play a leading role

in the AtlantOS governance structure and to promote European science and innovation in ocean observation at both European and international levels.

Putting the needs of users at its centre, EOOS will promote European leadership and innovation delivering crucial data to drive environmental policy, sustainable blue economy and serve wider society.

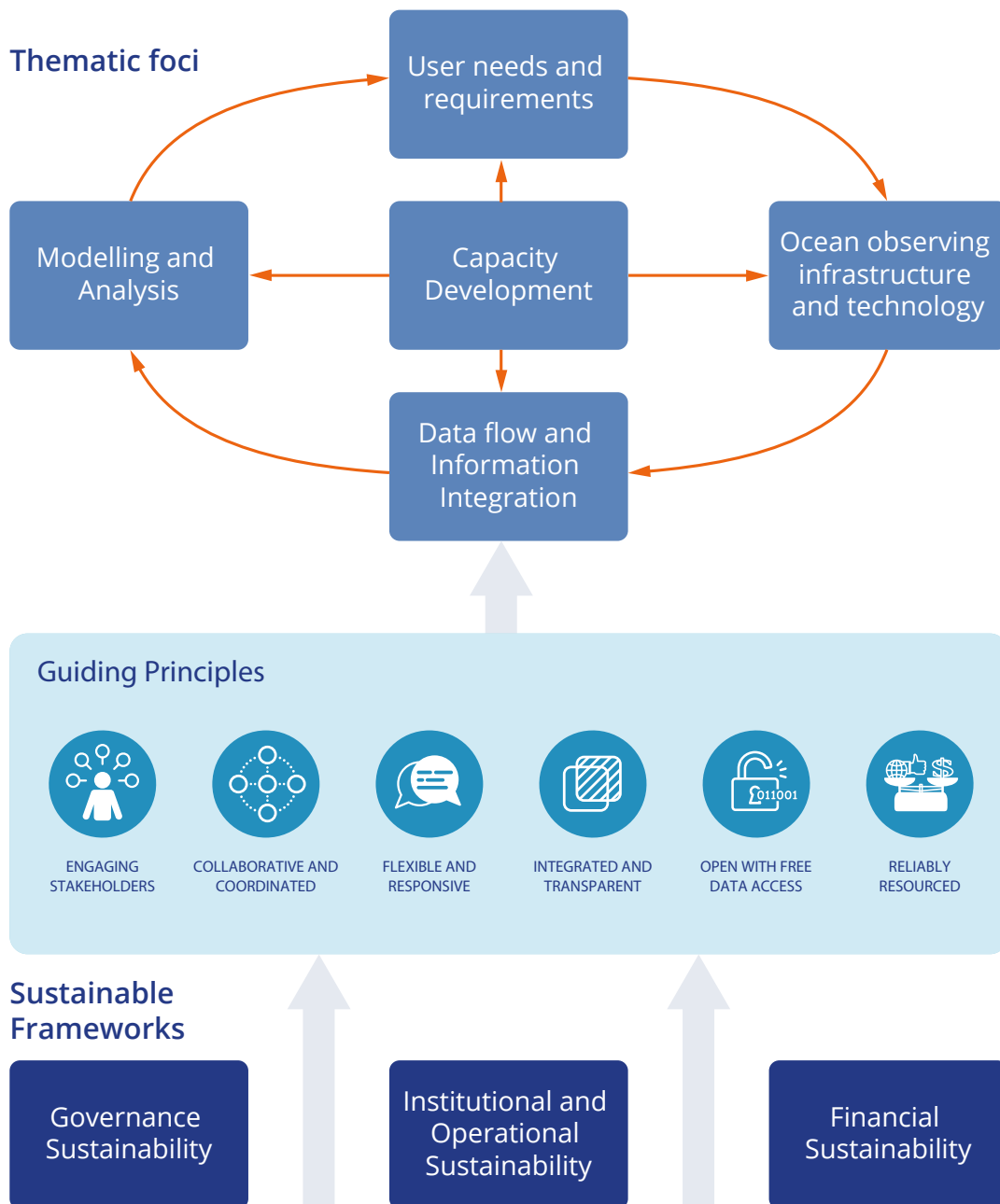


Figure 1. Implementing the European Strategy for All-Atlantic Ocean Observing System

# 1. European Strategy for the All-Atlantic Ocean Observing System - AtlantOS

The EU H2020 AtlantOS project delivered a new forward-looking framework and basin-scale partnership, building on existing efforts, for a sustainable, multi-disciplinary, efficient, and fit-for-purpose ocean observing system in the Atlantic ocean. The AtlantOS vision is:

**A comprehensive All-Atlantic Ocean Observing System that benefits all of us living, working and relying on the ocean.**

By 2030, AtlantOS is foreseen to have the following attributes:

- All designated AtlantOS data providers are integrated and making accessible all relevant ocean observing essential ocean variables as part of the Global Ocean Observing System,
- All AtlantOS services are available and functioning at the desired level,
- A fully functioning governance framework is in place and provides a forum for coordination, resource mobilization, review and decision making, and
- Long-term sustainability has been achieved through voluntary national contributions and long-term commitments.

Europe has developed a strategy to support the implementation of AtlantOS in order to advance the utility of ocean observations to meet the following goals:

- Support a sustained management of the ocean and blue economy including improved maritime safety and efficiency, fishery and aquaculture management, renewable energy development, advanced seafloor mapping.
- Improve operational ocean and weather forecasts and prediction of climate change and their effects on European regional and coastal seas and nations including an effective mitigation of effects caused by natural hazards.

- More effectively sustain biodiversity and ecosystem health in European seas including the use of marine resources, maximization of sustainable food management, and habitat characterization.
- Support scientific research to understand the earth system including measurements of ocean heat and circulation providing regional sea level monitoring, ocean circulation changes and climate feedbacks, and changes that affect ocean life, such as regional pH and oxygen levels.

All these activities will contribute to European policies (e.g. Integrated Maritime Policy) and directives such as the Marine Strategy Framework Directive, Water Framework Directive, and Maritime Spatial Planning Directive. They will also support the delivery of high-quality reliable oceanographic services via the EU Copernicus programme. Vision for the European component of AtlantOS is:

**By 2030, the European component of the All-Atlantic Ocean Observing System will be fully coordinated and fit-for-purpose. Common strategic priorities have been set out and accompanied by national and regional implementation plans and voluntary commitments, contributing to the system's sustainability.**

**The European component will be fully integrated in AtlantOS.**

To conserve and protect our ocean, especially in the context of food security, coastal protection, and climate change, it is crucial to track and understand large-scale interactions within and among ocean regions as well as the resulting impacts on the overall Earth system. Improved ocean observing is neces-

sary for informed decision-making directed towards ensuring sustainable ocean services and environmental stewardship. There is a compelling need to develop a sustainable, internationally-coordinated and comprehensive ocean observing system to assess current trends and predict future scenarios to support ocean management.

The ocean plays a vital role in the global climate system and biosphere, providing crucial resources for humanity including water, food, energy and raw materials. It is the primary controller of the global climate that makes this planet habitable for humankind, taking up 93% of the excess heat and 30% of global emissions of greenhouse gases. In addition to its paramount life-support functions, the ocean also represents the seventh largest economy in the world, with goods and services from coastal and marine environments amounting to US\$2.5 trillion each year. Our growing use of the ocean, in particular expanding activity at high latitudes, poses challenges for environmental management and for our social and economic dependence on ocean resources.

## 1.1 Why do we need a European Strategy for Atlantic Ocean Observing?

The ultimate objective of current ocean policies, including, for example, science funding programmes, international agreements, regional conventions, and European and national legislations, is to ensure healthy oceans and their sustainable resources and services and to promote sustainable blue economy. But this requires a fit-for-use data collection and systematic ocean observing system linked to and driven by users.

In 2030, the AtlantOS will provide data and information to fulfil the implementation of European policies and initiatives, including essential data and information will be available for the implementation of European ocean related legislations or directives (e.g. DMA, MSFD and MSP), and to assess their effectiveness and to propose their revision when needed.

For the case of science funding programmes, systematic, sustained ocean observations will allow to

investigate ocean dynamics and processes at unprecedented temporal and spatial scales, which cannot be approached by observations obtained from short-term research funding schemes (e.g. climate change effects). With a regular process for stakeholder engagement and co-design, emerging scientific-based information from ocean observing will, in turn, identify the need for future policies and data collection, and the adaptive observational strategy of the future Atlantic ocean will allow their rapid implementation.

Coordination is needed as well as bringing together the data from many sources. By working together, time, money and energy could be used more effectively. Data should be integrated sustainably and efficiently. Observation results should be shared widely, facilitating many uses of the same data to obtain the greatest value.

This strategy contributes to two initiatives that already exist:

- Firstly, it serves as the European input for the All-Atlantic Ocean Observing System Strategy developed through the AtlantOS BluePrint process. This strategy lays out the principles and plans for sustained ocean observations in the North and South Atlantic in two documents – a vision and an implementation document. Both documents benefit from active engagement from all interested parties and partners. Therefore, the added value of this strategy to the BluePrint process is that European perspectives and capabilities are displayed. It showcases, which products and services the European community needs, at what stage the European governance structure is, and where the ocean observing community wants to be at 2030.
- Secondly, the strategy presents one possibility for how to implement the Atlantic component of European ocean observing capability, through the EOOS framework. EOOS aims at connecting Europe's existing and emerging ocean observation and monitoring capabilities and stakeholders<sup>1</sup>. EOOS will strengthen the European contribution to ocean observation at global level (European EEZ and beyond, including the Atlantic ocean).

<sup>1</sup> [www.eoos-ocean.eu](http://www.eoos-ocean.eu)

Therefore, the AtlantOS European Strategy can be an early pilot activity within the EOOS framework development, as a basin-scale strategy for European ocean observing.<sup>2</sup>

In general, the strategy supports the implementation of the Global Ocean Observing System (GOOS) operated by IOC/UNESCO and contributes to the Blue Planet Initiative of the Group on Earth Observations (GEO).

## **1.2 Structure of this strategy**

The strategy document focuses on six topics that need to be taken into account for a fully coordinated and fit-for-purpose European contribution to AtlantOS:

- Chapter 2 describes user needs and mechanisms to identify and review those for the European part of AtlantOS;

- Chapter 3 outlines existing and evolving observation networks and systems and their capabilities and needs for the coming decade;
- Chapter 4 focus on the European contribution to an improved AtlantOS data management system;
- Chapter 5 addresses opportunities and benefits derived from capacity development;
- Chapter 6 outlines the structure of a European governance structure supporting AtlantOS;
- Chapter 7 presents the outlook, including achieving longer-term financial stability for ocean observing.

These key components are presented with the guiding principles of the Strategy in Figure 1, with the governance and financial sustainability as overarching components central to coordinating and implementing the other components.

<sup>2</sup> This is not yet described in the EOOS draft Implementation Plan but can be proposed as a new concrete action, led by the AtlantOS community.



## 2. Meeting user needs: from requirement setting to product delivery

The All-Atlantic Ocean Observing System Strategy (AtlantOS) highlights that:

*AtlantOS is envisioned as an agile system that will evolve as user needs change, new technologies are developed and new frontiers in ocean and earth system research are discovered. AtlantOS will support many users including governmental and intergovernmental, commercial, non-governmental organizations, and scientific sectors to advance the use of ocean observations in the delivery of public services, sustained economic benefits and earth systems research. Regular monitoring of user requirements, therefore, is a vital activity for AtlantOS.*

### Goal:

The requirements of European users will be mapped on a biannual basis via dedicated user meetings focussing specifically on delivering information for operational services, climate and marine ecosystem health applications.

The implementation will be an important component of the European contribution to the AtlantOS governance structure (see Chapter 6).

### 2.1 Recurring process of multi-stakeholder consultation for user requirements and co-design

User needs evolve with changing citizens concerns, public policies, industry priorities, and ocean states, as well as technological improvements which enhances the feasibility of new measurements. Thus, individual components of the blue value chain (e.g., networks, data managers, application developers) and integrators across the components must constantly work with end-users to refine high-level requirements and to optimise the information, delivery methods, and ocean technologies to ensure that the clients are receiving quality timely information in a form that they can use.

### Action 2.1

Identify current and potential end-users for ocean information using existing documents and surveys, including:

1. AtlantOS' national surveys for Deliverable 9.4;
2. Pilot projects from AtlantOS Work Package 8: Societal benefits from observing/information systems;
3. Results from IOC's GOSR reports;
4. Agenda 2030 and Sustainable Development Goals, and
5. Exchange with GEO and EuroGEOSS/GEOSS. A further survey should be conducted among the needs of end users such as fishermen, shipping and maritime traffic., etc. in terms of services and information products.

This adjustment and refinement process requires ongoing education from both sides – those providing observations and synthesizing data to learn client requirements, and the end-users to understand what observations are needed to meet those, along with technological limitations and cost. In addition, end-user involvement in the design of information products and services will hasten uptake of ocean information, benefiting the economy and environment, promoting the value chain, and lead to the improved long-term stability of the entire system.

### Action 2.2

The first consultation will be performed in March 2019 in connection with the final meeting of the H2020 project AtlantOS, where this strategy will be presented.

The *Framework for Ocean Observation* outlines the language needed for this consultation, the links between user needs and observations: the applications, models, and products needed to provide the information for user needs, the scientific knowledge needed to provide these products, and the observation variables and sampling strategies needed to understand the ocean.

### Action 2.3

Establish and define a common vocabulary before any co-designed processes and provide, in clear and understandable terms, scientific knowledge and technological processes to end users/products.

Part of the refinement process is the careful tracking of metrics designed to measure how well the observing platforms are performing, how readily the data is made available, how accurate and timely the products and services are, how much uptake there is on part of the users, and how the information affects decision-making. While data providers and synthesizers can track the internal workings of the blue value chain themselves, constant consultations with end-users are required to track the uptake and effect on decision-making. Optimising results for individual end-users is important, but there must also be basin-wide tracking to ensure efficiency and sustainability of the entire system.

### Action 2.4

Work with JCOMMOPS and EMODnet to help develop EOVS and information-based tracking metrics and key performance indicators to augment the platform tracking that they already do in their online monitoring of the observation networks. Share information with other observing systems (such as terrestrial) to optimize the observation and compare key performance indicators.

This concept of co-design presents the second advantage of the social acceptance of research activities in the oceans. The influence of civil society on marine activities is increasingly observed in seabed exploration activities where economic activities are independently developed for exploitation and the rejection by the civil society of certain research activities may lead to withdraw scientific missions, even in Europe (as an example: <https://medsalt.eu/1173-2/>). The Ocean Observation science prepares the ground for the economic development of this sector, or for an integrated observing system which could raise the “a priori” of the society (feeling of being observed).

In order to remove locks before they are even put in place, co-designed projects with end-users should be presented/shared afterwards with NGOs, governments, MEPs and stakeholders. An exchange and communication as soon as possible would make it possible to take into account all aspects of ocean observation and ensure the acceptance by the society.

### Action 2.5

Once end-users and providers/integrators agree on co-design observing systems, a multi-stakeholder consultation or presentation should include the civil society, represented by deputies at the European parliament or by NGOs.

## 2.2 The 'blue' value chain – Products driven by user needs

It is envisioned that by 2030 an integrated Atlantic Ocean Observing system will provide essential data and knowledge of ocean processes to underpin a knowledge-driven society that can advance the Blue Economy whilst ensuring environmental sustainability. Successful delivery of ocean products for societal benefit critically depends on interactions between many centres of competence operating across the boundaries between knowledge, society and policy. Societal requirements for timely and adaptive policy responses on, for example, climate mitigation and adaptation, ecosystem health and operational services, will be based on an efficient transfer of information which occurs through two branches of the observing system value chain – see Fig 2.1:

1. Scientific advisory and assessment;
2. Operational services delivery.

Both branches of the so-called blue value chain will rely on sustained ocean observations delivering against requirements of Essential Ocean Variables. These requirements will have been reconciled with the end user needs for a variety of ocean applications.

To meet the user needs, the system must, therefore, ensure an uninterrupted execution of the blue value chain by the elimination of all critical gaps in observing capacity, technology, data availability and sustainability.

The 2030 observing system will be capable of adapting its multi-platform design according to the changing user needs, funding opportunities, and technological advances, ensuring a comprehensive and concerted

observing of the ocean’s physical, biogeochemical and biological state and evolution. It will furthermore provide rapid access to reliable and accurate information, freely and openly available for end-user exploitation.

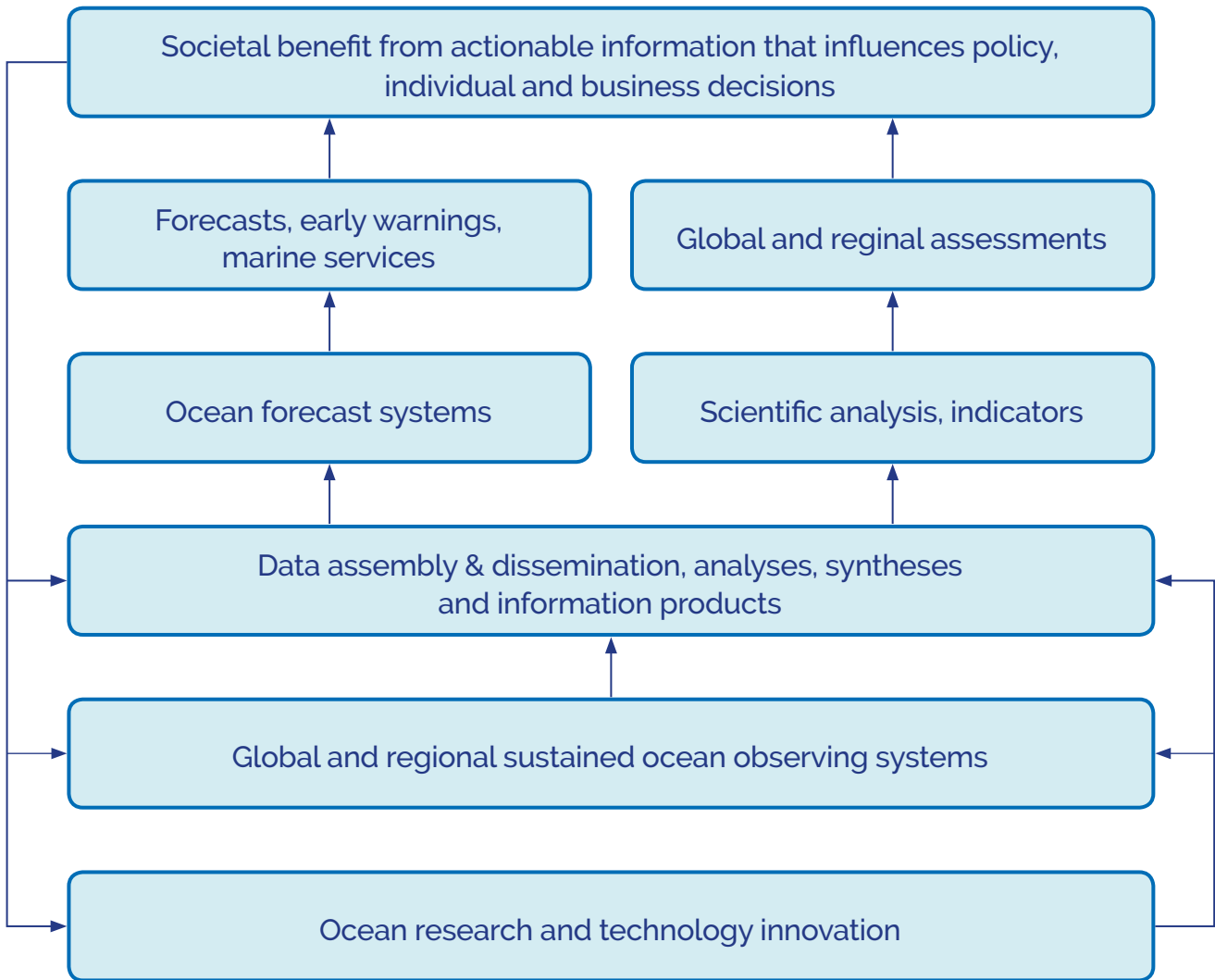


Fig. 2.1 Blue value chain (Adapted from G7 Ocean Expert Group Think Piece, May 2016)

In anticipation of ever-changing needs of a society forced to respond to various scenarios of climate change and exploitation, an iterative requirement set-

ting process based on a continuous end-user evaluation of targeted products will be a critical element of the 2030 Integrated Atlantic Ocean Observing System.

## 2.3 European policy drivers

In Europe, over the past few decades, a very rich, yet complex, marine science-policy landscape has developed. These contribute to global marine science and wider environmental policy initiatives and downscale to local regulations in order to secure services and resources. Policy drivers and wider societal needs for ocean observing are set in the context of wider marine and environmental policy developments (AtlantOS Deliverable D10.11, Larkin and Heymans 2018). Drivers for ocean observing range from climate and ocean services to marine and wider environmental policies and understanding ocean health (EOOS Consultation Document, 2016).

In terms of European policy, there are a range of European Directives and legislations adopted which have acted as top-down policy drivers for national, regional and European observation and monitoring programmes. Europe's Integrated Maritime Policy (IMP), adopted in 2007 offers a framework for more coherence in marine/maritime policies and after which European marine and ocean observation coordination efforts largely gained momentum (EOOS Consultation document, 2016; Larkin and Heymans, 2018). European ocean observation and monitoring can also provide crucial datasets for international policies

Some examples of known and emerging drivers and related policies requiring systematic ocean observation, where European ocean observing coordination efforts can add value include: (1) European policies (like Marine Strategy Framework Directive, Water Framework Directive, Birds and Habitats Directives, Common Fisheries Policy, Integrated, Coastal Management Policy and Maritime Spatial Planning Directive), (2) environmental status monitoring and assessment programmes, (3) global policies (like European contribution to the Convention on Biological Diversity

(CBD), Biodiversity Beyond areas of National Jurisdiction (BBNJ), Intergovernmental Panel on Climate Change (IPCC), Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES), World Ocean Assessment (WOA) and the Sendai Framework for Disaster Risk Reduction), (4) fisheries and aquaculture monitoring, (5) the wider blue economy, (6) pollution including ocean plastics, (7) weather forecasting and wider mapping and prediction of ocean phenomena and natural hazards, and (8) Climate change monitoring. The EOOS Strategy<sup>3</sup> goes into more detail with regard to this.

### Action 2.6

Regular consultation and mapping of European policy requirements for systematic ocean observation and monitoring data is required to ensure the European ocean observing capability is fit to deliver the right data and information to meet European and international policy and wider societal needs. This could be done by a number of European organizations and initiatives, potentially as a workshop every 2 years, and where relevant related to the EurOCEAN marine science-policy conference series, to identify how European policy is changing and how this may influence future European ocean observing system design.

Europe has, with the Copernicus programme, set up a long-term and ambitious earth monitoring programme. Copernicus relies on the development of an outstanding satellite component (Sentinels), an in-situ component organized by member states and a series of services (in particular the marine and climate services). The benefits of EU investments in the Copernicus Space, Marine and Climate Change Service components will not be fully achieved without a consolidated and improved in-situ observing system in the Atlantic.

# 3. Existing and Evolving Observing Networks and Systems

An envisioned multiplatform, multidisciplinary AtlantOS is composed of many networks and systems. Together, they seamlessly deliver essential information for the many observing objectives that have to be considered for the Atlantic Ocean and its marginal seas.

Europe will enhance collaboration and cooperation of various types of observing networks and observing systems to increase the readiness level of European observing efforts to deliver essential, fit-for-purpose information to the society. To this end, the following contributions to the improvements and developments will have been achieved:

## Goals (achieved by 2025)

- Information on observing networks assets and their status and performance with respect to all EOVs is centrally available and updated on at least monthly basis.
- Observing networks and systems activities as well as future plans are being routinely reviewed and assessed with respect to changing requirements.
- All elements of observing networks adhere to globally-accepted standards and best practices.
- Selected biogeochemical and biological observations are integrated into existing observing networks (e.g. GO-SHIP, PIRATA, OceanSITES).
- First dedicated biological observing networks reach a mature readiness level.
- Requirements for European observations of anthropogenic pressure variables are established.

## 3.1 Examples of some present capabilities and future targets<sup>4</sup>

### Argo

Europe through the Euro-Argo ERIC now contributes to Argo network in the Atlantic by maintaining an array of about 850 floats and by contributing to pilot projects for the development of Deep Argo and BGC Argo (24 and 64 floats). By 2030, Europe will/should contribute to Argo and its extensions (Deep and BGC Argo) in the Atlantic by maintaining an array of 600 T&S floats and 150 deep floats and 150 BGC floats. Europe will focus its contributions on the following areas (to be detailed) and will collaborate with international partners to ensure a full coverage of the Atlantic.

### Integrated Carbon Observation System - Ocean Thematic Centre (ICOS-OTC)

The Integrated Carbon Observation System (ICOS) is a European Research Infrastructure with the Ocean Thematic Centre (OTC) as its marine component. ICES Thematic Centre (OTC) as its marine component. ICOS-OTC provides long-term oceanic observations, which are required to understand the present state and better predict future behaviour of the global carbon cycle and climate-relevant gas emissions. The network is currently composed of 21 ocean stations from seven countries monitoring carbon uptake and fluxes in the North Atlantic and its marginal seas. It is also the European component of the global Surface Ocean CO<sub>2</sub> Observing Network (SOCONET). Coordinated sampling occurs on several observing platforms (research vessels, moorings, buoys, and commercial vessels) equipped with state of the art sensors providing highest quality measurements of the Inorganic Carbon EO. The ICOS-OTC monitoring system will support governments in their efforts to mitigate climate change as well as holding them accountable for reaching their mitigation targets. Therefore, it is of strategic importance to expand the network and supply the investment needed to ensure high quality measurements of greenhouse gas concentrations that are independent, transparent and reliable.

<sup>4</sup> This overview is not comprehensive and only gives examples of some key networks.

### Goals (achieved by 2030)

- European long-term ocean observing activities are sustained.
- Majority of biological EOV observations are carried out via regionally or globally coordinated observing networks.
- European infrastructures for coordinated observation of anthropogenic pressure variables are established.
- New technologies are evaluated by the AtlantOS and its integration into the system is efficient, streamlined, and encouraged when relevant.

### Moorings (OceanSITES incl. PIRATA and EMSO)

The mission of OceanSITES is to collect, deliver and promote the use of high-quality data from long-term, high-frequency observations at fixed locations in the open ocean. OceanSITES typically aims to collect physical, biogeochemical, and biology/ecosystem data worldwide from the open-ocean, covering the full-depth water column, the sea floor as well as the overlying atmosphere. The sites serve multiple purposes defined by the regional needs grouped under: (1) transport moored arrays, (2) air/sea flux reference sites, and (3) global ocean watch multidisciplinary time series. In the European context the EMSO ERIC organizes part of the European mooring infrastructure. The PIRATA array which is part of the Tropical Atlantic Observing system (TAOS) is composed by a DBCP part, that comprises the real-time data transfer for the surface modules, and an OceanSITES part, that deals with the subsurface delayed mode time series data.

### Gliders

The European Glider Network is represented in the Atlantic Ocean and European marginal seas through the maintenance of 10 repeated observing sections and multiple dedicated process studies by sampling physical and BioGeoChemical EOVs. The recent endorsement of the Ocean Gliders program by the GOOS open a new era in the development and the

sustainability of the glider network, in particular in the Atlantic where both sides of the North basin are very active. By 2030, Europe will bring together the increasing number of glider groups taking part of the Observing effort in the Atlantic and European marginal seas. Europe should support the development and the maintenance of an array of 20 endurance lines and any process studies occurring in its boundary regions, water transformation areas and adjacent polar regions. The data management system will be widened to integrate the entire scope of BGC EOVs that gliders will be capable to measure in the next decade. Ocean Gliders program will work toward a full coverage of the Atlantic, North, South and marginal seas, and the harmonization of sampling and management practices.

### Research Vessels (GO-SHIP)

Research Vessels are a very important component of the ocean observing system performing a number of tasks and with capacity to measure a wide range of EOVs, some for which other platforms fall short. The repeat hydrography program focus on repeated sections with high quality measurements according to the GO-SHIP best practices and criteria. The core component consist of long sections - continent to continent - with full ocean depth measurements at 30nm intervals repeated on a decadal scale. The associated network encompasses additional shorter lines with fewer variables, depth and resolution, but with the aim to occasionally encompass a more complete suite of variables and sampling intensity. The GO-SHIP program is actively supported by a range of European nations.

### Research Vessels (national)

Many operations at sea are in some respect related to the use of Research Vessels. In contrast to GO-SHIP, which targets multi-annual repeat hydrography, many Research Vessels expeditions are not necessarily designed for repeat occupation. Still the data is of high quality and is important to consider in the European observing context. The SeaDataNet European data infrastructure provides access to meta information of most European Research Vessel operations collected via the cruise summary report (CSR). Via the CSR scheme, which is mandatory to provide

for almost all national research ships operations, the Research Vessels are a key platform connecting all different observing, from fisheries to decadal surveys.

### **Ships of Opportunity Program (SOOP)**

The network of SOOP ships currently working in the North Atlantic provides a backbone of essential basin-wide observations of physical and biogeochemical parameters that cannot be measured by other means, including carbon parameters and nutrients, as well as SST and SSS ground-truth. These measurements enable for example monthly resolution of the net North Atlantic Ocean atmosphere CO<sub>2</sub> flux, accurate to better than 20% when integrated with ARGO, satellite and physical re-analysis data, provided that coverage is coherent and well-coordinated.

### **AMOC monitoring systems/networks**

Atlantic Meridional Overturning Circulation (AMOC) arrays are composed by fixed point observatories (part of the OceanSITES) measuring mass transport across certain latitudes. Array maintenance is carried out every 1 to 2 years and opens opportunities for ship access to other networks (Argo deployments, GO-SHIP cruises). Currently 6 arrays (OSNAP; NACO; RAPID/MOCHA; MOVE; 11°S; SAMBA-SAMOC) are operational. Except of NOAC (University Bremen, Germany) and MOVE (Scripps, USA) they arrays are international initiatives with partners from both sides of the Atlantic. The arrays provide important references data/metrics for climate stability of the Atlantic Ocean. Moreover, the arrays focus on boundary currents and deliver other ocean observing information, outside the climate domain, for the open ocean / coastal area transition zone.

### **Marine Biodiversity Observation Network (MBON)**

The Marine Biodiversity Observation Network (MBON) is a network under the umbrella of the Group On Earth Observations Biodiversity Observation Network (GEO BON) and the biodiversity arm of GEO Blue Planet. The objective of the MBON is to link existing groups engaged in ocean observation and help define best practices and methods to track changes in the number of marine species, the abundance and biomass of marine organisms, the diverse interactions between

organisms and the environment, and the variability and change of specific habitats of interest. The goal is to augment the capabilities of present national and international observing systems to characterize diversity of life at the genetic, species, and ecosystem levels using a broad array of *in situ* and remote sensing observations. As part of this goal, the MBON seeks to advance practical and wide use of marine biology Essential Variables (EBVs and EOVs) to address the need to evaluate status and trends of life in coastal and open ocean environments. Although this network aims to be global some pilot projects are under way in the US (US MBON) and with the program Pole-to Pole in the Americas that include also a number of Latin American countries.

### **ICES coordinated stock assessment**

Although not traditionally considered as an observing network, ICES coordinate the standardized assessment of approximately 200 stocks in Atlantic European waters and the Baltic annually, in many cases accounting for several decades of data. The assessment of each stock is based on the collection and analysis of an important number of biological and population variables and fishing activity, as one of the few coordinated networks providing data on an anthropogenic pressure. These biological, population and fishing activity variables provide standardized data on the variability of crucial biological components of the ecosystem which respond to environmental dynamics and anthropogenic pressures. Furthermore, stock assessment has progressed in the last decades from single-stock to an ecosystem approach, which implies the systematic harvesting a large number of ecosystem variables (physical, chemical and biological) and the assessment of fishing impacts on the ecosystem.

### 3.2 Role of observing networks and observing systems in the blue value chain

The European observing community leads or contributes to many international observation networks spanning all three ocean disciplines: physics, biogeochemistry and biology. Some of the networks already have well established European structures (e.g. EuroARGO, EUMETSAT, ICOS OTC). However, the landscape of ocean observation is extraordinarily diverse and presents important differences in maturity, depending on factors such as the typology of the variables (e.g. physical vs. biological), the observing platforms (ships, satellites, fixed and drifting buoys, etc.), the geographical coverage (jurisdictional vs. non-jurisdictional waters, North vs. South Atlantic, domain, habitat, etc.). This diversity has its roots in the complexity of the coupled climate and ocean dynamics and also on the scientific or service drivers of each of the existing networks that have arisen to a large extent independently.

#### Action 3.1

Shift from independent or loosely coordinated observation efforts on a limited number of EOVs to an integrated system of long-term, sustained observing networks and programmes delivering quality controlled data obtained for all EOVs from a myriad of platforms to enable the development of societal benefit products.

Besides the great development in the observation of ocean physical variables during the last decades, there are important gaps related to key oceanographic phenomena (e.g. heat and air-sea fluxes) that must be fulfilled in the future.

#### Action 3.2

- Increase and optimize sampling in the deep ocean to better constrain deep ocean heat flux, and in the upper 10 m to allow better validation of satellite data.
- Better sample the marginal seas in the northern hemisphere Atlantic to account for their role in changing thermohaline circulation and oxygen distribution and their biological importance.

- Enhance and optimize multidisciplinary observations in boundary currents and water transformation areas to better understand the impact of climate change on fluxes of heat, but also biogeochemical cycles, biodiversity and ecosystem change and fishery production in these ocean hot spots.
- Increase and optimize the European contribution to OceanGliders program to meet the global target of sustainably sampling boundaries current regions, water transformation areas and storms pathways.
- Further develop, optimize and integrate High Frequency Radar network with regard to the development of operational coastal services.

Although the bathymetric and geological characterization of the seafloor is fundamental for the management of many ocean resources, services and hazards, at global scale only 15% of the ocean surface and only 50% of the continental shelves are mapped by direct measurements.

#### Action 3.3

- Establish a coordinated European mapping strategy to contribute to the objective of the Nippon Foundation – GEBCO Seabed project to bring together all available bathymetric data to produce and make publicly available the definitive map of the world ocean floor by 2030.

Significant progress has been achieved in increasing the readiness level of marine biogeochemistry observations, however, many observing networks remain loosely coordinated and there are several EOVs which are not at all yet observed in a systematic and sustained manner. The role of new sensors and platforms in addressing gaps in biogeochemistry and biological observations will depend on the increased network density and on the successful interaction with other components of the ocean observing system, including satellites, shipboard programs, and various time series stations.



### Action 3.4

- Further the integration of biogeochemical and biological sensors into the existing PIRATA buoy network and repeat hydrography lines in the tropical ocean to better understand the changes and impacts of intense air-sea interactions in the region.
- Strengthen the Integrated Carbon Observation System Ocean Thematic Centre (ICOS-OTC) as the European component of the Surface Ocean CO<sub>2</sub> Observing Network (SOCONET) used to map CO<sub>2</sub> levels in the mixed layer over time for robust estimates of air-sea CO<sub>2</sub> fluxes and uptake of CO<sub>2</sub> by the ocean for use in assessments and evaluation.
- Increase and optimize the European contribution to the global Biogeochemical Argo program to meet the global target of 1000 floats with all six biogeochemical sensors deployed at any given time, surveyed key open ocean hot spots in the Atlantic.
- Develop new remote sensing algorithms to better survey a greater number of EOVs (in particular for biogeochemistry and biological habitat variables).

In the biological domain, methodological constraints possibly explain the paucity of existing organised and long-term networks related with the observation of biological variables. Although new technologies are opening present and future opportunities, data acquisition still depends mostly on traditional sampling procedures by divers or on-board research vessels. In the biological domain, methodological constraints possibly explain the paucity of existing organised and long-term networks related with the observation of biological variables. Although new technologies are opening present and future opportunities, data acquisition still depends mostly on traditional sampling procedures by divers or on-board research vessels.

### Action 3.5

- Achieve a balance between identifying the most relevant biology and ecosystem EOVs and the sustainability and efficiency of the observing methodologies while adopting a high degree of flexibility depending on the geographical amplitude of the observing network or system, on the environmental realm (pelagic, benthic, coastal, open ocean) or the group of organisms considered more relevant.
- Support emerging biological networks (e.g. MBON and Deep Ocean Observing Strategy) and also a large number of initiatives mainly focussed on scientific collaboration (e.g. IGMETS, EMBRC-ERIC, ICES network of working groups...), not yet considered as observing networks, which currently integrate observing activities or promote methodological standardization.
- Increase the observation effort on Marine Protected Areas and Vulnerable Marine Ecosystems, particularly in areas beyond national jurisdiction.

In addition, there is lack of sufficient monitoring of a growing number of anthropogenic pressures (e.g. contamination, overfishing, noise and marine litter), their sources, pathways and impacts (e.g. global warming, ocean acidification, deoxygenation, eutrophication, loss of biodiversity).

### Action 3.6

- Integrate anthropogenic pressures and impacts into the Atlantic observational system: Marine contaminants and litter assessed by regional conventions (OSPAR, HELCOM, Barcelona), fishing pressure and impacts as part of the ICES coordination on fisheries management, and incentivise coordination on other pressures with non-existing or less matured networks (e.g. noise, marine traffic).

Although the observing system remains largely fragmented with respect to the different ocean disciplines, filling the gaps to meet the scientific and societal requirements demands cross-network and cross-disciplinary improvements and development.

### Action 3.7

- Increase and optimize the number of fixed-point (coastal, moored and ship-based) stations with long-term, coincident physical, biogeochemical and biological measurements.
- Ensure real time and delayed mode quality control and synthesis of time series physical, biogeochemical and biological data to provide information products in response to the societal needs on local to global scales (e.g. SDG14 indicators).
- Further develop the use of autonomous platform (Gliders, HFR, BGC ARGO) in coastal areas where observations are scarce and not harmonized, with regard to the assessment of biodiversity changes and fisheries, particularly in regions that are at risk by anthropogenic pressure and therefore depend on marine resources.
- Increase the collaboration with manufacturers (platforms and sensors) and extend this collaboration to industries operating at sea (e.g. fisheries, oil and gas, transport).

### 3.3 Advancing the observing system through new technology

New technologies are needed to make ocean observation more efficient, more accurate and more detailed. They will play a particularly important role on the incorporation of biological variables to the observational landscape of networks, contributing to reduce operational costs and facilitating their incorporation in automated platforms.

New technologies, regardless of their nature (platform, sensor, communication, energy, etc.) should also target the AtlantOS priorities and contribute to fill the spatial, temporal, data availability and sustainability gaps of the observing system. Finally, the rise of autonomous observation systems, considered as new technology ten years ago, acquiring more and more data is bringing to the forefront new challenges, such as big data transfer and data mining. These new challenges deserved to be anticipated by the development of new technologies to make the most of this increasing amount of information about ocean.

### Action 3.8

AtlantOS will actively encourage and support developments of new technology to obtain more efficient, accurate and detailed observations also taking into account reduced operational costs and environmental impact of the coming device (pollution, noise, electromagnetic disturbance, ecosystem perturbation, energy consumption, etc.). ARGO floats releasing lithium batteries in the seabed are a good example of the compromise between scientific benefits and environmental impacts that needs to be assessed when developing a new technology.

New fields of technological development for Ocean Observation have been identified here. This list is not exhaustive and must be updated frequently:

#### **BGC and biological technological development:**

- Methodologies for sample conservation for morphological and molecular studies,
- Meio-, macro- or mega-benthos, as well observations and measurements techniques for comparative biodiversity, systematic, ecologic or evolutionary research.
- Genomics monitoring,
- Imaged-based techniques combined with automated classification methods based on artificial intelligence.

#### **Communications:**

- Acoustic underwater data transfer,
- Wire independent, autonomous deep-sea sampling,

#### **Autonomous Platforms:**

- Robotics and autonomous marine research,
- Free-falling self-operated systems (bottom landers),

#### **Techniques and experiments:**

- Extensive *in situ* real-time studies,
- Application of big data and data mining techniques to Ocean Observations.

## 4. Data flow and information integration

Easy and fast access to reliable, high quality ocean environmental data is fundamental and an integral part of a well-functioning and fit-for-purpose observing system. Europe has over the past decades used huge resources in building marine data management facilities (CMEMS INSTAC, EMODnet, SeaDataNet). Building on these existing infrastruc-

tures and developments planned and designed under various H2020 projects such as AtlantOS it is the goal that European observations contributing to AtlantOS will be freely available together with data from European Regional Seas on these platforms. Further development of the data management system is requested.

### Goals (achieved by 2025)

- FAIR principles are endorsed by all the main European data systems managing the Atlantic observing networks, EuroGOOS ROOSs and European Integrated data service providers.
- Open Data Policy is endorsed by all the European Countries for the EOVS defined by GOOS.

### Goals (achieved by 2030)

- Open Data Policy is implemented all the main data systems of the European observing networks, EuroGOOS ROOSs and European Integrated data service providers.
- FAIR principles are implemented by all the main European data systems managing the Atlantic observing networks, EuroGOOS ROOSs and European Integrated data service providers facilitating the in situ data uptake in new field of applications.

The demand for ocean observation data is rapidly increasing, but the tools to manage, document, provide, find, access, and use such data are still underdeveloped owing to the combination of data complexity and increasing data volumes. In the past decade observing the ocean has evolved into a more coordinated landscape with:

- Labelling of Research Infrastructures (RI) within the Environment domain of ESFRI,
- Setting up of the Copernicus program and its in-situ service for the Marine Service that integrate data into products for the operational oceanography needs,
- EMODnet initiative to ensure that European marine data become easily accessible, interoperable, and free of restrictions on use,
- SeaDataNet infrastructure that coordinates more than 100 European national data centres that collect and archive a wide variety of research data,
- Better cooperation on data management issues between the EuroGOOS and ROOS observing system data centres.

### Action 4.1

The growth of autonomous vehicles such as BGC Argo, drones and gliders will increase the volume of data being collected at high resolution and will need to be integrated into the current observing systems. The ability to transmit data autonomously and cheaply while engaged in survey activities, and to process the data more efficiently for end users, needs to be a development priority.

The RI facilities and European ocean data centres were developed to respond to the needs of specific research and monitoring communities, following individual requirements and methods of specific disciplines. EuroGOOS and the European RIs are large producers and providers of in situ ocean environmental research data in Europe collected from and therefore the main actors of the European ocean data system.

## 4.1 FAIR as guiding principles

According to the FAIR principles, data and data products should be:

- **Findable:** Each dataset should be identified by a unique persistent identifier and described by rich, standardised metadata that clearly includes the persistent identifier. The metadata record should be indexed in a catalogue and carried on with the data.
- **Accessible:** The dataset and its metadata record should be retrievable by using the persistent identifier, using a standardised communications protocol. In turn, that protocol should allow for authentication and authorisation, where necessary. All metadata records should remain accessible even when the datasets they describe are no longer accessible.
- **Interoperable:** Both metadata and datasets use formal, accessible, shared, and broadly applicable vocabularies and/or ontologies to describe themselves. They should also use vocabularies that follow FAIR principles, and provide qualified references to other relevant metadata and data. Importantly, the data and metadata should be machine-accessible and parseable.
- **Reusable:** To meet this principle, data must already be Findable, Accessible, and Interoperable. Additionally, the data and metadata should be sufficiently richly described that it can be readily integrated with other data sources. Published data objects should contain enough information on their provenance to enable them to be properly cited and should meet domain-relevant community standards.

### Action 4.2

Professional Data management is an essential element of the FAIRness of an observing system and should be designed and properly funded with the observations.

Open data policy is essential to enhance accessibility to data, foster reusability of existing data and turn observation data into information necessary for end-users.

### Action 4.3

Open Data Policy should be a priority for EOVS (Essential Ocean Variable) acquired at European scale and should be supported by nations and EC.

Leveraging the RIs data systems providing those ECV/EOVs at same level of accessibility should be a priority. Support to standards and best practices implementation by the RIs should also be organised as it is key to enhance interoperability and reusability of existing data and avoid duplication of efforts.

### Action 4.4

Common standards for data /metadata and sharing protocols as well as Best Practices elaboration should be organised and properly funded in order to develop standards and enhance existing one to fulfil the needs of the RIs in due time.

The Atlantic data system should be designed as one piece of the GOOS data system and designed as a system of systems that will allow data to find easily findable, accessible and interoperable (avoiding mixing “apples with oranges”) and allowing reusability through thematic integrated products and services more suitable for downstream services.

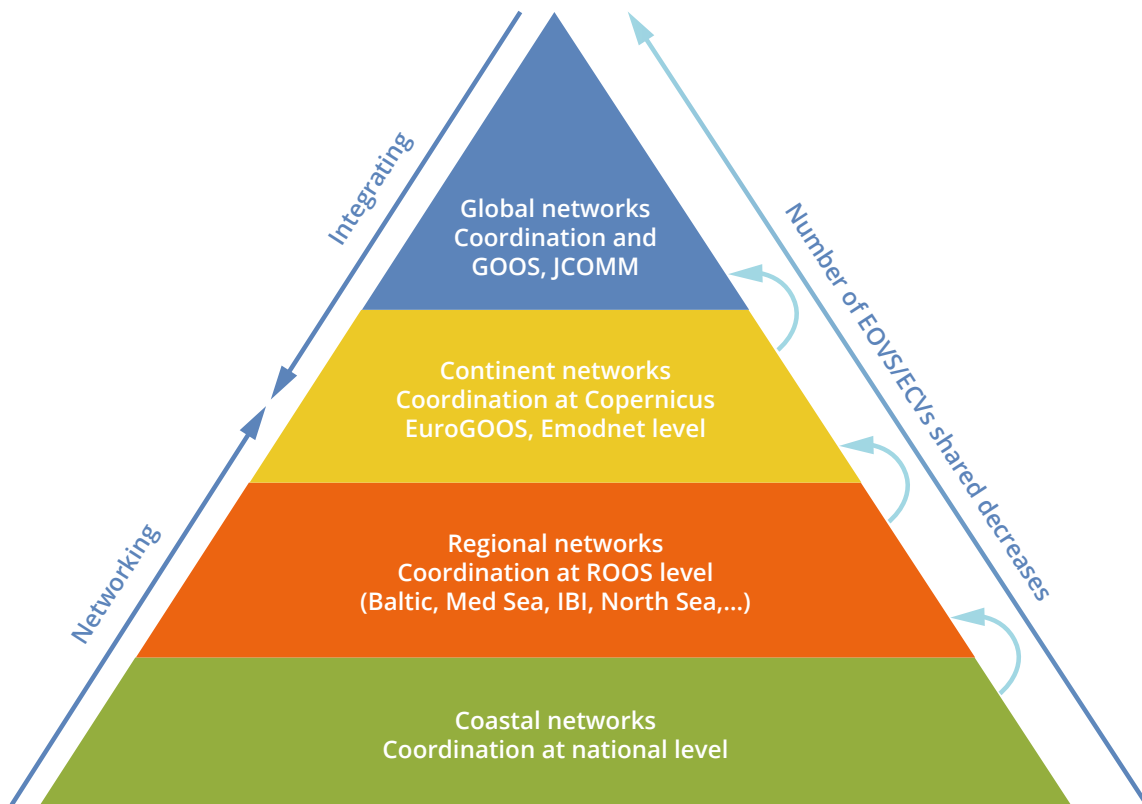


Figure 3: From coastal to global data integration

## 4.2 Information integration – Linking observations and modelling

Observations are a fundamental pillar of the operational services added value chain that goes from observation to information and users. The quality of operational products is thus highly dependent on the availability of upstream in-situ and satellite observations at global and regional/coastal scales. While the research community is more interested in observation data the closest to the observed measurements and require detailed information of the processing steps and the adjustment/calibration performed on the data, the operational and downstream users are more interested in the best version of the data with an estimation of the error-bar on the data as well as consolidated information calculated from observation that can be directly assimilated in their operational models or directly used for product validation or monitoring activities.

Indeed, there is recognition of the need to further link observations with models and make all existing data available for modelling, particularly for emerging parameters for biodiversity and wider ecosystem datasets (Heymans *et al.*, 2018)

Thematic assembly centres are an essential component of the global operational oceanography infrastructure and monitoring applications include climate change and anthropic impact monitoring. The quantity, quality and availability of data sets and data products directly impact the quality of ocean analyses and forecasts and associated services. More effective data assembly, more timely data delivery (near real time and historical time-series), improvements in data quality, better characterization of data errors and development of new or high-level data products are among the key data processing needs for operational oceanography and monitoring applications.

### Action 4.5

Maintain Thematic assembly centres that customize integrated services for targeted downstream and end users.

The rationale behind AtlantOS is to serve the society with relevant information's and services based on analysis of the observation data directly or model output quality assured by observational data. Therefore, a basic element in a European

strategy for development of information and services for the Atlantic Ocean will be to continuously update a database on user requirements, which shall contain information on quality and timeliness. These requirements will be translated to activities to adjust the existing production line (observations, data management, forecasting, information and service production). An important component of the information and service strategy will be to adjust the communication of result to newest communication technology.

# 5. Capacity Development

Capacity Development refers to educational and technical training for operating and using ocean observing platforms, data exploration, data archiving, using ocean observing downstream services (e.g. Copernicus Marine Environment Monitoring Service) with the aim to overcome geographical, economic or political limitations and to enhance international collaboration.

With new possibilities offered by e.g. scientific technologies, the ocean observing community can collect e.g. much more data (physico-chemical, biological, biogeochemical), information and knowledge that enhances our ability to assess and predict (through observations and modelling) the current and future ocean state (Muller-Karger *et al.*, 2018).

## Goals (achieved by 2025)

- Visibility and awareness of capacity and participation in ocean observing is enhanced and raised
- Strategies to enhance training and teaching in different areas that are important and essential for ocean observing (like observing techniques, data management, technical innovation, etc.) has been developed and implemented at national/regional level;
- Structures for coordinated citizen science activities have been defined and set;
- Ocean observing landscape has been evaluated regarding new jobs and education opportunities (e.g. in data infrastructure).

## Goals (achieved by 2030)

- Research policies/strategies to embed capacity development in ocean observation at national level are improved;
- European capacity development landscape has a clear governance structure supported by e.g. EOOS;
- Observational disadvantages because of geographical, economic or political issues are significantly reduced (indicators for analysis are discussed and set by the ocean observing community).

### 5.1 Enhancing visibility and raising awareness of capability and participation in ocean observing – supporting training and teaching

It is now acknowledged that ocean observation is a global effort to collect and integrate different measurements (EOV, ECV, EBV, etc.) by different means (autonomous platforms, observation from ships, fixed mooring, etc.) in different geographical areas. The scientific community has a responsibility to display and make available local and regional projects, programmes and data to participate in this global effort. Information and knowledge from bilateral or

multilateral agreements must be visible, as illustrated by the Galway and Belém Statements, encouraging nations to collaborate on regional observations in a global context and encouraging more countries to join the ocean observing community.

For European countries it should be important to implement key elements by e.g. developing new multidisciplinary job opportunities (in the area of data integration), coordinating technological infrastructures with non-European countries, inviting scientists to engage in capacity development activities or defining best practices that would be shared within the community.

### **Action 5.1: Implementing frameworks/strategies that already exist**

Identify technical standards that are already set - e.g. the Argo Data management plans or coordination plans of observation platforms as provided by JCOMM and monitoring system status tools (through JCOMMOPS) – that should guide training and teaching activities. Training creates and generates the capacity to implement and transfer a set of standardized methods or documented best practices (Costello *et al.*, 2016). Take into account the six key elements identified in the capacity development strategy from IOC to guide nations in gaining the capacity required to implement key international policies and capabilities. The six key elements are: developing human capacity, physical infrastructure, raising awareness, developing communities of practice, adopting marine research policies and sustained resource mobilisation.

### **Action 5.2: Promote training and teaching as key (ethical) value and fundamental for capacity development**

Training for ocean observation requires a broad cross-section of skills, from scientific understanding of the marine environment to technical, hands-on field work experience at sea and with sensors and samplers used to collect the ocean data that require deployment, maintenance and operation.

There is a need for technical training in different technologies, platforms and information systems. The need for replacement of personnel is also important for keeping standard practices and registry of observations. The aim is to have interested and adequately trained individuals in all countries and regions participating in capacity development initiative.

### **Action 5.3: Engaging with the civil society (1)**

Set the science for integrating data of citizen after the data are quality controlled by scientists. Citizens' contributions vary and range from data and information collection to data analysis, incidental observations to active participation in standardized surveys and monitoring protocols. This participation is likely to increase with the development of digital capabilities like smartphone applications, drones, etc. (EMB Policy Brief N°5, 2).

### **Action 5.4: Engaging with the civil society (2)**

Support massive online courses. With this interactive learning format large numbers of interested scientists, practitioners as well as citizens can be educated and capacity can be developed without the time and expense of travel. Such courses are developed for people involved in ocean issues or seek to know more about e.g. their local coastline, the fish they eat or the climate that the ocean regulates.



## Massive open online course: OCEANMOOC

The OCEANMOOC (<http://www.oceanmooc.org/en/index.php>) is a massive open online course titled 'One Planet – One Ocean: From Science to Solutions', and that speaks to interested people to learn from world's leading experts on ocean science. Those experts present the issues and potential solutions – grounded in rigorous scientific research – to fight for our endangered waters.

The OCEANMOOC was broadcast in 2016 and 2017, attracting over 6500 participants from 62 countries. It provides a knowledge base that bring people to the science and fascination of the ocean. The team of lecturer consists of marine scientists, economists, lawyers and philosophers so that a holistic view of (1) how the ocean functions, (2) how human interactions with the ocean can be understood, and (3) what solutions are available to support both sustainable use and stewardship of our blue planet is addressed.

## Partnership for Observation of the Global Oceans

An example for a program that has been effective in supporting capacity building for ocean observation is POGO. POGO is an organization of the directors and leaders of major oceanographic laboratories around the world. POGO has developed an extensive array of training and

education activities targeted primarily at Early Career Scientists or scientists from developing countries and those with economies in transition. These activities are funded through partnerships with foundations, institutions, laboratories. With linking activities for an integrated Atlantic Ocean observation system to already existing capacity development infrastructures such a system could operate in a more integrative way.

## Action 5.5: Promote young scientists through capacity development initiatives

Collaborations in ocean observing are also conducted on a bilateral level (between countries) where scientists and institutions provide training directly to developing countries through periodic courses or sponsor masters and PhD level exchanges and scholarships. The proposed IODE clearing house mechanism could provide a means of cataloguing much of capacity building activities conducted in European countries in the future to avoid duplication of effort in capacity development.

There are currently wide arrays of capacity development activities underway worldwide varying from short courses in particular topic areas e.g. Ocean Teacher Global Academy supported through IODE to shipboard training supported through POGO and PIRATA as well as longer term training supported through the Nippon Foundation-POGO Centre of Excellence.

Capacity development allows, inter alia, to provide observations in areas where they do not exist and facilitates the interoperability of data collected by different people with different means in different countries (Muller-Karger *et al.*, 2018). In capacity building, the place of young scientists is important, and the Partnership for Observation of the Global Oceans (POGO) or PIRATA programmes (among many others) offering opportunities for joint training and teaching.

## 5.2 Improving and promoting research policies to embed ocean observation at national level

Science has a role to play in environmental governance and the interface between policy and science must be strengthened (UNESCO High-Level Conference on the United Nations Decade for the Ocean, Paris, 2018).

### **Action 5.6: Europe as flagship region for a common ocean observing strategy and strengthening capacity development**

In Europe, more than 300 environmental policies have been adopted and coherence between new and existing policies must be ensured. In many countries, marine research policies are not yet part of national thinking (even for nations with a coastline) and this impedes the ability to secure funds and resources for activities around ocean observing and marine science and development more widely. Europe must offer leadership in providing guidance and support nations worldwide that lack the knowledge or resources to develop their own marine research policies.

Support and organize training courses on foresight and stakeholder engagement for prospective countries developing marine research and innovation policies as one of the high-level objectives for the UN Decade for Ocean Science (2021-2030).

### **Action 5.7: Define common indicators for policy priorities**

To ensure that the message is understood, it would be relevant to consider common indicators that could be developed to integrate the ocean into policy priorities: economic, social and environmental indicators directly related to ocean knowledge and capacity development.

The visibility of best practices for the entire scientific community is as important as the fundamental concept of data sharing, as it avoids the loss of information and expertise and the use of inappropriate technologies (United Nations Data Revolution Report, 2014). The IODE Ocean Best Practices initiative provides a basis for the documenting and reuse of best practices for a wide array of techniques and methods from initial data collection, through quality assurance, data archival to the development of ocean products (Pearlman *et al.*, submitted).

### **Action 5.8: Growing a vibrant Ocean Observing Community – building trust**

The integration of the multiple dimensions of our ocean can only be based on cooperation and acceptance of knowledge from different places. This is only possible if a relationship of trust is established! Trust is an important factor to coordinate (capacity development) activities in ocean observing. To do so in the ocean observing community, it is e.g. essential to coordinate ocean data and information: Data collection platforms must make data publicly available and provide details on quality assurance and quality control (QA/QC) and data processing procedures, including the methods used, references, third parties involved in any proceedings and where they are hosted – training and teaching third parties is a very important step.

Another way to build trust is sharing existing ocean observation infrastructures and facilities: this approach is cost-effective, reduces service and maintenance costs, extends geographical coverage and integrates new measures, avoids duplication and minimizes investment. These infrastructures and the associated good practices (for platforms, sensors, etc.) must be visible (Barbier *et al.*, 2018).

### **Action 5.9: Supporting emerging initiatives**

Encourage participation in the international networks for emerging observing technologies including gliders, HF radars, genomics and animal tracking among others. JCOMM and GEO have initiated coordination of some of these activities at the global scale focusing on best practices, technology transfer and data management strategies. There is a need to promote these global networks to engage more countries planning ocean observing programmes and to increase the use of such technologies in e.g. GOOS or EuroGOOS as well as the data systems (like EMODnet and JCOMMOPS).

# 6. Governance System

The organisation and governance structure of the European contribution to AtlantOS shall serve two main purposes:

- Support the governance established for the basin-scale system (AtlantOS)
- Ensure a well-coordinated and smooth implementation of the European contribution to AtlantOS

The tasks and responsibilities related to the management of the European component will be delegated to EOOS, who will setup a group responsible for this task.

## Goals (achieved by 2025)

EOOS has established an office which includes a task team responsible for the coordination and management of Europe's contribution to AtlantOS with the following key responsibilities:

- Cooperate closely with the AtlantOS management team;
- Strengthened coordination and strategic planning between key European nations and organizations engaged in Atlantic Ocean observations;
- Liaison with national funding entities;
- Performing regular user consultations;
- Support initiatives towards free and open data exchange based on the FAIR principles.

## Goals (achieved by 2030)

The EOOS AtlantOS task team is mature, operational and compliments other regional contributions to AtlantOS. Organisation and task are adjusted regularly to reflect new developments in AtlantOS and the European contribution.

### 6.1 AtlantOS Governance

The governance of the European contribution to AtlantOS shall naturally build on and support the AtlantOS governance structure as outlined in the All-Atlantic Ocean Observing System Strategy (AtlantOS) (de Young *et al*, 2018), which built upon clearly expressed and transparent principles.



Figure 4: From coastal to global data integration

The AtlantOS governance structure therefore includes:

- Coordination mechanisms that span three dimensions: the observing system, resource engagement, and ocean information delivery;
- A Resource Board to promote long-term funding;
- Implementation of a formalized, dynamic and flexible Ocean Partnership Panel (OPP);
- A review process;
- Countries should establish an Ocean Focal Point or Ocean Ministry.

## 6.2 European Governance

Central in establishing a governance structure for the European contribution to AtlantOS is EOOS, which is a coordinating framework designed (1) to align and integrate Europe's ocean observing capacity for

the long term, (2) to promote a systematic and collaborative approach to collecting information on the state and variability of our seas and oceans, and (3) to underpin sustainable development, protection and conservation of the marine environment and its resources. Thus, there is a strong synergy between the two initiatives.

In 2018, following stakeholder consultation, an EOOS Strategy and draft Implementation Plan 2018-2022<sup>4</sup> were published and discussed by the ocean observing community. These can be a starting point for future EOOS planning and implementation.

EOOS is, however, still in its establishment phase. Presently, the governance structure includes a Steering Group and an Advisory Board. It is therefore crucial that the European AtlantOS community quickly establish a dialog with the EOOS Steering group to work on the following actions:

### Action 6.1

Build an organisational structure for EOOS that serves EOOS as well as European AtlantOS component needs. Key elements will be:

- User engagement;
- Observation coordination;
- Sustained funding;
- Partnership panel;
- National Focal point;
- Review process.

It is of key importance that EOOS establishes an adequately staffed office to handle day to day management tasks. This office shall have a group devoted to Atlantic Ocean work only, to link with other sea basin observing.

### Action 6.2

EOOS should investigate options to register as a legal entity in order to be able to receive funding to run an office. This could entail making legal arrangements with a relevant organisation e.g. EuroGOOS.

### Action 6.3

Establish a formal agreement with EOOS on their engagement, responsibilities and conditions for managing the European contribution to AtlantOS.

### Action 6.4

EOOS shall immediately start to:

- Ensure funding for the implementation of the planned governance structure from participating nations and organisation;
- Implement agreed organisation incl. establish office;
- Organise user consultation; and
- Engage with national and institutional funding entities.

<sup>4</sup> <http://www.eoos-ocean.eu/strategy-and-implementation/>

### 6.3 Ethical considerations

Scientists have a role to play as stewards of the oceans, as the knowledge and new technologies developed have a de facto impact on the decision-making processes. In this important task, marine scientists have a responsibility to act in an ethical manner. Ocean ethics is defined as a reasoned reflection and action based on technological advances to develop oceanographic knowledge that takes into account external dimensions such as societal, legal, political, economic and cultural (Barbier *et al*, 2018). The fundamental principles described in the Cape Town Declaration on Geoethics should apply to the ocean observing community: (a) ethical values regarding behavior, honesty, integrity, courtesy and equity; (b) social values calling for sustainability,

prevention and education; and (c) cultural values to strengthen community relations (Peppoloni and Di Capua, 2017). The basis and criterion of geo-ethics is responsibility.

Governance adapted to social-ecological systems has to consider different dimensions: economic (cost-efficiency), politic and social, legal (European and national legislations) and scientific (environmental issues). Ocean observing is complex, multi-dimensional and is facing uncertainties and the adoption of a governance adapted to social-ecological systems considering different aspects of the observation is thus challenging but necessary. The European AtlantOS governance system will promote ethical key principles that ocean observation experts could follow.

The nine key principles are:

- Provide free access to research and data;
- Be effective;
- Respect the environment and preserve nature;
- Comply with the laws;
- Engage in a relationship of reciprocity and cultural respect ;
- Ensure equality and equity;
- Establish governance adapted to the socio-ecological system;
- Consider animal ethics in ocean observation;
- Transfer their knowledge.

#### Action 6.5

Integrate ethical considerations/dimension in the governance of the European ocean observing systems in order to 1) ensure a global, fair and equitable ocean observing system, 2) build trust between European and developing and emerging countries, as a prerequisite for a true global ocean observing system; 3) ensure respect of the fundamental human rights and adoption of the European code of conduct on research integrity 4) recall the responsibility of the research ocean observing community in their tasks.

#### Action 6.6

Adopt a governance adapted to social-ecological systems in order to 1) ensure the efficiency and usefulness of European ocean observing system in global ocean observation; 2) facilitate the societal acceptance of research activities conducted in the ocean; 3) ensure the protection and resilience of the Ocean system, and to a larger extent to the Earth system.

# 7. Outlook – Financial sustainability

A successful European contribution to AtlantOS will require a long-term plan for sustained funding.

The funding plan shall be based on a continuation of the existing activities but shall also take into account contributions to filling gaps in the existing observation system.

Research projects and professional analyses has pointed to the fact that existing in-situ observations in the Atlantic Ocean face severe gaps, which can be divided into four categories:

- Gaps in the observing networks;
- Gaps in data availability;
- Gaps in sustainability;
- Gaps in technology.

A successful implementation of AtlantOS will require an ability to properly address all four gap categories by developing a framework to improve the performance of existing networks, develop or test new components and seek to optimise the whole integrated observing system. A key issue will be secure sustained funding to operate AtlantOS.

Recent studies by the Copernicus (Buch *et al*, 2019) has analysed the sustainability issue and concluded that there are severe sustainability issues regarding environmental in situ observations. The gap in in-situ observations due to lack of sustained funding can be subcategorised as follows:

- There is a lack of sustained funding for observations in general. Only 28 % of the ocean observing networks have sustained funding while the remaining 72% are partly or fully dependant on time limited research funds. 52% of the networks face funding problems in the near future, 9% already have severe problems and 11% do not have funding today but expect in the near future.
- Observing networks lack sustained funding for coordination or management of the network.

## Goals (achieved by 2025)

- A forum for national and EU funding entities has been established. Each nation has one representative which require establishment of a national coordination body.
- A long-term funding plan for Europe's engagement in AtlantOS has been prepared.

## Goal (achieved by 2030)

- A long-term plan for national commitments to a sustained funding of Europe's contribution AtlantOS has been approved.

In-situ observations are based on infrastructures, primarily supported by national agencies and the number of observation sites or platforms are decreasing due to:

- Ageing of instruments/networks;
- Changes in scientific goals and priorities;
- Funding opportunities decreasing;
- Environmental effects (climate change, harsh environment).

The implementation of AtlantOS as designed and outlined in the Blueprint process documents is based on a cooperative movement, where nations around the Atlantic Ocean commit to perform a certain share of AtlantOS – this commitment includes a sustained funding for operating that particular share. The benefit to the individual nations is that by covering a small percentage of the total cost of AtlantOS they get the full picture of Atlantic Ocean environment.

Europe is prepared to contribute substantially to a successful implementation of AtlantOS. The European contribution will be:

- Guided by the requirements and priorities of European user communities
- Performed by marine research and monitoring institutions from European nations with an interest in the Atlantic Ocean environment.
- Primarily be funded via national funds.

The European contribution to AtlantOS will, as mentioned in Chapter 6, be coordinated by EOOS. This framework will be a platform to promote dialogue with funders on sustained funding for ocean observing. This has already started with a Call to Action<sup>5</sup>, released in November 2018, where the European ocean observing and monitoring community “call on European countries and the EU to examine what is currently being done under their responsibility and establish roadmaps with specific actions and indicators to move towards a more integrated, transparent and coordinated approach.” A future EOOS project office could build on this to have a structured dialogue with national and European funding entities (see Actions 7.1 and 7.2 below).

### Action 7.1

EOOS project office shall liaise with national funding entities to secure national long-term sustained funding plans for contribution of the European component of AtlantOS. The funding plan shall include expenses for:

- Instrument purchase;
- Operational costs;
- Data transmission and data management to the level where quality assured data are available on a data portal;
- Coordination costs;
- Capacity building – internal training and education as well as support to third- countries primarily in the South Atlantic.

In most nations this task will require working with representatives from several ministries and funding entities to establish a national funding plan.

### Action 7.2

To ease the long-term coordination is will be beneficial to:

- Promote the idea of establishment of a national ocean observing coordination body;
- Establish a European AtlantOS funding forum with a representative from each of the participating European nations.

<sup>5</sup> <http://www.eoosconference2018.eu/call-action>

## 8. Summary

The EU H2020 project AtlantOS initiated an planning activity on formulating a vision for the future Atlantic Ocean Observing System (AtlantOS) involving representatives from countries around the Atlantic Ocean. The result – **the All-Atlantic Ocean Observing System Strategy (AtlantOS)** (de Young *et al.*, 2018) - outlined an ambitious vision and an integrated concept for a forward-looking framework and basin-scale partnership to establish a comprehensive ocean observing system for the Atlantic Ocean as a whole that shall be sustainable, multi-disciplinary, efficient, and fit-for-purpose. The ambitions for AtlantOS are that by 2030:

- All designated AtlantOS data providers are integrated and making accessible all relevant ocean observing essential ocean variables as part of the Global Ocean Observing System,
- All AtlantOS services are available and functioning at the desired level,
- A fully functioning governance framework is in place and provides a forum for coordination, resource mobilization, review and decision making, and
- Long-term sustainability has been achieved through voluntary national contributions and long-term commitments.

European countries and the EU have already invested significantly in ocean observing infrastructure and technology. There is increasing recognition of the need for effective coordination and governance in ocean observing systems in the global ocean in general, and the Atlantic in particular. This is set to continue as the political interest in the ocean increases and the societal need for the ocean as a resource increases along with the need for sustainable management. Europe is therefore prepared to make a substantial contribution to a successful implementation of AtlantOS to meet requirements for products and services expressed by European user communities of which Copernicus (services and satellite missions), Blue Growth, EU Directives, regional conventions etc. are important representatives with whom regular consultation will be established.

It is recognized that European institutions already operate platforms, networks, and systems at vari-

ous maturity levels. The European contribution to AtlantOS will built on these existing observing activities and go beyond the status quo by increasing the level of activity, securing sustainability and especially establish a cross-disciplinary coordination.

Securing a fit-for-purpose observation system means a constant focus on innovation to take onboard observations of new essential variables, increase quality, reduction of cost, minimizing effect on environment etc. Close cooperation with instrument developers and manufactures is therefore an integral part of the of the European contribution to AtlantOS which additionally will raise the competitiveness of European industry.

AtlantOS and the European contribution to it only makes sense, if there is easy and fast access to the generated data. Europe will therefore secure that an open data policy is implemented based on the FAIR principle. Europe has over the past decades invested large resources in building marine data management facilities, which will form the basis for the management and handling of the European component of AtlantOS. These data management systems will be under continuous development to meets the requirements from users regarding availability and quality.

The European contributions to AtlantOS will follow internationally agreed standards and best practices, education and training of involved personnel will therefore be a continuously ongoing process fully integrated into the governance structure.

Europe's contribution to AtlantOS will be composed of input from numerous organisations from several European countries. An effective European component of AtlantOS will therefore require a strong and well-organised governance structure that on the one-hand can secure coordination a multinational, multi-institutional and multi-disciplinary effort and on the other hand can contribute substantially to the overall AtlantOS governance. The governance of Europe's contribution to AtlantOS will be a special activity of EOOS and the EOOS office will establish a separate group to handle the daily coordination and management tasks related to the European AtlantOS component. EOOS will additionally secure that Europe plays a



leading role in the AtlantOS governance structure with timely and high quality inputs, and are represented in the leading management bodies with the right and recognized ocean observation professionals.

This strategy is aimed at European and international ocean observation stakeholders both within and beyond the AtlantOS network, in particular those involved in the programming and planning of ocean observing activities but also the wider marine science community. It also aims to inform policy makers of the latest developments in ocean observation coordination and provide input to future planning of research agendas and financing of ocean observation coordination in the Atlantic Ocean and beyond. Within this strategy, the European capability and strategy for future efforts will be assessed and should be seen as European contribution to the international AtlantOS BluePrint process.

This strategy collectively calls for European institutions and nations to join force to reach the defined goals which are:

### Goals achieved by 2025:

- The requirements of European users will be mapped on a biannual basis via dedicated user meetings focussing specifically on delivering information for operational services, climate and marine ecosystem health applications.
- Information on observing networks assets and their status and performance with respect to all EOVS is centrally available and updated on at least monthly basis.
- Observing networks and systems activities as well as future plans are being routinely reviewed and assessed with respect to changing requirements.
- All elements of observing networks adhere to globally-accepted standards and best practices.
- Selected biogeochemical and biological observations are integrated into existing observing networks (e.g. GO-SHIP, PIRATA, OceanSITES).
- First dedicated biological observing networks reach a mature readiness level.
- Requirements for European observations of anthropogenic pressure variables are established.
- FAIR principles are endorsed by all the main European data systems managing the Atlantic observing networks, EuroGOOS ROOSs and European Integrated data service providers.
- Open Data Policy is endorsed by all the European Countries for the EOVS defined by GOOS.
- Visibility and awareness of capacity and participation in ocean observing is enhanced and raised.
- Strategies to enhance training and teaching in different areas that are important and essential for ocean observing (like observing techniques, data management, technical innovation, etc.) has been developed and implemented at national/regional level.
- Structures for coordinated citizen science activities have been defined and set.
- Ocean observing landscape has been evaluated regarding new jobs and education opportunities (e.g. in data infrastructure).
- EOOS has established an office which includes a task team responsible for the coordination and management of Europe's contribution to AtlantOS with the following key responsibilities:
  - cooperate closely with the AtlantOS management team;
  - strengthened coordination and strategic planning between key European nations and organizations engaged in Atlantic Ocean observations;
  - liaison with national funding entities;
  - performing regular user consultations.
  - support initiatives towards free and open data exchange based on the FAIR principles.
- A forum for national and EU funding entities has been established. Each nation has one representative which require establishment of a national coordination body.
- A long-term funding plan for Europe's engagement in AtlantOS has been prepared.

### Goals achieved by 2030:

- European long-term ocean observing activities are sustained.
- Majority of biological EOVS observations are carried out via regionally or globally coordinated observing networks.
- European infrastructures for coordinated observation of anthropogenic pressure variables are established.
- New technologies are evaluated by the AtlantOS and its integration into the system is efficient, streamlined, and encouraged when relevant.
- Open Data Policy is implemented all the main data systems of the European observing networks, EuroGOOS ROOSs and European Integrated data service providers.
- FAIR principles are implemented by all the main European data systems managing the Atlantic observing networks, EuroGOOS ROOSs and European Integrated data service providers facilitating the in-situ data uptake in new field of applications.
- Research policies /strategies to embed capacity development in ocean observation at national level are improved.
- European capacity development landscape has a clear governance structure supported by e.g. EOOS.
- Observational disadvantages because of geographical, economic or political issues are significantly reduced (indicators for analysis are discussed and set by the ocean observing community).
- The EOOS AtlantOS task team is mature, operational and complements other regional contributions to AtlantOS. Organisation and task are adjusted regularly to reflect new developments in AtlantOS and the European contribution.
- A long-term plan for national commitments to a sustained funding of Europe's contribution AtlantOS has been approved.

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# Annex 1 List of Actions

The following actions have been highlighted:

**Action 2.1:** Identify current and potential end-users for ocean information using existing documents and surveys, including 1) AtlantOS' national surveys for Deliverable 9.4; 2) pilot projects from AtlantOS Work Package 8: Societal benefits from observing/information systems; 3) results from IOC's GOSR reports; 4) Agenda 2030 and Sustainable Development Goals, and 5) exchange with GEO and EuroGEOSS/GEOSS. A further survey should be conducted among the needs of end users such as fishermen, shipping and maritime traffic., etc. in terms of services and information product.

**Action 2.2:** The first consultation will be performed in March 2019 in connection with the final meeting of the H2020 project AtlantOS, where this strategy will be presented

**Action 2.3:** Establish and define a common vocabulary before any co-designed processes and provide, in clear and understandable terms, scientific knowledge and technological processes to end users.

**Action 2.4:** Work with JCOMMOPS and EMODNET to help develop EOVS and information-based tracking metrics and key performance indicators to augment the platform tracking that they already do in their online monitoring of the observation networks. Share information with other observing systems (such as terrestrial) to optimize the observation and compare key performance indicators.

**Action 2.5:** Once end-users and providers/integrators agree on co-design observing systems, a multi-stakeholder consultation or presentation should include the civil society, represented by deputies at the European parliament or by NGOs.

**Action 2.6:** Regular consultation and mapping of European policy requirements for systematic ocean observation and monitoring data is required to ensure the European ocean observing capability is fit to deliver the right data and information to meet European and international policy and wider societal needs. This could be done by a number of European

organizations and initiatives, potentially as a workshop every 2 years, and where relevant related to the EurOCEAN marine science-policy conference series, to identify how European policy is changing and how this may influence future European ocean observing system design.

**Action 3.1:** Shift from independent or loosely coordinated observation efforts on a limited number of EOVS to an integrated system of long-term, sustained observing networks and programmes delivering quality controlled data obtained for all EOVS from a myriad of platforms to enable the development of societal benefit products.

## **Action 3.2:**

- Increase and optimize sampling in the deep ocean to better constrain deep ocean heat flux, and in the upper 10 m to allow better validation of satellite data.
- Better sample the marginal seas in the northern hemisphere Atlantic to account for their role in changing thermohaline circulation and oxygen distribution and their biological importance.
- Enhance and optimize multidisciplinary observations in boundary currents and water transformation areas to better understand the impact of climate change on fluxes of heat, but also biogeochemical cycles and fishery production in these ocean hot spots.
- Increase and optimize the European contribution to OceanGliders program to meet the global target of sustainably sampling boundaries current regions, water transformation areas and storms pathways.
- Further develop, optimize and integrate High Frequency Radar network with regard to the development of operational coastal services

**Action 3.3:** Establish a coordinated European mapping strategy to contribute to the objective of the Nippon Foundation – GEBCO Seabed project to bring together all available bathymetric data to produce and make publicly available the definitive map of the world ocean floor by 2030.

**Action 3.4:**

- Further the integration of biogeochemical and biological sensors into the existing PIRATA buoy network and repeat hydrography lines in the tropical ocean to better understand the changes and impacts of intense air-sea interactions in the region.
- Strengthen the Integrated Carbon Observation System Ocean Thematic Centre (ICOS-OTC) as the European component of the Surface Ocean CO<sub>2</sub> Observing Network (SOCNET) used to map CO<sub>2</sub> levels in the mixed layer over time for robust estimates of air-sea CO<sub>2</sub> fluxes and uptake of CO<sub>2</sub> by the ocean for use in assessments and evaluation.
- Increase and optimize the European contribution to the global Biogeochemical Argo program to meet the global target of 1000 floats with all six biogeochemical sensors deployed at any given time, surveyed key open ocean hot spots in the Atlantic.
- Develop new remote sensing algorithms to better survey a greater number of EOVs (in particular for biogeochemistry and biological habitat variables).

**Action 3.5:**

- Achieve a balance between identifying the most relevant biology and ecosystem EOVs and the sustainability and efficiency of the observing methodologies while adopting a high degree of flexibility depending on the geographical amplitude of the observing network or system, on the environmental realm (pelagic, benthic, coastal, open ocean) or the group of organisms considered more relevant.
- Support emerging biological networks (e.g. MBON and Deep Ocean Observing Strategy) and also a large number of initiatives mainly focussed on scientific collaboration (e.g. IGMETS, EMBRC-ERIC, ICES network of working groups...), not yet considered as observing networks, which currently integrate observing activities or promote methodological standardization.
- Increase the observation effort on Marine Protected Areas and Vulnerable Marine

Ecosystems, particularly in areas beyond national jurisdiction.

**Action 3.6:** Integrate anthropogenic pressures and impacts into the Atlantic observational system: Marine contaminants and litter assessed by regional conventions (OSPAR, HELCOM, Barcelona), fishing pressure and impacts as part of the ICES coordination on fisheries management, and incentivise coordination on other pressures with non-existing or less matured networks (e.g. noise, marine traffic).

**Action 3.7:**

- Increase and optimize the number of fixed-point (moored and ship-based) stations with long-term, coincident physical, biogeochemical and biological measurements.
- Ensure real time and delayed mode quality control and synthesis of time series physical, biogeochemical and biological data to provide information products in response to the societal needs on local to global scales (e.g. SDG14 indicators).
- Further develop the use of autonomous platform (Gliders, HFR, BGC ARGO) in coastal areas where observations are scarce and not harmonized, with regard to the assessment of fisheries, particularly in regions that are at risk by anthropogenic pressure and therefore depend on marine resources.
- Increase the collaboration with manufacturers (platforms and sensors) and extend this collaboration to industries operating at sea (e.g. fisheries, oil and gas, transport).

**Action 3.8:** AtlantOS will actively encourage and support developments of new technology to obtain more efficient, accurate and detailed observations also taking into account reduces operational costs and environmental impact of the coming device (pollution, noise, electromagnetic disturbance, ecosystem perturbation, energy consumption, etc.). ARGO floats releasing lithium batteries in the seabed are a good example of the compromise between scientific benefits and environmental impacts that needs to be assessed when developing a new technology.

**Action 4.1:** The growth of autonomous vehicles such as BGC Argo, drones and gliders will increase the volume of data being collected at high resolution and will need to be integrated into the current observing systems. The ability to transmit data autonomously and cheaply while engaged in survey activities, and to process the data more efficiently for end users, needs to be a development priority

**Action 4.2:** Professional Data management is an essential element of the FAIRness of an observing system and should be designed and properly funded with the observations.

**Action 4.3:** Open Data Policy should be a priority for EOVS (Essential Ocean Variable) acquired at European scale and should be supported by nations and EC.

**Action 4.4:** Common standards for data /metadata and sharing protocols as well as Best Practices elaboration should be organised and properly funded in order to develop standards and enhance existing one to fulfil the needs of the RIs in due time.

**Action 4.5:** Maintain Thematic assembly centres that customize integrated services for targeted downstream and end users.

**Action 5.1:** Identify technical standards that are already set - e.g. the Argo Data management plans or coordination plans of observation platforms as provided by JCOMM and monitoring system status tools (through JCOMMOPS) – that should guide training and teaching activities. Training creates and generates the capacity to implement and transfer a set of standardized methods or documented best practices (Costello *et al.*, 2016).

Take into account the six key elements identified in the capacity development strategy from IOC to guide nations in gaining the capacity required to implement key international policies and capabilities. The six key elements are: developing human capacity, physical infrastructure, raising awareness, developing communities of practice, adopting marine research policies and sustained resource mobilisation.

**Action 5.2:** Training for ocean observation requires a broad cross-section of skills, from scientific understanding of the marine environment to technical,

hands-on field work experience at sea and with sensors and samplers used to collect the ocean data that require deployment, maintenance and operation.

There is a need for technical training in different technologies, platforms and information systems. The need for replacement of personnel is also important for keeping standard practices and registry of observations. The aim is to have interested and adequately trained individuals in all countries and regions participating in capacity development initiative.

**Action 5.3:** Set the science for integrating data of citizen after the data are quality controlled by scientists. Citizens' contributions vary and range from data and information collection to data analysis, incidental observations to active participation in standardized surveys and monitoring protocols. This participation is likely to increase with the development of digital capabilities like smartphone applications, drones, etc. (EMB Policy Brief N°5, 2).

**Action 5.4:** Support massive online courses. With this interactive learning format large numbers of interested scientists, practitioners as well as citizens can be educated and capacity can be developed without the time and expense of travel. Such courses are developed for people involved in ocean issues or seek to know more about e.g. their local coastline, the fish they eat or the climate that the ocean regulates.

**Action 5.5:** Collaborations in ocean observing are also conducted on a bilateral level (between countries) where scientists and institutions provide training directly to developing countries through periodic courses or sponsor masters and PhD level exchanges and scholarships. The proposed IODE clearing house mechanism could provide a means of cataloguing much of capacity building activities conducted in European countries in the future to avoid duplication of effort in capacity development.

There are currently wide arrays of capacity development activities underway worldwide varying from short courses in particular topic areas e.g. Ocean Teacher Global Academy supported through IODE to ship-board training supported through POGO and PIRATA as well as longer term training supported through the Nippon Foundation-POGO Centre of Excellence.

**Action 5.6:** In Europe, more than 300 environmental policies have been adopted and coherence between new and existing policies must be ensured. In many countries, marine research policies are not yet part of national thinking (even for nations with a coastline) and this impedes the ability to secure funds and resources for activities around ocean observing and marine science and development more widely. Europe must offer leadership in providing guidance and support nations worldwide that lack the knowledge or resources to develop their own marine research policies.

Support and organize training courses on foresight and stakeholder engagement for prospective countries developing marine research and innovation policies as one of the high-level objectives for the UN Decade for Ocean Science (2021-2030).

**Action 5.7:** To ensure that the message is understood, it would be relevant to consider common indicators that could be developed to integrate the ocean into policy priorities: economic, social and environmental indicators directly related to ocean knowledge and capacity development.

**Action 5.8:** The integration of the multiple dimensions of our ocean can only be based on cooperation and acceptance of knowledge from different places. This is only possible if a relationship of trust is established! Trust is an important factor to coordinate (capacity development) activities in ocean observing. To do so in the ocean observing community, it is e.g. essential to coordinate ocean data and information: Data collection platforms must make data publicly available and provide details on quality assurance and quality control (QA/QC) and data processing procedures, including the methods used, references, third parties involved in any proceedings and where they are hosted – training and teaching third parties is a very important step. Another way to build trust is sharing existing ocean observation infrastructures and facilities: this approach is cost-effective, reduces service and maintenance costs, extends geographical coverage and integrates new measures, avoids duplication and minimizes investment. These infrastructures and the associated good practices (for platforms, sensors, etc.) must be visible (Barbier *et al.* 2018).

**Action 5.9:** Encourage participation in the international networks for emerging observing technologies including gliders, HF radars, genomics and animal tracking among others. JCOMM and GEO have initiated coordination of some of these activities at the global scale focusing on best practices, technology transfer and data management strategies. There is a need to promote these global networks to engage more countries planning ocean observing programmes and to increase the use of such technologies in e.g. GOOS or EuroGOOS as well as the data systems (like EMODnet and JCOMMOPS).

**Action 6.1:** Build an organisational structure for EOOS that serves EOOS as well as European AtlantOS component needs. Key elements will be:

- User engagement;
- Observation coordination;
- Sustained funding;
- Partnership panel;
- National Focal point;
- Review process.

It is of key importance that EOOS establishes an adequately staffed office to handle day to day management tasks. This office shall have a group devoted to Atlantic Ocean work only, to link with other sea basin observing.

**Action 6.2:** EOOS should investigate options to register as a legal entity in order to be able to receive funding to run an office. This could entail making legal arrangements with an relevant organisation e.g. EuroGOOS.

**Action 6.3:** Establish a formal agreement with EOOS on their engagement, responsibilities and conditions for managing the European contribution to AtlantOS.

**Action 6.4:** EOOS shall immediately start to:

- Ensure funding for the implementation of the planned governance structure from participating nations and organisation,
- Implement agreed organisation incl. establish office,

- Organise user consultation, and
- Engage with national and institutional funding entities.

**Action 6.5:** Integrate ethical considerations/dimension in the governance of the European ocean observing systems in order to 1) ensure a global, fair and equitable ocean observing system, 2) build trust between European and developing and emerging countries, as a prerequisite for a true global ocean observing system; 3) ensure respect of the fundamental human rights and adoption of the European code of conduct on research integrity 4) recall the responsibility of the research ocean observing community in their tasks.

**Action 6.6:** Adopt a governance adapted to social-ecological systems in order to 1) ensure the efficiency and usefulness of European ocean observing system in global ocean observation; 2) facilitate the societal acceptance of research activities conducted in the ocean; 3) ensure the protection and resilience of the Ocean system, and to a larger extent to the Earth system.

**Action 7.1:** EOOS project office shall liaise with national funding entities to secure national long-term sustained funding plans for contribution of the European component of AtlantOS. The funding plan shall include expenses for:

- Instrument purchase;
- Operational costs;
- Data transmission and data management to the level where quality assured data are available on a data portal;
- Coordination costs;
- Capacity building – internal training and education as well as support to third- countries primarily in the South Atlantic.

**Action 7.2:** To ease the long-term coordination is will be beneficial to:

- Promote the idea of establishment of a national ocean observing coordination body;
- Establish a European AtlantOS funding forum with a representative from each of the participating European nations.



## Annex 2: Glossary of acronyms and terms

<b>AANChOR CSA</b>	All AtlaNtic Cooperation for Ocean Research and innovation Coordination Support Action (European H2020 project, starting October 2018 - 2022)
<b>AIR</b>	Atlantic International Research Centre
<b>AORA</b>	Atlantic Ocean Research Alliance
<b>AORA CSA</b>	Atlantic Ocean Research Alliance Coordination Support Action (European H2020 project, 2015-2020)
<b>ASG</b>	Atlantic Strategy Group
<b>AtlantOS</b>	Integrated Atlantic Ocean Observing System
<b>BCLME</b>	Benguela Current Large Marine Ecosystem
<b>CFP</b>	Common Fisheries Policy
<b>CMEMS</b>	Copernicus Marine Environment and Monitoring System
<b>COFASP</b>	Cooperation in Fisheries, Aquaculture and seafood processing
<b>CSA Oceans</b>	A European Framework Programme 7 funded Coordination and Support Action to support JPI Oceans in its start-up phase
<b>DFO</b>	Department of Fisheries and Oceans, Canada
<b>DG MARE</b>	European Commission Directorate-General of Maritime Affairs and Fisheries
<b>DG RTD</b>	European Commission Directorate-General for Research and Innovation
<b>EATiP</b>	European Aquaculture Technology and Innovation Platform
<b>EBV</b>	Essential Biodiversity Variable
<b>EC</b>	European Commission
<b>ECMWF</b>	European Centre for Medium-Range Weather Forecasts
<b>EEA</b>	European Environment Agency
<b>EFARO</b>	European Fisheries and Aquaculture Research Organisations
<b>EMB</b>	European Marine Board
<b>EMODnet</b>	European Marine Observation and Data Network
<b>EMSO ERIC</b>	European Multidisciplinary Sea Observatory ERIC
<b>EOOS</b>	European Ocean Observing System
<b>EOV</b>	Essential Ocean Variable
<b>eEOV</b>	Ecology Essential Ocean Variable
<b>ERA-NET</b>	European Research Area Net
<b>ERIC</b>	European Research Infrastructure Consortium
<b>ESFRI</b>	European Strategy Forum on Research Infrastructures
<b>EUMETSAT</b>	European Organisation for the Exploitation of Meteorological Satellites

## AtlantOS – European Strategy for the All-Atlantic Ocean Observing System (AtlantOS)

<b>Euro-Argo ERIC</b>	European infrastructure for the Argo programme
<b>EuroGOOS</b>	European Global Ocean Observing System
<b>GCOS</b>	Global Climate Observing System
<b>GEOTRACES</b>	An International Study of the Biogeochemical Cycles of Trace Elements and their Isotopes
<b>GES</b>	Good Environmental Status
<b>GEOSS</b>	Global Earth Observation System of Systems
<b>GIS</b>	Geographic Information Service
<b>GOSIC</b>	Global Observing Systems Information Center (GOSIC)
<b>GOOS</b>	Global Ocean Observing System
<b>GRA</b>	Global Regional Alliance (of GOOS)
<b>HLPF</b>	High-level Political Forum on Sustainable Development (HLPF)
<b>ICES</b>	International Council for the Exploration of the Sea
<b>ICEMASA</b>	International Centre for Education, Marine and Atmospheric Sciences over Africa
<b>ICSU</b>	International Council for Science
<b>IEOM</b>	Integrated Ecosystem Observation and Monitoring (IEOM)
<b>IOC</b>	Intergovernmental Oceanographic Commission
<b>IMOS</b>	Integrated Marine Observing System
<b>IMP</b>	Integrated Maritime Policy (European Union)
<b>INSPIRE</b>	INfrastructure for SPatial Information (European Union Directive)
<b>IOC</b>	Intergovernmental Oceanographic Commission (of UNESCO)
<b>IODE</b>	International Oceanographic Data and Information Exchange (of IOC)
<b>IOOS</b>	Integrated Ocean Observing System (U.S.)
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>JCOMM</b>	Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology
<b>JPI Oceans</b>	Joint Programming Initiative on Healthy and Productive seas and oceans
<b>MBON</b>	Marine Biodiversity Observation Network
<b>MCCIP</b>	United Kingdom Marine Climate Change Impacts Partnership (MCCIP)
<b>MDG</b>	Millennium Development Goal
<b>MMRS</b>	EU Strategy for Marine and Maritime Research
<b>MSFD</b>	Marine Strategy Framework Directive (European Union Directive)
<b>MSP</b>	Maritime Spatial Planning
<b>MPA</b>	Marine Protected Area

<b>NGO</b>	Non-Governmental Organization
<b>NOAA</b>	National Oceanic and Atmospheric Administration
<b>OECD</b>	Organisation for Economic Co-operation and Development
<b>OGC</b>	Open Geospatial Consortium
<b>ODP</b>	Ocean Data Portal
<b>OSPAR</b>	Oslo and Paris Commission. Regional Sea Convention for the Protection of the Marine Environment of the North-East Atlantic
<b>OSPAR-ODIMS</b>	OSPAR's Data and Information Management System
<b>OTN</b>	Ocean Tracking Network
<b>POGO</b>	Partnership for Observation of the Global Ocean
<b>RSC</b>	Regional Sea Convention
<b>ROOS</b>	Regional Ocean Observing System (of GOOS)
<b>PIRATA</b>	Prediction and Research Moored Array in the Atlantic
<b>RFM</b>	Regional Fisheries Management
<b>RRI</b>	Responsible Research and Innovation
<b>SAMOC</b>	South Atlantic Meridional Overturning Circulation
<b>SA MRECO</b>	South Atlantic Patterns and Processes of the Ecosystems of the Southern Mid-Atlantic Ridge
<b>SAON</b>	Sustaining Arctic Observing Networks
<b>SCI</b>	Sites of Community Importance (EU Habitats Directive)
<b>SDG</b>	Sustainable Development Goal
<b>SEAS-ERA</b>	Towards integrated European marine research strategy and programmes (European FP7 project 2010-2014)
<b>SFPA</b>	Sea Fisheries Protection Authority
<b>SME</b>	Small and Medium-sized Enterprises
<b>SOCCO</b>	Southern Ocean Carbon and Climate Observatory
<b>SOLAS</b>	Surface Ocean Lower Atmosphere Study
<b>SOOS</b>	Southern Ocean Observing System
<b>SRIA</b>	Strategic Research and Innovation Agenda
<b>TAC</b>	Thematic Assembly Centre
<b>TPOS</b>	Tropical Pacific Observing System
<b>UN</b>	United Nations
<b>UNEP</b>	United Nations Environment Programme
<b>UNESCO</b>	United Nations Educational, Scientific and Cultural Organization

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<b>UNFCC</b>	UN Framework Convention on Climate Change
<b>WCRP</b>	World Climate Research Programme
<b>WFS</b>	Web Feature Service
<b>WMO</b>	World Meteorological Organization
<b>WMS</b>	Web Map Service
<b>WS</b>	Wild Species
<b>WTP</b>	Waterborne Technology Platform



