28 January 2022

European Union and its Member States contribution for the 2022 United Nations Informal Consultative Process on Oceans and the Law of the Sea "Ocean Observing"

European Union

Contribution of the European Union on the topic of focus of the twenty-second meeting of the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea: "Ocean Observing"

Background: Ocean Observing Significance

The global ocean, covering more than 70% of the Earth's surface, is the main regulator of the planet's climate, the largest carbon sink and biodiversity reservoir and is the primary resource for sustaining life, both marine and on land, including through its role in the water cycle. Either directly or indirectly, all life including humans, animals, and vegetation depends on the ocean for their sustenance, food, and well-being. Pressures from climate change, anthropogenic pollution, biodiversity loss and overexploitation of resources affect the ocean and can have significant environmental, social, and economic implications from the local to the global scale[1].

The Green Deal is the European Commission's response to the existential threats of climate change and environmental degradation. The ocean will play an important role in this new strategy for sustainable growth. The Ocean can and will be a source of clean energy, low emission food and a space where revolutionary innovation will provide new solutions for old challenges. It should also be a space where marine biodiversity is protected and restored, increasing the ocean's resilience to warming temperatures and its capacity to absorb carbon. To achieve the aforementioned progress in the marine domain, we need to improve our knowledge of the ocean environment, regarding all aspects, including from a socio-economic perspective, but also putting extra focus on the effects of climate change. Such knowledge is essential to achieve the decarbonisation of the EU and global economies, to protect coastal populations and to produce energy and high-quality food, while ensuring that the

[1] von Schuckmann et al. 2021, Copernicus Marine Service Ocean State Report, Issue 5, Journal of Operational Oceanography 14:sup1, 1-185, DOI: 10.1080/1755876X.2021.1946240

ocean and its ecosystems are not put under further pressure but are protected and restored. The foundation for marine knowledge is ocean observation.

European Union progress status regarding Ocean Observing

Data from ocean observation are essential for efficient, effective and safe operations of economic activity at sea and for measuring impacts on the environment, including with a view to their reduction. Observation is consequently undertaken or commissioned by public bodies responsible for activities such as research, fisheries management, environmental monitoring, safe navigation, coastal protection or licensing new offshore or coastal activities

The European Union has long ago recognised the importance of the Ocean in its political priorities and has taken significant action for a better consideration of the future of Seas and Ocean. Policies like the Marine Strategy Framework Directive[2] and the Marine Spatial Planning Directive[3] are instrumental and exemplary for increasing and consolidating Marine Knowledge and encouraging the EU Member States to establish and sustain Ocean Observation networks that will support efficient implementation of necessary measures.

Through targeted investments during the last two decades, the European Commission has established a robust foundation in Marine Knowledge: key ocean observations in-situ and satellite, European Research Infrastructures, and a wealth of research projects covering observations in all marine scientific fields.

European Marine Research Infrastructures (such as: EuroArgo, EMSO, EMBRC, JERICO and more) are diverse and range from fixed observatories, data centres to research vessels and autonomous vehicles that generate, analyse and apply in situ, remote sensed and modelled data and provide an array of services that aim to inform science, policy and society. These data and associated services are essential for ocean and coastal sea monitoring, biological and ecological research and for numerous established, and emerging, industries in the Blue Economy[4]

The European Marine Research Community, which includes marine institutes and universities, collects a large part of Ocean Observation, as their work is heavily dependent on the availability of continuous and abundant marine

[2] Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive)
[3] Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning
[4] The United Nations Decade of Ocean Science for Sustainable Development 2021-2030– IOC (2018) https://unesdoc.unesco.org/ark:/48223/pf0000261962

data. The European Commission, through its Research & Innovation Horizon programmes is also funding projects which aim in optimising and enhancing Ocean Observing Systems (such as: EuroSea, AtlantOS and more)

Additionally, observations for fisheries management are mostly carried out by national research institutes. Their outputs are used to support advice on measures under the Common Fisheries Policy, such as fisheries management plans, catch quotas, gear restrictions and area closures. The EU's Data Collection Framework[5] supports this activity with €75 million annually, while the EU Member States contribute with an investment amounting to €40 million annually.

EU Member States are collecting data and observations to be able to assess the environmental status of their waters, adopt adequate management measures and fulfil their obligations under relevant EU legislation (Marine Strategy Framework Directive, Water Framework Directive, the Habitats and Birds Directive, the Nitrates Directive and other environmental policies). Member States also collaborate and coordinate their data collection and observation activities with their neighbours in the different Regional Seas Conventions around Europe in which they are members, although the situation is uneven in this regard. Although the collection and use of marine data is not always specified in detail, the total spending amounts to a minimum of €100 million annually.

To ensure that the in-situ ocean observation collected through different sources[6] is consolidated, the European Commission has invested in the creation of the European Marine Observation and Data Network (EMODnet)[7]. EMODnet brings together more than 120 organisations, to aggregate the existing in-situ marine observation and data in the marine waters under the sovereignty and jurisdiction of the EU Member States, process them according to international standards, harmonise them and make them openly available as interoperable data layers and data products.

EMODnet provides access to European marine data and data products across seven disciplinary areas: bathymetry; geology; seabed habitats; chemistry; biology; physics and human activities. It is a *best-practice example of the benefits of efficient networking*: the different organisations brought together are collaborating to provide free access to marine data belonging to different data owners around Europe, while they invest in the creation of high-level, harmonised data products, which provide a detailed and integrated overview of the state of marine waters under the sovereignty and jurisdiction of the EU Member States. One key example out of many

[5] Regulation (EU) 2017/1004 of the European Parliament and of the Council of 17 May 2017 on the establishment of a Union framework for the collection, management and use of data in the fisheries sector and support for scientific advice regarding the common fisheries policy and repealing Council Regulation (EC) No 199/2008

[6] With the exception of data collected through the Data Collection Framework, which are considered proprietary and are made available in a consolidated format or under request.

[7] https://emodnet.ec.europa.eu/en

is the Bathymetry Digital Terrain Model, providing the highest resolution of bathymetrical data available in Europe, which is widely used for scientific and industrial purposes (hydrodynamic and climatic modelling; extraction of resources; planning and development of renewable energy facilities; etc.). Another key example is the harmonisation of the MS data regarding marine litter around the European coasts and seas.

Additionally to the thematic data services, EMODnet provides a Data Ingestion service, through which organisations, businesses and other stakeholders can bring forward their marine data and make them openly available.

In addition to in-situ observations, which are deployed by Member States or European research infrastructures supported by the Commission, the EU space programme holds an earth observation Component through its Copernicus programme[8]. Copernicus operates and maintains over time a fleet of satellites, the Sentinels (8 are deployed) to ensure global monitoring of the planet: oceans, atmosphere and land. In this frame, Sentinel 3 (altimeter and ocean colour sensor) and Sentinel 6 (precise reference altimetry) are satellite families with 2 deployed units each dedicated to the observation of ocean physics and biogeochemistry (e.g. sea level, sea surface temperature, current, sea-ice, waves, water quality, chlorophyll, nutrients, optical properties, minerals, etc.). In addition, the SAR mission Sentinel 1 is heavily used as well for sea ice monitoring, wind and wave monitoring as well as ship detection or oil pollution monitoring. Sentinel 2, a family of optical satellites is increasingly used for high resolution coastal monitoring (water quality, shoreline, bathymetry and land interfaces). Combining in situ ocean observation and remote sensing from space, Copernicus operates a marine service for real time monitoring, forecasting and climate predictions of the blue, green and white ocean (namely physics, biogeochemistry and ice). Copernicus regularly publishes long time series and reprocessing of in situ observations and ocean monitoring indicators[9]. The Copernicus programme is sustainable, with a fleet of satellites planned for launch and lifetime until the 2040s. By 2030, 2 additional satellites of Sentinel 3, 6 and new missions for the Arctic (CIMR, CRISTAL, ROSE-L) will be launched. The next generation to be launched post 2030s is currently under design.

The European Commission is working actively at the international level to support progress in relation to Ocean Observing, either by developing bilateral collaboration to exchange capacity and increase data sharing under international interoperability standards or by funding large scale international research collaboration efforts that include the sharing of ocean observation capacities (for example: All-Atlantic Research Alliance).

[8] https://www.copernicus.eu/en
[9] https://marine.copernicus.eu/access-data/ocean-monitoring-indicators

Ocean Observing gaps and future priority areas for the European Union

A recurring discussion during the last decades in the EU has concerned recognised gaps and organisational aspects related to the management of Ocean Observation. The European Commission's 2020 report on the implementation of the Marine Strategy Framework Directive[10] reported that the lack of sufficient data hampers Member States efforts to establish and implement targets and measures for good environmental status. The European Environment Agency "Marine messages" 2019 reported[11] that "*a large proportion of the formal EU nature/environmental/resource legislative reporting still includes many instances of 'unknown', 'not assessed', etc., despite decades of implementation efforts*."

In the field of the Common Fisheries Policy, there is also shortage of data on species stocks, which leads to the inability of the Intergovernmental Council for Exploration of the Sea (ICES) - the lead organisation for providing advice to the Commission for the stocks in northern waters - to provide advice in relation to maximum sustainable yields and therefore hinders efforts to achieve long term sustainability of fisheries[12,13]. In addition, while the data collected under the Data Collection Framework is often made available through various data sharing platforms, including EMODnet, as well as others such as the ICES DATRAS database, further work is required to ensure the more systematic sharing of data collected in specific regions such as the Mediterranean and Black Sea. The EU's new Biodiversity Strategy[14] requires more and better ocean data to "*effectively manage all protected areas, defining clear conservation objectives and measures, and monitoring them appropriately*". Better marine observation will be needed to "*take monitoring and outlook efforts to the next level*[15].

With the adoption of the Communication on a new approach for a sustainable blue economy in the EU[16], the Commission highlighted the relevance of blue economy in the effort towards the green and digital transition and the need to put maritime activities on a sustainable path. The Commission pointed out that "*Reliable, high-quality and harmonised ocean data are the prerequisite for a sustainable transformation of the blue economy*".

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[10] COM(2020) 259 final
[11] Marine messages II Navigating the course towards clean, healthy and productive seas through implementation of an ecosystem-based approach EEA Report 17/2019
[12] the largest yield (or catch) that can be taken from a species' stock over an indefinite period
[13] European Court of Auditors Marine environment: EU protection is wide but not deep
[14] EU Biodiversity Strategy for 2030 - Bringing nature back into our lives COM/2020/380 final
[15] Commission Staff Working Document "Towards a monitoring and outlook framework for the Zero Pollution Ambition" SWD(2021) 141
[16] COM(2021) 240 final

The OECD reports[17] that most targets for Sustainable Development Goal 14[18] are not measurable because the data are not yet available. Even at a European level, Eurostat reported[19] that the lack of data makes it impossible for example to analyse trends in dissolved nitrogen in the Atlantic, to gauge the true effect of over-fishing in the Mediterranean, or to draw conclusions as to the effectiveness and equity of marine protected areas.

In-situ observations are instrumental to deliver high quality ocean services with fit for purpose temporal and spatial resolution, and reduced uncertainties. This can be achieved if sufficient in-situ observations are available in all areas around the Earth both in surface and in depth. Such in-situ data is required for assimilation into models to ensure the representability and accuracy of models outputs; they are also necessary to calibrate satellite missions, validate the quality of processing and modelling and estimate uncertainties. The need for increased observations have been identified for the purpose of Copernicus marine service[20]. The most critical needs are in the area of biogeochemical observations, including carbon, deep sea and under ice observations, and better coverage or data sharing over regional seas and their coastal areas, in addition to the sustainability of existing observation network coverage. Such increase is deemed necessary to match the evolution of quality and resolution of the models expected to reach kilometric resolution at global scale and sub mesoscale resolution in regional and coastal seas in the decade to come.

In this regard, the European Digital Twin Ocean[21] infrastructure DTO) aims to provide consistent high-resolution, multi-dimensional description of the ocean: its physical, chemical, biological and socio-ecological and economical dimensions, with forecasting periods from season to multi-decades, transforming data into knowledge. Through co-creation and inter-disciplinary approaches, it will bring together in a single virtual environment all actors, actions and investments of the European Union, Member States and territories. The greater the number of ocean observations available, the more they adhere to common standards and the longer the time series, the more confidence we will have in the applications of the DTO, which is a priority in the EU and at international level.

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[17] OECD Issue Paper A preliminary assessment of indicators for SDG 14 on "Oceans" , November 201

[18] Conserve and sustainably use the oceans, seas and marine resources

[19] Eurostat, Sustainable development in the European Union Monitoring report on progress towards the SDGs in an EU context 2020 Edition

[20] https://marine.copernicus.eu/sites/default/files/inline-files/CMEMS-requirements-In_Situ_03_2021_VF.pdf

[21] The European Digital Twin is going to be underpinned through a series of actions which have initiated with through the EU Green Deal Call and will continue through the Mission Restore our Seas and Oceans by 2030. It will build on existing EC assets, as Copernicus Marine, EMODnet and the marine European Research Infrastructure Consortia and will consolidate an array of activities, aiming in the consolidated description of the ocean, its ecosystems and the influence of human activities.

Taking into consideration the aforementioned, the European Commission has proposed and is currently developing an ***Ocean Observation Initiative***. The purpose of the initiative is to provide the most efficient and effective process for programming and implementing ocean observation in order to provide a sound basis for national, EU and international measures to protect and restore marine biodiversity and ecosystems, mitigate and adapt to climate change, monitor and guide the biodiversity strategy, strengthen the blue economy and underpin EU policies through more transparency and more collectiveness. Transparency is to be understood as accessible information on what needs to be observed, what is being observed, what will be observed, how it will be observed, and dissemination of this information to all potential users and actors. Collectiveness means a process whereby the very diverse institutions in EU Member States engaging in observation or requiring observation work together in collective discussion and make collective decisions.

The initiative aims to achieve a coherent approach to European ocean observation that will allow EU Member States to build and operate a marine observation infrastructure that meets their priorities, maximises the potential for measuring once and using the data for many purposes. It should facilitate the sharing of responsibility and assets between different communities and different countries in order to produce the most effective results for the least cost, to face the challenges of our rapidly changing oceans.

In 2020, in the context of the aforementioned initiative, the European Commission launched a study[22] on Marine Technology on the state of the development of sensors and platforms in ocean observation. According to the study, with the introduction of new technologies such as sensors and drones, the amount of data collected from the ocean will continue to increase. A collective approach in EU Ocean Observation is likely to stimulate an increase in the European market for relevant equipment, thus capitalising in the significant existing investment in research. Through the EU's 7th Framework Programme for Research and Innovation, €50 million have been invested in the development of sensors for the "Oceans of Tomorrow", while similar amounts have been invested under Horizon 2020, the 2014-2020 Framework programme for research and innovation. The consolidation aimed through the EU Ocean Observation initiative can provide thus an opportunity for the European sensors and equipment market to get established and grow significantly.

[22] https://cinea.ec.europa.eu/publications/uptake-new-technology-ocean-observation_en

International Collaboration prospects in Ocean Observation

Ocean observation and the related services are an essential element for building the knowledge base for International Ocean Governance. Strengthening international ocean research and data is one of the three central pillars of the EU's International Ocean Governance Agenda (IOG) adopted in 2016[23]. The European Commission's assets, EMODnet, Copernicus Marine Services and the Ocean State report were highlighted in the 2019 IOG progress report[24] among the flagship actions taken to implement the IOG Agenda. Since ocean observations have also featured in the recommendations from the relevant stakeholder consultation as a key avenue to strengthen the ocean knowledge base, they should also be covered in the new proposal for an International Ocean Governance Agenda to be adopted in 2022.

Marine Knowledge, specifically Ocean Observation, satellite and in-situ, are also at the core of the UN Decade of Ocean Science for Sustainable Development. Activities undertaken under the IOG will contribute towards the goals of the decade, while Copernicus Marine and EMODnet are also expected to contribute towards these goals, representing the European Commission contribution to the Decade. Currently, the European Commission, through its services and EMODnet is represented in the Ocean Decade Coordination Group, aiming to identify opportunities for collaboration, to exchange of good practices and to achieve substantial progress in the interoperability and open sharing of ocean observation at the global level. The European Commission is also participating in the G7 Future of our Seas and Oceans Initiative (FSOI), where all of the priority areas are related to better coordination and sharing of Ocean Observation, from networks, to infrastructure and advancement of technologies. In both the aforementioned international fora, the need for more coordinated action regarding global Ocean Observing is considered as fundamental.

Given the scarcity of biological observations and the progressive development of ecosystem models at operational scale (as required by increased policy development in relation to biodiversity protection, restoration and sustainable use, climate change and its impact on marine biodiversity and ecosystems), it is critical to encourage an open and large international cooperation on the subject. This collaboration should focus on structuring the

[23] https://ec.europa.eu/oceans-and-fisheries/ocean/international-ocean-governance_en
[24] JOINT REPORT TO THE EUROPEAN PARLIAMENT AND THE COUNCIL Improving International Ocean Governance – Two years of progress - JOIN/2019/4 final

collection, harmonization and sharing of biological information, whatever their sources and types, with an appropriate governance, fostering open and free data policies as well as data preservation. Although there are still gaps in some other sectors, such as with regard to physical and chemical observation, this is partly compensated by operational and fairly automated capacities in ocean observation, with in-situ platforms, surveys and satellites providing standardised flow of data (where available). On the other hand, biodiversity data are very different and cannot be as easily automated, and thus making this more expensive to obtain. Furthermore, this becomes even more complicated because of the difference of biodiversity in different regions. This lack of data explains why biodiversity modelling is yet not very well developed.

Belgium

Initiatives/activities at the Federal level

Ocean observing is of the utmost importance for Belgium, as we need to know, in order to protect. Belgium uses all kinds of means to perform ocean observations. Ships (including the **Research Vessel "Belgica",** but also other 'vessels of opportunity') and the **OO-MMM** plane stand out as platforms for data collection/ocean observation, but **satellite monitoring** and **other autonomous measuring systems** (such as measuring buoys and tripodes with measuring equipment placed on the seabed) are also used intensively. We are also moving more and more towards deploying ROVs (Remotely Operated Vehicles), **AUVs** (Autonomous Underwater Vehicles), **ocean gliders** etc.

In principle, the work of all the marine research groups of the **Royal Belgian Institute of Natural Sciences (RBINS)** can be framed within it. This is both in relation to increasing the fundamental understanding of marine processes, ensuring the sustainable use of marine resources (biotic and abiotic), making marine forecasts for the benefit of all kinds of users, national MSFD reporting, etc.

An overview of the themes/activities per research group, can be found on the website of Royal Belgian Institute of Natural Sciences (RBINS):https://www.naturalsciences.be/en/science/do/98

Here the vision and mission of OD Nature are displayed, and it is also possible to click through to the different research groups and get an overview of the themes of these groups.

The following are related to the marine environment:

- **ATECO, part MARECO (Marine Ecology and Management)**: https://www.naturalsciences.be/en/science/do/98/page/2521
- **BEDIC** (Biodiversity & Ecosystems Data & Information Centre; storing data and making them available to the various users, as well as quality control, are indeed at least as important as collecting the data): https://www.naturalsciences.be/en/science/do/537/scientificresearch/research-programmes/98
- **ECOCHEM** (Ecosystems Physico-Chemistry): https://www.naturalsciences.be/en/science/do/534/scientific-research/researchprogrammes/98
- **ECODAM** (Ecosystems Processing and Modelling):

https://www.naturalsciences.be/en/science/do/535/scientific-research/researchprogrammes/98 ; four teams in this group (see below) • REMSEM (Remote Sensing and Ecosystem Modelling): http://odnature.naturalsciences.be/remsem/

- **SUMO** (Suspended Matter and Seabed Monitoring and Modeling): https://www.naturalsciences.be/en/science/do/98/page/2471
- **ECOMOD** (Ecosystem Modelling): https://www.naturalsciences.be/en/science/do/98/page/2475
- **MFC** (Marine Forecasting Centre): https://www.naturalsciences.be/en/science/template/2644
- **MUMM** (Management Unit of the Mathematical Model of the North Sea), including both the MARIMA (Marine Management) and SURV (Aerial Surveillance) teams: https://www.naturalsciences.be/en/science/do/538/scientific-research/researchprogrammes/98 , more detail at https://odnature.naturalsciences.be/mumm/
- **MSO** (Measurement Service Ostend & RV Belgica): https://www.naturalsciences.be/en/science/do/536/scientific-research/researchprogrammes/98, more on the Belgica also on https://odnature.naturalsciences.be/belgica/

RBINS is also represented through several of the above-mentioned research groups in various international projects, consortia, agreements, etc. dedicated to Ocean Observation. Here it is mainly about integrating, standardizing, expanding the many national ocean observation efforts in international (regional, European and global) context, creating frameworks for exchange of research infrastructure etc.

- **EuroGOOS** https://eurogoos.eu/, the European component of the Global Ocean Observing System (GOOS, https://www.goosocean.org/) of the Intergovernmental Oceanographic Commission of UNESCO, the EuroGOOS secretariat is incidentally housed at RBINS and our colleague S. Legrand is currently also the chairman of one of the five regional components of EuroGOOS (of the North West Shelf Operational Oceanographic System NOOS, of which the Emergency Sea is part; http://noos.eurogoos.eu/)
- **ERICO project** https://www.jerico-ri.eu/
- **Project Eurofleets** https://www.eurofleets.eu/
- **Project EuroSea** https://eurosea.eu/ , here we are only involved for the communication of the results

Initiatives/activities at the sub-national level

Herewith a list of published documents relevant to the topic of ocean observing, produced in the context of projects and initiatives where a contribution was made by Flemish experts, by the **VLIZ (The Flanders Marine Institute)** or documents published by our international partner European Marine Board (of which Belspo and EWI/VLIZ are members).

SCIENCE-POLICY and STRATEGIC DOCUMENTS ON OCEAN OBSERVATIONS

- **H2020 EuroSea project deliverable "Report on initiatives, strategies and roadmaps that contribute to foresight in ocean observation"** https://www.marineboard.eu/publications/report-initiatives-strategies-and-roadmapscontribute-foresight-ocean-observation (good for a general overview on how complex the governance is on Ocean observation)
- **European Marine Board (EMB) Policy Brief on "Sustaining in situ Ocean Observations in the Age of the Digital Ocean"** https://www.marineboard.eu/publications/sustaining-situ-oceanobservations-age-digital-ocean
- **EMB Policy Brief on "Next Generation European Research Vessels"** https://www.marineboard.eu/publications/next-generation-european-research-vessels (and the more detailed Position Paper)-> deze publicatie werd gelanceerd op de EUROCEAN Conferentie in 2019 en wordt als belangrijk vertrekpunt gebruikt in de aankomende 'OneOcean Summit' in Brest (FR) 9-11 Februari 2022.
- **EMB Future Science Brief on "Strengthening Europe's Capability in Biological Ocean Observations"**
- **The European Ocean Observing System Strategy for 2018-2022** (the Strategy is currently being updated, but major changes in the vision and mission are not expected) https://www.eoos-ocean.eu/download/eoos-strategy-2018-2022-october2018/?wpdmdl=1126&refresh=61e52cadd9db41642409133 (the EOOS website is being revamped, so hopefully this link will work in the future)
- **The European Global Ocean Observing System (EuroGOOS) 2030 Strategy** https://eurogoos.eu/download/?wpdmdl=10076
- **EuroSea, EuroGOOS, GOOS Survey Report to European GOOS National Focal Points on "Funding and Coordination across Ocean Observing and Marine monitoring in Europe"** https://www.eoos-ocean.eu/download/eoos-survey-of-goos-national-focalpoints/?wpdmdl=1150&refresh=61e52d2b726a11642409259

- **7 H2020 projects' report on sustainable ocean observation and management** https://eurosea.eu/download/nourishing-blue-economy-and-sharing-oceanknowledge/?wpdmdl=3973&refresh=61e5307e5e92a1642410110
- **G7 Future of the Seas and Ocean Initiative (FSOI) activities on Ocean Observation** https://www.g7fsoi.org/activities/
- **EU4OceanObs action on international ocean governance for the enhanced collection and use of ocean data for societal benefit on a global scale** https://www.eu4oceanobs.eu/

VLIZ (Flanders Marine Institute) SCIENTIFIC PUBLICATIONS

• **Steinhoff, T.; Gkritzalis, T.; Lauvset, S.K.; Jones, S.; Schuster, U.; Olsen, A.; Becker, M.; Bozzano, R.; Brunetti, F.; Cantoni, C.; Cardin, V.; Diverrès, D.; Fiedler, B.; Fransson, A.; Giani, M.; Hartman, S.; Hoppema, M.; Jeansson, E.; Johannessen, T.; Kitidis, V.; Kortzinger, A.; Landa, C.; Lefèvre, N.; Luchetta, A.; Naudts, L.; Nightingale, P.D.; Omar, A.M.; Pensieri, S.; Pfeil, B.; Castaño-Primo, R.; Rehder, G.; Rutgersson, A.; Sanders, R.; Schewe, I.; Siena, G.; Skjelvan, I.; Soltwedel, T.; van Heuven, S.; Watson, A.** (2019). Constraining the oceanic uptake and fluxes of greenhouse gases by building an ocean network of certified stations: the ocean component of the Integrated Carbon Observation System, ICOS-Oceans. Front. Mar. Sci. 6: 544. https://dx.doi.org/10.3389/fmars.2019.00544 , details

• **Theetaert, H.; Gkritzalis, T.; Hartman, S.; Brown, P.; McGarry, E.** (2020). Surface water CO2 measurements in the North Atlantic Ocean: optimize methodologies and analytical procedures, in: ICOS Science Conference 2020: Book of Abstracts. pp. 82, details

• **Gkritzalis, T.; T'Jampens, M.; Theetaert, H.; Cattrijsse, A.; Houthoofdt, R**. (2018). The Flanders Marine Institute (VLIZ) ICOS Ocean Stations. Marine Inorganic Carbon and GHGs observations in the southern part of the North Sea. Summary of poster presented at VLIZ ICOS Science Conference 2018. Flanders Marine Institute (VLIZ): Oostende. , details (2020). ICOS Science Conference 2020: Book of Abstracts. Integrated Carbon Observation System (ICOS): Europe. 137 pp., details

• **Amadei Martínez, L.; Mortelmans, J.; Dillen, N.; Debusschere, E.; Deneudt, K.** (2020). LifeWatch observatory data: phytoplankton observations in the Belgian Part of the North Sea. Biodiversity Data Journal 8: e57236. https://dx.doi.org/10.3897/bdj.8.e57236, details

• **Deneudt, K.; Reubens, J.; Mortelmans, J.; Debusschere, E.; Knockaert, C.; Tyberghein, L.; Dekeyzer, S.; Hernandez, F.; Mees, J.** (2016). Building an innovative and multidisciplinary marine biodiversity observatory for Lifewatch, in: Degraer, S. et al. (Ed.) North Sea Open Science Conference 7-10/11/2016. Abstract Booklet. pp. 67, details

• **Desmet, P.; Van Hoey, S.; Reyserhove, L.; Brosens, D.; Oldoni, D.; Milotic, T.** (2019). Standardizing biologging data for LifeWatch: camera traps, acoustic telemetry and GPS tracking. Biodiversity Information Science and Standards 3: e37413. https://dx.doi.org/10.3897/biss.3.37413, details

• **Mortelmans, J.; Goossens, J.; Amadei Martínez, L.; Deneudt, K.; Cattrijsse, A.; Hernandez, F**. (2019). LifeWatch observatory data: zooplankton observations in the Belgian part of the North Sea. Geoscience Data Journal 6(2): 76-84. https://dx.doi.org/10.1002/gdj3.68, details

• **Mortelmans, J.; Ollevier, A.; Hernandez, C.; Deneudt, K.** (2020). LifeWatch biodiversity data: trends and dynamics of Copepods in the Belgian Part of the North Sea, in: Mees, J. et al. Book of abstracts – VLIZ Marine Science Day. Oostende, Belgium, 18 March 2020. VLIZ Special Publication, 84: pp. 67, details

RESEARCH INFRASTRUCTURES FOR OCEAN OBSERVATION

1) **EUROPEAN**

http://www.vliz.be/en/lifewatch

http://www.vliz.be/en/integrated-carbon-observation-system

http://www.vliz.be/en/european-marine-observation-and-data-network

VLIZ hosts the EMODnet secretariat and develops the central portal. VLIZ is also the coordinator of the BiologyLot.

2) **LOCAL**

http://www.vliz.be/en/vliz-monitoring

VIDEO

- **De Waegemaeker, B.; Fockedey, N.; De Smet, B.; Seys, J.** (2021). The European Research Infrastructures ICOS, LifeWatch & EMBRC, ***in:*** *Waegemaeker, B. et al. Video series 'Visit VLIZ virtually'. Series of 6 English spoken videos (with English and Dutch subtitles) focusing on a selection of VLIZ facilities that are not accessible due to Corona. pp. English spoken and subtitled. 4:46 min,* details

- **De Waegemaeker, B.; Fockedey, N.; De Smet, B.; Seys, J.** (2021). The European Research Infrastructures ICOS, LifeWatch & EMBRC, in: Waegemaeker, B. *et al. Video series 'Visit VLIZ virtually'. Series of 6 English spoken videos (with English and Dutch subtitles) focusing on a selection of VLIZ facilities that are not accessible due to Corona*. pp. English spoken and subtitled. 4:46 min, details

The Kingdom of Denmark

The Kingdom of Denmark would like to call attention to the following potential sub-topics of the theme "Ocean Observing":

● Strengthen the collaboration across nations during UN's Ocean Decade[25]

● Expanding Biological Observing Networks and Marine Biodiversity Observations into the Central Arctic Ocean and other areas previously covered by sea ice

● Develop and maintain sea level references in order to track global and regional sea level rise, land subsidence and related phenomena

● Develop and maintain gravity field reference surfaces to support ocean circulation monitoring from space

● Facilitate the mapping uptake of multi-sensor bathymetry (lidar, echo soundings of opportunity) in under-surveyed regions, especially in the Arctic

[25] Denmark, Dansk Center for Havforskning https://www.havforskning.dk/ took the initiative to establish the Action plan for the Arctic Oceans.

Estonia

Estonia, as a small marine country on the coast of the Baltic Sea acts on marine/ocean observations on several levels:

- First, at local, national level. Here the main task and legal obligation is to plan and execute measures to achieve a good ecological status of our marine area in the Baltic Sea, reduce pollution and nutrient loads, develop sustainable blue economy and protect our valuable marine species and habitats. Environmental monitoring is also managed at national level by Estonian Ministry of the Environment through a National Environmental Monitoring Programme.
- Second, at regional, the Baltic Sea level. Tight cooperation between HELCOM countries and scientists has resulted in elaboration of science-based and -justified environmental status assessment system as well as the „Baltic Sea Action Plan" as a management tool to achieve good and healthy environmental status of the entire Baltic Sea. Also a „HELCOM Science Agenda" for the benefit of the Baltic Sea was elaborated in 2021, where further scientific development and innovation needs and priorities are agreed, incl. methodological development needs in marine monitoring and assessment schemes.
- Third, at European/EU level. Current cooperation between EU member states has been enforced by the implementation needs of the Marine Strategy Framework Directive. Legally binding cooperation needs between countries as well as on regional level are set there, as well as specifications and standardised methods for monitoring and assessment of marine waters. At EU level a cooperation between different marine regions of Europe and development of joint data centres to gather and share monitoring data are rather important. Joint EU databases and info systems like COPERNICUS, EMODnet and others (incl. regional databases) provide valuable platforms for scientists and other data users easy to access and share their data. Clear reporting formats and metadata requirements have been agreed which guarantees accessible and reusable data for all.

Based on our current practices – the crucial issue is to guarantee proper data collection and monitoring as a base for further assessments and development work. Baltic Sea is one of the world's largest brackish water bodies with shallow water, which makes it an extremely fragile ecosystem. The water transparency and euphotic zone are limited. Due to these natural pecularities Estonian marine scientists have a good experience in monitoring of upper layers of the water column, e.g. using and developing remote sensing and automatic monitoring tools and platforms. Although introduction of new technologies, developed by scientific research projects to national environmental monitoring takes some time, we have good experiences in testing new equipment and methods (e.g. eDNA) to upgrade also routine monitoring and enhance cooperation between different scientific fields. Joint and harmonized data collection provide valuable synergies and possibilities for innovation by different stakeholders and data-users.

As an example of the best practice of ocean monitoring technology development Tallinn Technical University and Estonian Environment Agency have further developed and implemented national operational sea ice monitoring service in Estonia. The service is based on Earth Observation data from Sentinel missions and Copernicus programme as well as on citizen science observational data (https://jaakaart.envir.ee/, in Estonian only). This service, developed at the national level, is transferrable to the other states who deal with seasonal sea and lake ice coverage, and to the member states of the Arctic Council in a global scale. Our neighbouring countries Finland and Sweden have already shown interest in implementing the sea ice monitoring system components developed in Estonia.

At EU level a lot of efforts and resources have been used for development joint databases and data centres (SeaDataNet, COPERNICUS etc). There is well established collaboration between EU countries and UK on the Marine and Ocean Observations using satellite data and delivering marine weather and ocean services (e.g. forecasts, reanalysis) within the Copernicus Marine Environmental Monitoring Service (CMEMS).

Equally important is also to develop cross-border observation systems between different marine regions that are currently not in place. Without developing broader monitoring system it's hard to believe that our datacentres services can be improved essentially. Planning effective *in situ* monitoring, several data and assessment needs should be taken into account – e.g. environmental issues, operative prognosis, climate change, extremal events, scientific questions etc. By understanding and recognising different tasks and data needs of stakeholders, monitoring and observations can be developed in an integrated manner enabling also co-financing by different data-producers and -users. In addition to declaring the importance of cooperation, states should take actual obligations to finance or provide means for cross-border observations.

Acknowledging challenges and nuances on developing cross-regions ocean/marine observation systems, long-term processes must be taken into account same time as the operational monitoring tasks should be covered by these systems. The system must be usable and useful for broader range of data-users and generate data for science and research. Harmonization of practices and cross-border coordination need to be addressed as well as sharing and circulation of knowledge and experiences. Nevertheless, a pan-European (or wider) observation system would improve data-quality for both, monitoring and science needs, and also helps to save the costs. For these purposes a pan-European monitoring system and infrastructure JERICO RI development has been started (an integrated pan-European multidisciplinary and multi-platform research infrastructure dedicated to a holistic appraisal of coastal marine system changes) which enables to improve the quality of different marine services and data products.

Scientific cooperation between EU countries and within the CMEMS partner institutions is well established and is progressing fast (e.g. by issuing Ocean State Report each year). More efforts and funds should be allocated to facilitate global cooperation on ocean observations. In this respect Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans) is one of the valuable platforms for international cooperation between marine scientists.

Considering the policy goals, the human impact to our seas and oceans ecosystems will increase in near future. To achieve and keep the sustainability of our marine usage, proper assessment tools should be elaborated. As marine ecosystems are suffering from multiple anthropogenic pressures, the cumulative impacts of these pressures need to be assessed to avoid the collapse of marine ecosystems. In HELCOM region a Baltic Sea Pressure Index (BSPI) and Baltic Sea Impact Index (BSII) are developed, reflecting the level of human pressures and their impact on sensitive species and habitats respectively and allowing to assess cumulative impacts in the Baltic Sea. All the necessary input data layers and values of indices are available and downloadable as GIS-layers also at the HELCOM Map & Dataservice. For Estonian marine area a relevant web-based assessment tool with some amendments (e.g. for assessment of ecosystem services) have been developed (PlanWise4Blue) and was used also in the elaboration of our marine spatial plan. Despite that, there are still huge development needs in cumulative impact assessment methodologies to create a valuable tool for directing human activities and use of marine resources towards sustainability, thus enabling to achieve a good environmental status of our seas and oceans.

France

Contexte et enjeux de l'observation de l'Océan

L'océan est un pourvoyeur unique de services essentiels pour la société. Il régule le climat, fournit de la nourriture et de l'énergie, et soutient une série d'activités économiques importantes. Pourtant, l'océan et ses écosystèmes sont menacés. Ils subissent les effets du changement climatique (réchauffement, élévation du niveau de la mer, acidification, appauvrissement en oxygène) et d'autres pressions d'origine humaine telles que la pollution, la pêche, l'extraction des ressources et la destruction des habitats. Les Nations unies ont reconnu l'importance de l'océan dans leur Agenda 2030 pour le développement durable en incluant un objectif de développement durable (ODD 14) dédié à la "conservation et l'utilisation durable des océans, des mers et des ressources marines pour le développement durable". Pour y parvenir, il est essentiel d'améliorer la connaissance de toutes les parties du système marin, des mers côtières aux parties les plus profondes de l'océan mondial. Dans ce contexte les Nations unies ont lancé une Décennie pour les Sciences Océaniques au service du Développement Durable (2021-2030). Ainsi, il est aujourd'hui, plus que jamais, nécessaire d'observer et de surveiller l'océan en permanence afin de contribuer à cet objectif et d'accéder à un suivi du climat.

La France, pays doté du deuxième domaine maritime au monde, soutient aussi la nécessité d'une observation pérenne de l'océan et de sa surveillance qui fait l'objet d'un large consensus scientifique et politique. Il s'agit d'améliorer la capacité à observer, simuler, comprendre et prévoir l'océan pour guider les politiques de développement durable, notamment vis-à-vis des impacts anthropiques, de la gestion des ressources, des événements extrêmes et des échelles climatiques. Il est donc important de développer des services d'analyse et de prévision intégrant l'ensemble du domaine océanique du large à la côte.

Les actions nationales françaises en faveur de l'observation de l'Océan

La France est dotée d'un écosystème pour la recherche marine reconnu au niveau mondial. Les universités (le réseau national des Universités marines qui regroupe 17 universités https://www.universites-marines.fr/fr), les instituts de recherche français de premiers rangs mondiaux tels que l'Institut français de recherche pour l'exploitation de la mer (Ifremer) et le Centre national de la recherche scientifique (CNRS) et même des sociétés comme Mercator Ocean International sont ainsi engagés dans cette dynamique scientifique pour laquelle la

France est considérée comme leader. Cette dynamique s'appuie également sur un ensemble d'infrastructures de recherche et de programmes structurants nationaux soutenus par le ministère en charge de la recherche, permettant une coordination de ces acteurs aux niveaux national, européen et international. Ainsi, la Flotte océanographique française composée de navires de recherche, d'engins sous-marins et d'équipements mobiles permet aux scientifiques d'être présents sur l'ensemble de l'océan et des mers du globe. Au niveau national, l'observation de l'océan joue également un rôle clef dans le cadre du programme prioritaire de recherche (PPR) « Océan et Climat » piloté par le CNRS et l'Ifremer, annoncé par le Président de la République Emmanuel Macron et lancé le 8 juin 2021, qui bénéficie d'un budget de 40 millions d'euros et a reçu la labellisation de la Décennie pour les sciences océaniques.

Un défi scientifique majeur appelant à une forte coopération internationale

La communauté scientifique a joué un rôle important dans le développement du système d'observation de l'océan qui existe aujourd'hui. Des technologies, des méthodes et des normes ont été développées pour collecter un éventail toujours plus large de données marines. Étant donné que l'océan est coûteux d'accès et qu'il est très variable et imprévisible, il est difficile de collecter des données marines de manière systématique, en particulier dans les zones situées au large et dans les eaux plus profondes. Des efforts sont continuellement déployés pour améliorer les capacités, la durabilité, l'efficacité et pour réduire les coûts des équipements d'observation et de surveillance. Cependant, des lacunes importantes subsistent pour toute une série de paramètres géologiques, chimiques, biologiques et écologiques indispensables à la compréhension de la santé des océans et de ses liens avec le bien-être humain, ce qui fait de l'observation de l'océan un défi scientifique majeur. Au-delà de la collecte de données en continu (mesures satellitaires, mesures in-situ issues des réseaux de capteurs, de bouées et de mouillages et des campagnes en mer) qui permet de mieux surveiller et comprendre le fonctionnement de l'océan, de ses écosystèmes et de son rôle sur le climat, il est nécessaire d'assimiler les données collectées et de produire des modèles numériques notamment dans le domaine de l'océanographie opérationnelle ou de la modélisation climatique. Au-delà de ces utilisations, le concept de jumeau numérique, représentation virtuelle d'un système, issu d'un modèle ou d'un ensemble de modèles qui, lorsqu'ils sont intégrés et alimentés de manière appropriée avec des données pertinentes, peuvent être utilisés par les chercheurs et les utilisateurs finaux pour expliquer les changements passés et actuels du système, ambitionne de prévoir et d'analyser ce qui pourrait se produire sous différents scénarios, notamment socio-économiques. Le jumeau numérique de l'océan vise ainsi à fournir une description multidimensionnelle et à haute résolution cohérente de l'océan : ses dimensions physiques, chimiques, biologiques, intégrant les dimensions socio-écologiques et économiques, avec des périodes de prévision allant de la saison à plusieurs décennies, transformant les données en connaissance. Ce qui implique la prise en compte des questions d'observation, de modélisations numériques dont l'assimilation des données, avec l'apport du "big data", du calcul haute performance et de l'Intelligence Artificielle. Il suppose plus largement la capacité d'intégrer différentes solutions numériques dans une plateforme interactive permettant de tester et valider des scénarios impactant pour l'océan et l'environnement marin.

Compte tenu de l'inhérente complexité de l'observation de l'océan, la France insiste donc sur l'importance de la coopération internationale en complément des programmes nationaux. En ce sens, il conviendrait tout particulièrement de proposer un cadre de coordination permettant la planification stratégique de l'observation de l'océan dans le monde.

L'Union européenne, un acteur de premier plan dans l'observation de l'Océan

Les Etats membres de l'Union européenne disposent d'une capacité large et diversifiée en matière d'infrastructures de recherche marine et de plateformes d'observation de l'océan. Ces éléments structurants contribuent d'ores et déjà au développement de l'océanographie opérationnelle européenne. Dans ce cadre, le programme d'observation de la terre Copernicus et son service de surveillance du milieu marin (Copernicus Marine Environment Monitoring Service – CMEMS) est essentiel pour fournir par exemple des informations sur l'état analysé et prévu des paramètres physiques et biochimiques de l'océan notamment via les données satellites et in situ. De même, le réseau européen d'observation et de données marines (EMODNet) propose des produits et des métadonnées pour fournir aux utilisateurs publics et privés des données marines de qualité assurée, standardisées et harmonisées, interopérables et exemptes de restrictions sur l'utilisation et utilisables pour les modèles numériques.

L'Union fournit également un soutien à ses Etats membres afin de faciliter la mise en œuvre des objectifs européens de préservation de l'environnement marin. Ainsi, certains dispositifs de surveillance sont développés dans le cadre des appels à projet pour la mise en œuvre de la directive-cadre « stratégie pour le milieu marin » (DCSMM) 2008/56/CE, mise en place par la Direction Générale Environnement de la Commission Européenne. Il convient par ailleurs de rappeler que la Commission Européenne a également organisé une consultation sur l' « Observation des océans » en février 2021 dans l'objectif de recueillir des avis sur l'efficacité, l'efficience et la pertinence de l'observation de l'océan par l'UE et par ses États membres, ainsi que sur la manière d'améliorer cette observation.

Le nécessaire soutien aux initiatives multilatérales régionales et globales

La coopération internationale est aujourd'hui déjà particulièrement importante dans la mise en œuvre de certaines initiatives et accords régionaux de protection de l'environnement marin. Ainsi, les campagnes de survol SCANS (Small Cetaceans in European Atlantic waters and the North Sea) sont menées conjointement par les Etats européens de l'Atlantique nord-est (Portugal, Espagne, France, Royaume-Uni, Belgique, Hollande, Allemagne, Danemark, Suède et Norvège) depuis 1995. Autre exemple, la campagne ACCOBAMS Survey Initiative (ASI) a été organisée à l'été 2018, incluant un survol multi-cibles (mammifères marins, tortues marines, oiseaux marins, grands poissons, déchets flottants et activités humaines) de la presque totalité du bassin Méditerranéen.

A l'échelle multilatérale globale, la Commission océanographique intergouvernementale (COI) de l'Unesco fournit aux États membres un cadre essentiel de coopération pour l'étude de l'océan. En effet, l'un des principaux objectifs de la COI est d'aider les gouvernements à résoudre les problèmes liés à l'océan et aux côtes, en permettant le partage des connaissances, de l'information et des technologies et en coordonnant les programmes nationaux. Les grands programmes (Global Ocean Observing System - GOOS, ARGO, COAST…) doivent continuer à être soutenus, y compris dans leur déclinaison européenne (EuroGoos, EuroArgo, EMSO, JERICO). La France porte et participe à plusieurs programmes et projets internationaux et européens d'observations océaniques concernant les observations des écosystèmes côtiers et littoraux (ILICO au niveau national et participation au projet JERICO), des écosystèmes profonds (EMSO) et de la colonne d'eau (participation à l'infrastructure de recherche Euro-ARGO élément du programme international ARGO). Par ailleurs, l'observation de l'océan s'inscrit également tout particulièrement dans les priorités de la Décennie des Nations unies pour les sciences océaniques au service du développement durable (2021-2030).

L'observation de l'océan fait par ailleurs l'objet de discussions au sein d'autres enceintes multilatérales pertinentes. Il convient notamment de rappeler les travaux du « G7 sur l'avenir des mers et des océans », qui dès 2019 a publié une déclaration qui souligne l'importance des activités d'observation et de surveillance de l'océan et qui s'est traduit par la création d'un centre de coordination des plateformes d'observation de l'océan en lien avec GOOS.

<u>Portugal</u>

A sustainable and resilient **global Ocean observation system**, able to provide the acquisition of **high resolution and both short and long term time series** with a dense **geographical coverage**, feeding **open access databases** of comprehensive Ocean data, is fundamental for an adequate **holistic understanding of the Ocean** system and its interactions and processes, which include Ocean Circulation and Ocean-Atmosphere Interaction, with a deep impact on climate.

It is critical for well **constrained modeling of oceanic processes**, for **ecosystem monitoring and protection**, for monitoring **human activities and impacts**, for **safety** of operations at sea, and for effective **early warning** systems for coastal **population safety** and **mitigation of impacts** from marine hazards.

Besides observing the water column, **ocean floor and sub-seafloor observation with geophysical methods, instrumentation and monitoring** is also of high importance, namely in areas of potential **high geological hazard** (e.g. instrumentation at the seafloor of active fault zones detected by high resolution bathymetry, and sub-seafloor seismogenic zones through scientific drilling in the scope of the International Ocean Discovery Program - **IODP**) and areas of **hydrothermalism** and **gas seepage** (in particular **methane**) as these have an impact on marine hazards, the Ocean chemistry, extreme ecosystems, and potentially also on climate.

A comprehensive **global bathymetric observation with the adequate resolution** of the **Ocean floor** (e.g. SEAMAP 2030) is also a priority, as defined in the UN Decade of Ocean Science for Sustainable Development (2021-2030), with strong impacts on ecosystem mapping, identification of areas of potential hazard and modelling of oceanic processes.

This requires **global cooperation and coordination** of national, regional and global observing systems, open databases to access **validated ocean data** in commonly agreed standardized formats, and **promoting capacity development** of LDCs and SIDS, regarding setting up, operating and maintaining national ocean observing systems, and enabling them to fully access ocean data, make use of ocean data mining facilities, feed this data to global databases, improve data processing and modeling capacity to transform data into information, critical to support informed decisions.

Ocean Observation in Portugal

Portugal is part of major **international ocean observation and ocean data management initiatives**, such as GOOS, IODE, IODP, ESA, Copernicus, ERIC EMSO, EMODnet, SeadataNet, amongst many others.

The **real-time monitoring infrastructure MONIZEE**, operated by the Portuguese Hydrographic Institute comprehends **tide gauge** and **coastal HF radar** stations and **multiparametric buoys**.

Besides **long-term monitoring at fixed stations**, the observations conducted **onboard research vessels** during multidisciplinary surveys remain the main component for observation. These involve characterization of the **sea bottom structure** (bathymetry and sediments) and water column variability with **multisensory probes**. Ferry-box systems and other continuous pumping systems (e.g. IH continuous sampler for microplastic monitoring) are progressively being installed onboard research vessels (e.g. NI MARIO RUIVO) and on opportunity ships (program VOS, initiatives MARE). Portuguese SMES specialized in the development of these systems are providing monitoring services to research institutions and the private sector.

As concerns the global **ARGO Float Network**, critical to cover the gaps in the sparsely collected data from ships and in-situ ocean observations of temperature, salinity and biogeochemical parameters, with a higher temporal and spatial resolution, the Portuguese Institute for the Sea and Atmosphere (IPMA) will acquire, in 2022, one full biogeochemical ARGO float, one core ARGO float with dissolved oxygen sensor and four core ARGO floats, to be deployed in 2022 and 2023.

Several Portuguese research groups have been developing **Autonomous Underwater (AUVs)** and **Surface Vehicles (ASVs)**, including gliders, with emphasis on **low-cost** systems that operate standalone or in **multisystem cooperative swarms** with vessels and other platforms. This technology development is strongly supported by a well established **European and international cooperation**. These autonomous observations are complemented by in-situ **Remotely Operated Vehicles (ROV)** namely the ROV Luso, capable to dive down to 6,000m.

Portugal is one of the five funding members of the **EMSO-ERIC** (European Multidisciplinary Seafloor and water column Observatory) network, critical to monitor, in real-time and long-term, environmental processes related to the interaction between the geosphere, biosphere and hydrosphere. EMSO-PT will **ensure the Iberian Margin node of EMSO-ERIC**, contributing to the Atlantic EMSO network with **2 underwater observatories** equipped with EGIM–EMSO Generic Instrument Modules, to be deployed in 2022, complemented with data collected by other observing platforms, such as gliders, water column profiler and OBSs.

Portugal is taking the unique opportunity to replace the CAM (Continent, Azores and Madeira Islands) Ring with **SMART Submarine Cables** to develop a large, open seismic and environmental monitoring network, providing data in real time. The integration of sensors into future undersea telecommunications cable will open new opportunities to **detect earthquakes and tsunamis** as well as to better understand the **impact of climate change in the ocean**.

As part of the Atlantic International Research Centre (AIR Centre), headquartered on Terceira Island – Azores, Portugal, a distributed network involving a large number of countries, Portugal is strongly promoting **space-based ocean observation**, including through building and launching small satellites. Coastal hazards, ocean color, sustainable fisheries and aquaculture, marine biodiversity, ocean-atmosphere interaction, remote sensing of marine litter, and metabolism of coastal cities are some of the main areas of interest. The ***Atlantic Constellation*** "flagship" project consisting of **small satellites** (with multispectral, hyperspectral, GNSS-R, AIDS and IoT sensors) designated, will provide measurements with a frequency of 2-3 hours. The sea-surface and oceanic observation component, is lead by the "Atlantic Observatory – Data and Monitoring Infrastructure" coordinated by IPMA, with national partners from Azores (FRCT) and Madeira (ARDITI), with the implementation of high resolution observing platforms and an infrastructure for marine data management and dissemination, through close partnership with Norway and Iceland.

Identified Gaps in Global Ocean Observation

It is of the utmost importance to **strengthen the global ocean observing network**, through an increased participation in international programmes and ERICs related to ocean observing systems (e.g., Euro-Argo, EMSO and ICOS).

A global investment in **Ocean Bottom Observatories** can fill important gaps in current observations and early warning systems.

There is a need to strengthen the current **ARGO Float network** global coverage, including with bioeochemical sensors and with deep ARGO floats.

New technologies and the definition of best data acquisition strategies are required to ensure the **permanent water-column observation of large areas of the coastal ocean**. This comprises increasing autonomy/speed of autonomous vehicles and developing new technologies to **extend sensor lifetime** in presence of biofouling (particularly severe in coastal waters).

A new challenge is the global integration of sensors into future undersea telecommunications cables (**SMART cables**) with high impact on early detection of earthquakes and tsunamis as well as better understanding the impact of climate change in the ocean.

Another identified gap is a **global comprehensive observing and early warning system** for **extreme events** such as incoming storms, floods and other **marine hazards such as tsunamis**, for better protection of coastal populations.

There is a critical need to **map the ocean floor with the adequate detail with high resolution** bathymetry and aim at mapping the global ocean floor, possibly with the possible exception of shallow areas, by 2030. Mapping shallower areas with high resolution is however critical for **adequate modelling of marine hazards impacts** in coastal zones, namely extreme events and tsunamis, in particular for areas with a higher seismic and tsunami potential.

Another important gap is ocean **observation from space**, with increased temporal resolution. Conventional satellites provide measurements with a low frequency (normally days) and there is an urgent need to obtain space measurements with a higher frequency (every 2-3 hours) and lower latency (less 1 hour) for applications such as monitoring of natural disasters and extreme weather events, fishery protection, search and rescue operations or detailed modelling of ocean phenomena, among others. The only way to provide space data with high frequency is with a constellation of satellites. The miniaturization of components made possible the development of small satellites (micro or nano-satellites) with high performance, based on "New Space", new trend of the space industry in recent years, centered on applications of small systems. The use of satellites in the Space Component is fundamental, because it is an observation system that provides synoptic measurements of the ocean due to its very long field of view.

There is also a clear need of an **improved coherent international network of fixed-point observation of the water column structure (moored eulerian observatories)**, sampling regularly vertical profiles of the Essential Ocean Variables, at least. This is critical for the construction of long (climatological) eulerian time-series of the water column profiles to infer about the long-term variability of the ocean stratification, ocean stability, mixed layer depth, thermocline/pycnocline strength. This will allow determining climatic change effects in the ocean subsurface structure and in ecosystem functioning, as well as better parametrization of the ocean models and re-analysis.

Distributed observing systems can be improved with the development of **low cost sensors**, and involving the **collaboration of various stakeholders**, including fishing and maritime transport companies, making use of moored and floating existing structures, and also resorting to **citizen science** (e.g. sensors on sailing boats).

Better biodiversity assessment and monitoring of **marine animal migrations** are also essential.

Areas that can benefit from better cooperation and coordination

There is a clear need for **better articulation between observation programs**, **avoiding duplication of structures** and developing **synergies**, defining **common standards** and **harmonization of procedures** based on **best practices**, and **optimizing resources**.

The current challenge is to **fully embed and better coordinate national efforts with larger regional and global initiatives** (e.g. CEOS, GOOS, IODE, GEO, All-Atlantic Ocean Research Alliance, UN Decade of the Oceans, etc.) and to effectively increase international collaboration, namely in the Atlantic Area, including through fostering seamless **Trans-National Access to marine research infrastructures** (e.g. JA AA-MARINET, Eurofleets, POGO).

Areas that will clearly benefit from an improved global cooperation and coordination include:

- Improving **common strategies** for **integrated multisystem sampling**
- Developing the basis for implementing a **system of systems**
- **Improving capacity** (technologies, strategies) to monitor biological, biogeochemical, geological, chemical and sedimentary variables, both in the Coastal and Open Ocean
- Developing new strategies/technologies to reduce **biofouling** problems in observation platforms
- Enhancing **interoperability** between Ocean observing systems
- **Improving articulation between observing systems and numerical models** (assimilation models, adaptive sampling, planning, Observing System Simulation Experiments, …)
- Technological development and **Miniaturized, Low-Cost Sensors**
- **Improving Remote Detection** of oil spills, plastics and ocean contamination
- Better **integrated early warning systems for Ocean hazards** and accredited warning centers for the various regions of the globe

- Improved **Sea ice monitoring** and **marine operations safety**
- **Investment in human resources training** with skills on marine technology and ocean data management, including training at sea. The IOC Ocean Teacher Global Academy can have an important role in this sense.