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1. Executive summary

This document advocates an approach for developing a **European High Frequency Radar (HFR) network governance, based on the requirements of the community**.

The proposed governance and operating structures employed will:

- Foster the **development, management and execution** of the European HFR network roadmap.
- Enable broad international **collaboration.**
- Be capable of **sustaining HFR measurements** over extended, decadal timescales.
- Be readily scaled to **tackle new region**s and **value additional HFR data products** (e.g. waves, winds, derived added value products).
- Be adapted beyond the established European HFR community, by boosting **stakeholder engagement** and co-design of the European HFR strategy and implementation actions.

In **section 2**, the **global, European and regional landscape** of ocean observing thematic areas, strategic objectives and governance structures are reviewed in order to propose a governance of the European HFR network in line with the existing framework.

In this context, the role of the EuroGOOS HFR Task Team for structuring the European HFR network is described in **section 3**, as well as the established terms of reference, contribution in the EuroGOOS strategy **and links** with other EuroGOOS Task Teams and Working Groups. Moreover, a detailed overview of the **current status** and the **activities of the HFR network** as well as the main projects and milestones achieved over the last 5 years is provided. In order to monitor and track the HFR network progress on action steps and to evaluate its impact on an annual basis, a **quantitative framework** has been established incorporating a broad range of expertise, including science, decision and policy makers. Additionally, the governance plan, its implementation and practices will also be evaluated yearly.

Section 4 includes the **long-term strategy,** fully aligned with the five high-level objectives of EuroGOOS, **and the HFR community roadmap** for the next 3 years, comprising the tasks, mid-term milestones and outcomes of the four main areas of actions (e.g. 1-Management and community building; 2-Sustainability, 3-Product and services and 4-Research & Development). The future strategy involves the use of HFR data to support operational, seasonal to decadal planning by governments, industry, science and communities.

Built from an already existing framework, a **robust and sustained Governance structure** is designed and proposed in **section 5,** as well as the human and infrastructure resources required to deliver the strategy. The **5 main components,** of the proposed framework include: (i) an international Steering and Executive Committee for HFR roadmap planning and oversight; (ii) the European HFR Node to overseeing the day-to-day **management of HFR data**; (iii) the HFR Operators & Manufacturers Working Group for management of HFR operations and maintenance; (iv) the Stakeholder Panel to connect with stakeholder communities and leveraged engagement and the Advisory Board, overarching guidance for defining the HFR network strategy. **For each of these elements**, the **composition**, their **roles/tasks**, the type and frequency of **meetings** and the future **strategy** for their implementation are addressed. Additionally, the **relationship** (in terms of data or policies/advice/process flow) between the different boards and committees are also established, thus creating a feedback loop ensuring a sustained governance able to respond to changing priorities and challenges over time as an iterative process. The governance framework should also be able to respond to new information, making data updates at annual or longer timeframes sufficient.

Concluding remarks are included in section **6**.

2. Introduction

The **mission of the EuroSea** project is **co-designing European ocean observing and forecasting services** and products that deliver information and support decision-making in the areas of climate, coastal and maritime activities, and ocean health.

Among coastal observing technologies, **High Frequency Radar** (HFR) is a land-based remote sensing instrument offering a unique insight to surface coastal ocean variability. The cooperative and transformative process of the **European HFR network** aims to increase its contribution and impact in the Operational oceanography value chain as a **key component of coastal observational systems.** The **global, European and regional landscape** of ocean observational networks will also be considered to establish the governance of the European HFR network.

2.1 HF radars as a key component of operational coastal oceanography

An increasingly high density of inhabitants gravitates for their living needs in littoral regions since marine ecosystems provide vital direct inputs. Nearshore areas are impacted by local anthropogenic pressures and further altered by massive international tourism. Apart from urbanization or habitat modification, other major coastal environmental issues include intense maritime traffic, harbor operations, marine litter pollution, oil spills, overfishing, marine heat waves or the proliferation of harmful algal blooms.

The “Decade of Ocean Science for sustainable development (2021-2030)” is an initiative recently launched by the United Nations to promote public awareness about such issues and engage governments for a healthy ocean by building an international cooperative infrastructure. To enhance nearshore communities’ resilience, operational coastal oceanography has emerged as the systematic activity of long-term accurate monitoring of the oceans and atmosphere. The backbone of operational oceanography consists of various interdependent core components, such as a multi-platform observation networks, robust ocean forecast systems and solid data management-accessibility infrastructures that can foster their rapid dissemination and interpretation for decision-making purposes.

The positive synergies between ocean forecast systems and coastal observations have underpinned the development of the so-called Blue Economy, by delivering customized fit-to-purpose downstream services of societal benefit to targeted sectors, ranging from aquaculture, fishery, recreational tourism and sports activities to transport, navigational safety, harbor services and coastal management. The existing operational ocean monitoring and forecasting systems, developed at regional scale over the past decades, must be expanded toward nearshore areas. This unavoidable need is going to be addressed though the EU Green Deal call named “Digital Twin of the Ocean” (DTO). The DTO consists of the integration of existing leading-edge capacities in ocean observation and forecasting with top-tier digital technologies (cloud infrastructures, supercomputing resources, etc.) to adequately provide a high-resolution, three-dimensional description of the ocean state in near real time. The main aim is to transform the intensive coastal ocean monitoring and data collection into added-value knowledge to further facilitate coherent, science-informed policy response, the conservation of natural resources and the effective maritime management with direct socioeconomic benefits.

In this regard, coastal HFR networks have rapidly grown worldwide as a profitable land-based asset for both commercial and research purposes, able to play a pivotal role. On one hand, HFRs provide fine-resolution maps of the surface circulation over broad areas in near real time. Additionally, they collect reliable wave information and estimations of local wind direction, although by today, these products remain rather unexplored. On the other hand, HFRs have proved to be cost-effective tools to monitor extreme coastal hazards, track pollutants or biological matter, enhance numerical simulations (by resolving fine-scale processes in intricate nearshore regions) and complement biogeochemical estimations provided by other observational platforms.

Given the broadly accepted credibility of HFRs on the latter fields, this technology must be integrated into robust analysis frameworks for improved marine governance over coastal resources. These frameworks should cover a range of dimensions, such as legislative, planning, infrastructure, technical, scientific and institutional partnerships at local and international levels. HFRs can positively contribute to the proper establishment of environmental policies and strategies, bridging the gap between research and societal challenges.

2.2 Components of the ocean observation landscape

In this section we provide an overview of the existing ocean observing network structures and how they are coordinated at global, European and regional levels.

As the ocean observing coordination involves a wide range of organizations, a clear governance model will help to optimize collaboration and integration of different actors and communities involved. We show here the nature and roles of the main already existing consolidated structures.

2.2.1 Global organizations

The Global Ocean Observing System of the Intergovernmental Oceanographic Commission of UNESCO (IOC GOOS) aims to provide one integrated system that can deliver ocean information across three key application areas: operational services, climate, and ocean health. GOOS defined the global strategy for 2030 with 11 strategic objectives focused on three areas (see Fig. 1): deepening engagement and impact, system integration and delivery, and building for the future.

Figure 1. GOOS Strategic objectives. Source: The Global Ocean Observing System 2030 Strategy (https://www.goosocean.org/index.php?option=com_oe&task=viewDocumentRecord&docID=24590)

The **GOOS governance model** is divided in three tiers: a multinational **Steering Committee** to provide oversight, **scientific Expert Panels** to guide system requirements, and the **Observation Coordination Group** (OCG) that implement global unified network execution. The GOOS **Project Office** facilitates the collaboration between different governance bodies: GOOS Expert panels (Physics and Climate OOPC, Biogeochemistry IOCCP, and Biology and Ecosystems GOOS-BioEco), GOOS Regional Alliances (GRAs), the Expert Team on Operational Ocean Forecast Systems (ETOOFS), and the OCG.

The **OCG** is charged to review, advise on, and coordinate across the global ocean observational networks to strengthen the effective implementation of a global ocean observing system (GOOS) from the observations side. A **key element** is advancing exchange of international metadata and system-wide monitoring capabilities through the **OceanOPS** programme (former JCOMMOPS).

For **HFR networks**, a **global** partnership (http://global-hfradar.org/) was established in 2012 as part of the Group on Earth Observations (GEO). In 2017, the Global HFR Network was recognized by the former Joint Technical WMO-IOC Commission for Oceanography and Marine Meteorology (JCOMM) as an observational network of the Global Ocean Observing System (GOOS), aiming to promote HFR technology and increase data sharing among operators and users (Roarty et al., 2019). The GEO HFR network governance is composed of 6 co-Chairs (with two European members). It is one of the networks coordinated under the OCG umbrella for GOOS purposes.

2.2.2 European ocean observing structures

In parallel with global initiatives, a strengthening in coordination at regional scale is necessary to ensure that the **right observations** are made and that they are made **on a systematic and sustained basis,** ensuring a better impact through co-designing and end-to-end implementation with stakeholders and users. An overarching strategy across all measurement platforms is required to ensure that best use is made of limited resources.

We list here the main structures in place coordinating the ocean observations at European level.

EuroGOOS – The European Global Ocean Observing System

EuroGOOS is the European regional component of GOOS. EuroGOOS is an association of national governmental agencies, research organizations, and private companies. Founded in 1994, EuroGOOS has today 44 members from 18 European countries providing ocean data, operational oceanographic services and carrying out marine research.

The **mission of EuroGOOS** focuses on aligning, integrating and promoting Europe's Ocean observing capacity. EuroGOOS's five objectives are: i) Coordinated representation; ii) Promotion of strategies; iii) Harmonized contributions; iv) Engagement; v) Networking.

The **five main actions for the strategy 2021-2030** are aligned with the functional plan for EuroGOOS 2030 Strategy: i) Stimulate communities of practice; ii) Advocate for coordinated and integrated European ocean observing and operational oceanography; iii) Strengthen and expand partnerships; iv) Promote sustainability across the value chain of operational oceanography and ocean observing; v) Mobilise the public on the importance of the ocean and oceanographic services.

Considering the **EuroGOOS governance** structure (see Fig. 2), the strategies and actions are decided by a **General Assembly** and an **Executive Board of Directors**. Actions are coordinated by the **EuroGOOS Office**, the **Board**, subsidiary bodies (Regional Ocean Observing Systems -ROOSs-, Working Groups -WGs- and observing Task Teams -TTs-) and they are implemented by the **members** (with own resources or projects funding). Development of ocean observing systems is carried out by the **ROOSes**. **Working groups** produce strategies, priorities and standards. Ocean Observational **Task Teams** organize and develop the individual observation communities and foster cooperation, also promoting synergy and technological collaboration among European ocean observing infrastructures in connection with the OCG programs. The EuroGOOS HFR Task Team plays a major role in structuring the European HF Radar community. Its role, structure and recent achievements will be detailed in section 3.

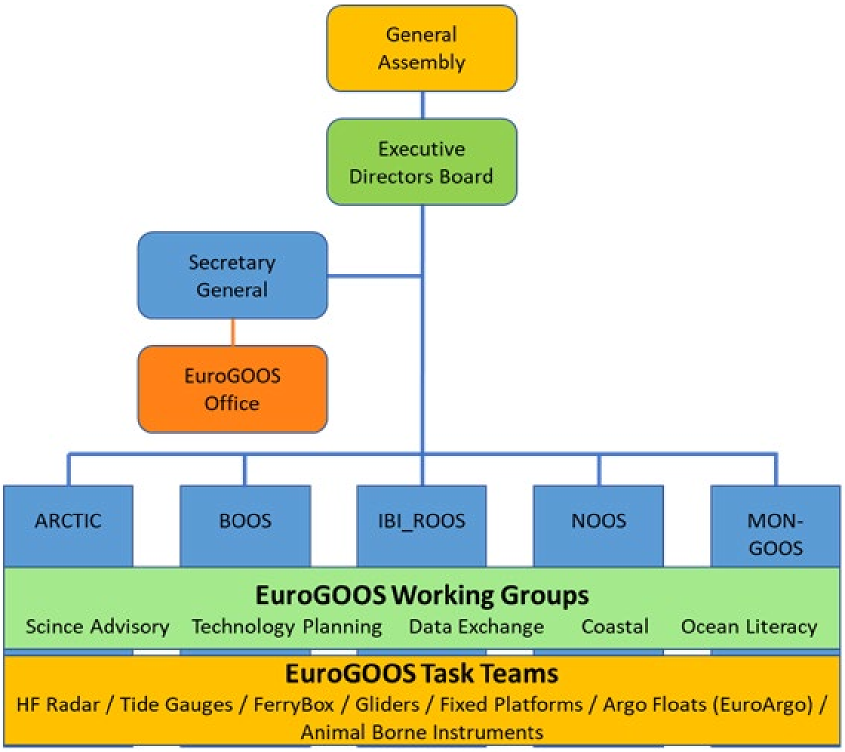

Figure 2.- EuroGOOS Governance structure (source EuroGOOS Office)

EOOS

A major part of EuroGOOS activities are developed within the framework of the **European Ocean Observing System**, (**EOOS**). The need for an end-to-end integrated and sustained EOOS, has been expressed by the oceanographic and scientific community during the development of the European Integrated Maritime Policy in 2007. In 2008, EuroGOOS and European Marine Board released a joint vision document (pdf) to outline the concept of this framework. EOOS has been consolidated as a coordinating framework designed to align and integrate Europe's ocean observing capacity. In addition to the predominant role of the Member States in the implementation and sustainability of the networks, European Commission's ocean observation initiatives need to be coordinated.

The **EOOS governance** structure (https://www.eoos-ocean.eu/governance/) includes four structures: the **Steering Group**, top level of the EOOS governance approving all decisions; the **Advisory Committee** that advises the Steering Group, bringing together a broader stakeholder base; the **Resource Forum** that represents the ministries and funding organizations of ocean observations in Europe; and the **Operations Committee (OC)** which represents the diversity of the ocean observing implementers at national, regional and pan-European levels. The chairs of the EuroGOOS Observing Systems Task Teams are members of the **OC**, as well as the ROOS chairs, the GOOS National Contact points and the European Marine Environmental Research Infrastructures.

In the last few decades, most of the observing networks have made significant progress in terms of European and Global coordination, with well-established infrastructure for some of them (See Table 1).

Table 1 - Status of the main European in-situ observing networks.

Observing platforms	Observational framework	Global coordination	European coordination	European infrastructure
Argo floats	Open ocean and European Marginal seas	Argo International	EuroGOOS Task Team	EuroARGO ERIC
Gliders	Open ocean	OceanGliders	EuroGOOS Task Team	GROOM II
	Coastal			JERICO RI
Fixed platforms	Open ocean	OceanSITES, DBCP	EuroGOOS Task Team	EMSO ERIC
	Coastal	DBCP		JERICO RI
Tide Gauges	Coastal	GLOSS	EuroGOOS Task Team	
HF Radars	Coastal	Global HFR Network	EuroGOOS Task Team	JERICO RI
Vessels	Opean Ocean - Coastal	SOT, GO-SHIP		EuroFLEETS RI
Ferry Boxes	Opean Ocean - Coastal		EuroGOOS Task Team	JERICO RI

Environmental Research Infrastructures

Research Infrastructures (RIs) are facilities that provide resources and services for research communities to conduct research and foster innovation[1]. The European Research Infrastructure Consortiums (ERICs) are a specific legal form that facilitates the establishment and operation of RIs with European interest.

Several observational communities have been playing an increasing role aiming at establishing strategies for well-established pan-European, intergovernmental or national RIs. During the last decade, different ocean observational efforts have been consolidated as sustained pan-European RIs through joint commitments of selected member states.

Established in 2014 the **Euro-Argo** (www.euro-argo.eu) ERIC sustains and optimises the European contribution to the international Argo programme. Hosted by Ifremer (France) and composed by 12 EU countries it deploys 25% of the global floats network (around 250 floats/year). In 2016, the **EMSO** (European Multidisciplinary Seafloor and water column Observatory) ERIC was established. EMSO is built by a set of regional platforms around Europe equipped with multiple BGC and physical sensors (water column and sea floor). EMSO provides different biogeochemical and physical parameters, which address natural hazards, climate change and marine ecosystems, with the aim to explain the critical role that these phenomena play in the broader Earth systems.

Also, the glider community is in the process of designing a European Marine RI, through the EC-H2020 funded project "Gliders For Research, Ocean Observations and Management: Infrastructure and Innovation" (GROOM II, www.groom-h2020.eu). GROOM II aims to build this network of distributed and fragmented infrastructures to a formal and sustained organization offering a world-class service to different stakeholders (research organizations, industry).

Another important component of the in-situ observation landscape is the **JERICO-RI** (www.jerico-ri). JERICO-RI is an integrated pan-European multidisciplinary and multiplatform Research infrastructure dedicated to the observation of the coastal marine system. JERICO-RI provides open-access to state-of-the-art, innovative facilities, resources, multidisciplinary FAIR data and fit-for-purpose services. JERICO-RI aims to foster international science collaboration, providing the base for integrated coastal research. The development of the JERICO-RI has been based on the outcomes of JERICO-FP7 and JERICO-NEXT (H2020) EU funded projects and is ongoing in the present, grounded by the progress of JERICO-S3 and the strategic outcomes of JERICO-DS (H2020) projects and the application for the ESFRI (European Strategy Forum on Research Infrastructures) roadmap in 2021.

As an example of an **ERIC governance** (shown in Fig. 3), the Euro-Argo ERIC is governed by the following bodies:

- The **Council** is the body having ultimate decision-making authority. It is composed of one delegate per Member State acting collectively. The Council elects its Chair among its members for a duration of three

[1] 'Research infrastructure' means facilities, resources and related services that are used by the scientific community to conduct top-level research in their respective fields and covers major scientific equipment or sets of instruments; knowledge-based resources such as collections, archives or structures for scientific information; enabling Information and Communications Technology-based infrastructures such as Grid, computing, software and communication, or any other entity of a unique nature essential to achieve excellence in research. (Article 2(a) of the ERIC regulation).

years. A co-Chair shall be elected by a qualified majority of the Council to carry out the duties of the Chair in case of her/his absence. The Council meets twice a year.

- The **Management Board** supervises the operation of the infrastructure and ensures that it operates and evolves in accordance with the strategic direction set by the Council, and the requirements set forth by the research and operational communities. The Management Board is composed of delegates designated by the Members and Observers. The Programme Manager and the Euro-Argo ERIC team take part in a consultative capacity in the Management Board meetings. The Management Board meets three times per year.

- The **Scientific and Technical Advisory Group (STAG)**, consisting of independent experts, is established to advise the Council on any scientific or technical matters (including data management and instrumentation) relevant to the operation, development, and evolution of the Euro-Argo ERIC, and access to its data by research and operational users. The STAG is also responsible for the scientific evaluation of the annual activities and participates in the User Workshop organised every 2 years. The STAG formulates recommendations to the Council on scientific and technical aspects and direction of the Euro-Argo ERIC, taking into account the European and international context. The Council may request the STAG to consider and make recommendations on issues that it needs to resolve.

- The **Programme Manager** is appointed by the Council, as the executive officer and legal representative of the Euro-Argo ERIC.

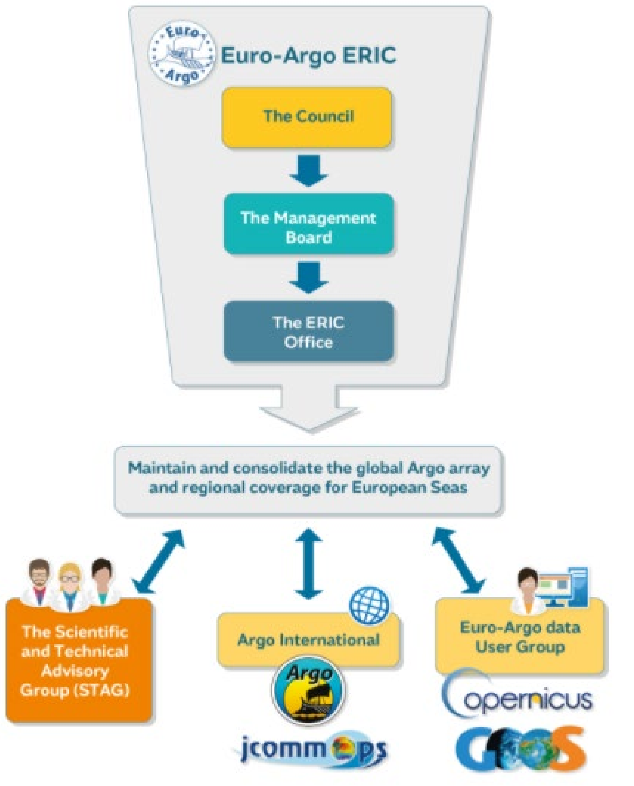

Figure 3. EuroARGO Governance. Source: https://www.euro-argo.eu/About-us/The-Research-Infrastructure/Organisation. Note: JCOMMOPS is the former name of the current OceanOPS.

In parallel, three European data and marine services devoted to **providing users with operational marine data and products** at a pan-European level, including HFR data. These are: the pan-European infrastructure for ocean and marine data management **SeaDataNet**, the European Marine Observation and Data network (**EMODnet**, Calewaert et al. 2016, Miguez et al. 2019), and the Copernicus Marine Environment Monitoring Service (**CMEMS**).

SeaDataNet is a distributed Marine Data Infrastructure in which almost all national oceanographic data centres in Europe are represented to enable **archiving and management** of large and diverse data sets from in situ observations of the seas and oceans and provides on-line integrated databases of standardized quality. SeaDataNet hosts various types of Metadata on observational efforts in Europe. SeaDataNet was established as non-profit association under the Belgian law (AISBL) in 2019.

The **European Marine Observation and Data Network, EMODnet**, is a **long-term marine initiative** implementing mechanism of the European Commission's Marine Knowledge 2020 strategy to **unlock the potential of Europe's wealth of marine data**. Based on the principle of collecting data once and using it many times for many purposes, **EMODnet is a network of organizations supported by the EU's Integrated Maritime Policy linked by a data management structure**. These organizations work together to facilitate the discovery and access to marine data and data products representing the following seven main themes: **bathymetry, biology, chemistry, geology, human activities, physics, and seabed habitats.** EMODnet provides a gateway to those marine data accompanied by their metadata and data products through a number of thematic portals, a central hub and an ingestion facility. It is developed by a large network of organizations that work together to: (i) observe the sea, (ii) process the data according to international standards and (iii) make that **information**, across the seven discipline-based themes, **freely available** as interoperable data layers and data products. Within the EMODnet program, EMODnet Physics links and makes available ocean physics data time series, profiles, and sampled datasets are made available, as recorded by fixed platforms (moorings, tide gauges, **HF radars**, etc.), moving platforms (ARGO, Lagrangian buoys, ferryboxes, etc.) and repeated observations (CTDs, etc.). Available products are collections of in situ data, reanalysis and trends from in situ data, elaboration in space and/or time of in situ data and model output for a given parameter.

Copernicus is the European Program for the establishment of a European capacity for Earth Observation and Monitoring. The Copernicus marine component (or Copernicus Marine Environment Monitoring Service, **CMEMS**) provides free, regular and systematic authoritative information on the state of the Blue (physical), White (sea ice) and Green (biogeochemical) ocean, on a global and regional scale. Within CMEMS, the Thematic Assembly Centers (TACs) are tasked with the collection of ocean observations, from both in situ (water column) and satellite observing systems. The mission of the In-Situ TAC (**INSTAC**, www.marineinsitu.eu) is to **provide integrated products** built from in-situ observations to meet the needs of internal and external CMEMS users.

Aligned with the above-mentioned European initiatives, several other coordinated actions established in past and ongoing projects have also been key to build the Governance structure of the European HFR community, like: INCREASE, JERICO-NEXT, JERICO-S3, MyCOAST, SHAREMED, EuroSea, contributing in addition to different technical advances (see Section 3.2).

2.2.3 Regional coordination in Europe

EuroGOOS supports five Regional Operational Oceanographic Systems (ROOS) in Europe. The EuroGOOS ROOSes coordinate and support development and joint service production in European maritime regions. The ROOSes feed marine data to pan-European portals bringing tangible added value to European cooperation. The connection with the Observing Platforms Task Teams in the EuroGOOS governance is ensured by ambassadors which represent them in the different ROOSes.

In addition, different specific **HFR coordination structures**, some of them only temporary, have been created both at **national** or **regional level, here a few examples**:

- In **Italy**, the flagship project RITMARE has been focusing its efforts on the integration of the existing local observing systems, toward a unified operational Italian framework and on the harmonization of data collection and data management procedures (Corgnati et al., 2015; Serafino et al., 2012).
- In the **Iberian Peninsula,** the working group IBERORED HF (http://www.iberoredhf.es/) is an inter-institutional network created with the objective of improving the visibility and exploitation of data generated by HFRs on Iberian Peninsula shores. IBERORED HF is presently working towards providing data through homogenized formats/protocols, in line with the HFR TT efforts and international initiatives.
- In **Spain**: the different HF Radar networks (PdE, RAIA, SOCIB, EUSKOOS…) are coordinated within the Spanish Committee for Ocean Observation: CEOO (Comité Español de Observación Oceánica).
- In **Germany**, HFR measurements taken in the German Bight are integrated into the pre-operational Coastal Observing System for Northern and Arctic Seas (COSYNA) system (Baschek et al., 2016), which includes a model-based forecasting capability.
- Between **Malta and Sicily-Italy**, the CALYPSO network (developed an ambitious HF Radar network with well-established applications like response against marine oil spills in the Malta channel.
- In the **Gulf of Trieste** (GoT), the National Institute of Biology, Marine Biology Station (NIB) in cooperation with the Slovenian Environment Agency (ARSO) placed a 12 channel system in the city of Piran (Slovenia), while the Istituto Nazionale di Oceanografia e di Geofisica Sperimantale (OGS) set up its system in Aurisina (Italy). The joint network allows to fight sea pollution of oil, toxic and hazardous substances in Adriatic Sea (http://www.hazadr.eu/ See bottom Right of the Front Page)

3. The European HF radar network

3.1 EuroGOOS HF Radar Task Team

As highlighted in the previous section, the coordination of the European HFR community has been, and is, mainly led by the EuroGOOS HFR Task Team. Since 2015, EuroGOOS Ocean Observing Task Teams aim to coordinate community building of the observing networks promoting scientific synergy and technological collaboration among European ocean observing infrastructures.

The benefits of being a Task Team under EuroGOOS are as following:

- become part of a bigger community with the main European actors of Operational Oceanography;
- contribute to the establishment of European Ocean Observing System;
- offers a permanent structure;
- helps to raise awareness of European HFR activities;
- EuroGOOS Office assists in communication/coordination;
- enable links to similar initiatives and activities on the local, regional and global scales;
- attract funding;
- Definition of common tasks, as a group, not as individual institutes.

3.1.1 Terms of Reference

The Terms of Reference (ToR) of the EuroGOOS HFR Task Team, as approved in 2015 by the EuroGOOS General Assembly and published in the EuroGOOS Task Team page (***https://eurogoos.eu/download/reference_documents_/ToR-HF-radar-Task-Team.pdf***) are provided in the next table:

Table 2. EuroGOOS High-Frequency Task Team: Terms of Reference

HFR Task Team *ToR*
1. To **develop the European HFR network** and assist the standardization of HFR operations, data and applications, including: ▪ All applications of coastal radars (surface current, wave, target detection…) ▪ Applications in integration with other technologies (including satellite, X-band, fixed platforms, gliders, numerical modelling…) 2. To **contribute to the development of the European Ocean Observing System** (EOOS) 3. To **ensure the integration of HFR networks in the European Marine Downstream Services** 4. To act as the **European component in the global HFR community** 5. To **ensure data availability** via the ROOS data portals 6. To **provide recommendations** (from operators to end-users) on: ▪ Data structure, format and dissemination (interoperability of datasets) ▪ Quality control procedures ▪ Validation procedures ▪ Technological solutions 7. To be a **framework for**: ▪ **Sharing** success stories and difficulties; ▪ **Improving administrative procedures**, regulations at European level that can be adopted in member states; ▪ Providing and exchanging **tools** (data analysis, applications…); ▪ **Promoting scientific synergies** for key questions; ▪ **Filling gaps and looking for complementarity** with other technologies or modeling products; ▪ Promoting **joint progress** through networking (e.g. creating synergies between different local consortia).

3.1.2 Role in EuroGOOS strategy 2014-2020

Since 2015, the HFR Task Team aimed to contribute in the implementation of the EuroGOOS strategy (2014-2020) with the following links with the five strategic fields:

i. Sustained observing system:

The HFR Task Team aims to enhance the current potential of the European HFR systems and to provide a coordinated European roadmap. A coordinated community at operator level is created for playing a role in establishing a sustainable integrated coastal observatory. The connection with global organizations (GOOS, GEO, OceanOPS) is improved via the Global HFR Network which is part of OCG.

ii. Data:

The HFR Task Team advocates for unlocking the access to data, involving providers and European data infrastructures. The ownership and visibility for the funding stakeholders sustaining observing systems is promoted. A European HFR inventory (https://eurogoos.eu/high-frequency-radar-task-team/) is performed and updated to monitor the development of the observing network. The progress on standardization of data format, metadata vocabularies, management and distribution is enhanced and promoted through the European HFR Node (shown in Fig. 4), boosting the integration of HFR data is established in CMEMS, SeaDataCloud and EMODnet. The use of HFR data is promoted and disseminated in all relevant fields (data assimilation and model assessment, marine safety, coastal and marine environment, marine resources).

iii. Products:

Specific efforts are devoted to improving the coordination in the development of advanced data products are aimed to be developed for enhancing the impact of HFR data (Data gap filling, refined grid products, short-term prediction, Lagrangian products, etc). The Task Team works both at the level of European infrastructures (JERICO-RI, EMODnet, CMEMS, etc.) and within downstream services (i.e. intermediate users applications, CMEMS User Uptake projects, etc.). The use of HFR data in Environmental programs related with Ocean Health (WFD, MSFD, …) is promoted with stronger hydrodynamic and transport monitoring components. Integration of HFRs with other observing technologies with wider horizontal (as the satellite remote sensing) and vertical coverage (as profilers, ADCPs in fixed stations or gliders) is developed in the context of different initiatives such as JERICO-RI.

iv. Communications Interface:

Outreach activities are performed as HFR European community (contents for EuroGOOS web, workshops, conferences, review paper, etc). The EuroGOOS office contributes to those communication actions. Joint initiatives between European HFR actors are supported. The visibility of the European HFR systems is improved both at European and Global level.

v. Cross-cutting activities:

The coordination and complementarities between different initiatives or projects are assisted. The Task Team contributes in involving more actors of the Ocean Observing community in EuroGOOS activities.

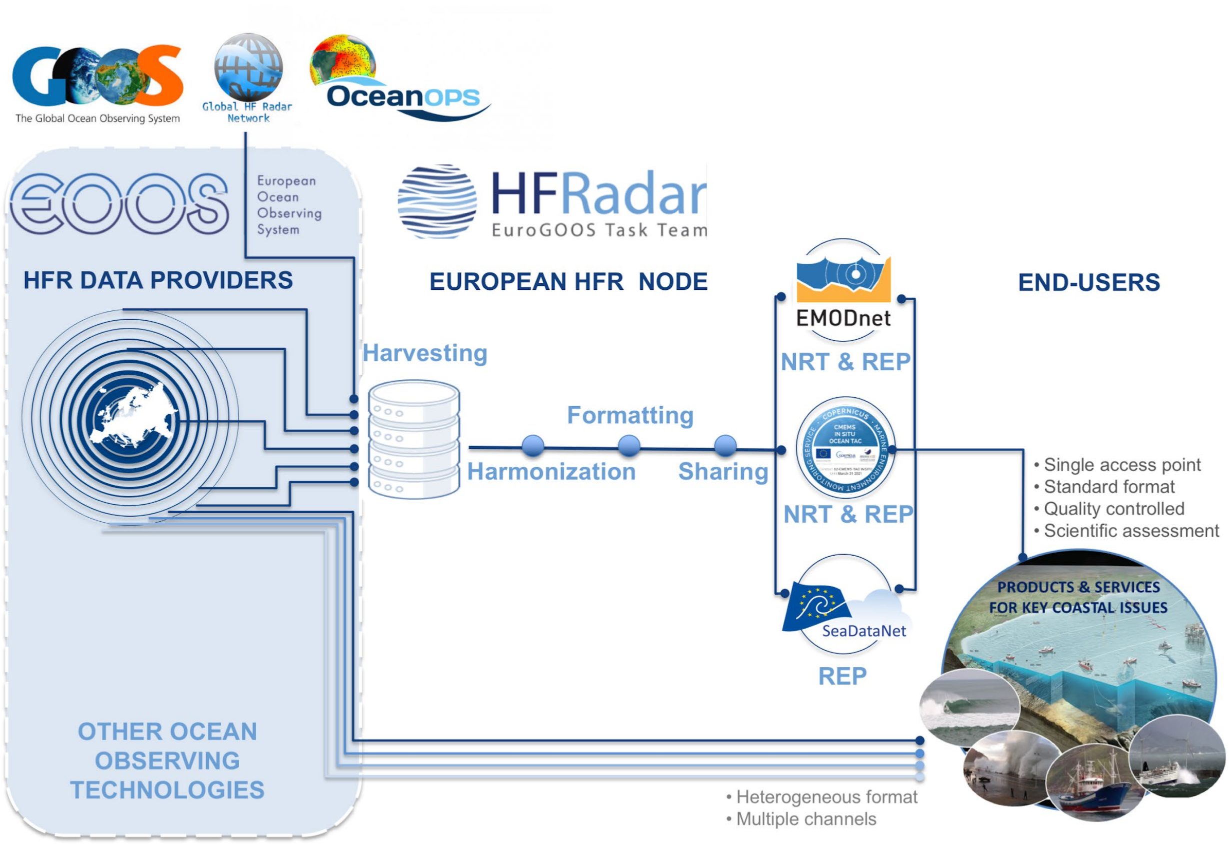

Figure 4. European Coordination for the homogenization and distribution of (NRT- Near Real time and REP - Reprocessed) HF radar data, from the data providers to the end-users.

3.1.3 Current Functioning of the HFR TT

The **HFR Task Team** is a body running under the general rules of the EuroGOOS governance components. The **members of the HFR Task Team** should play a role in the value chain of Operational Oceanography related to this specific radar technology: They could be technology developers or providers, operators, data managers, product developers, researchers or intermediate users.

The Task Team is open to non-EuroGOOS full members (https://eurogoos.eu/about-eurogoos/list-of-eurogoos-member-agencies-and-contact-persons/) but to organizations helping to strengthen the links e with the whole European Ocean Observing community, connecting new actors and building bridges within National representatives, Regional Systems and the European Ocean Observing System (EOOS).

The EuroGOOS Task Team chair and a core group of members constitute an **Executive Steering Committee (ESC)** which coordinate and lead the work plan. The progress is communicated to all the Task Team and European HFR operators at least twice a year by means of a biannual newsletter and periodic meetings (a Task Team meeting is held annually).

Within the EuroGOOS organization, the **ambassadors of the HFR Task Team** to the ROOSes play an important role for ensuring the integration and coordination of activities with the regions. Different meetings of the EuroGOOS Executive Board and Chairs are organized along the year and an annual presentation of a Progress Report takes place once a year in the EuroGOOS General Assembly in May.

Other **links with the EuroGOOS Working Groups** (i.e. Science Advisory, Technology Planning, Data Exchange, Coastal, Ocean Literacy) are ensured by at least one member of the Steering Group.

The **functioning, structure and governance of the HFR Task Team** is described in the Terms of Reference (ToR) which will be updated and should include information about the rational and link with the EuroGOOS strategic priorities, main objectives, composition and operation (e.g Chair's and members nomination process, mandate and responsibilities) and mode of operation, including Chairs mandates terms.

Finally, **the EuroGOOS Task Team Chair** has to be a member of the EOOS Operations Committee, established in 2020. The EOOS Operations Committee is part of the EOOS governance representing the ocean observing implementers at national, regional and Pan-European levels to help with the long-term sustainability of the ocean observing efforts in Europe and to implement EOOS progressively.

3.2 The current status of the European HFR network

3.2.1- Recent Activities

In the past 5 years, the work of the European HFR community has been undertaken thanks to several research and development projects. A non-exhaustive list of the most relevant ones (because of the participation of a high number of community members) is given in Table 3. A complete list of projects and their contributions to the development of HFR-related tasks is under construction in ZOTERO and can be consulted here (https://www.zotero.org/groups/2601948/eurogoos_hfradar_taskteam/collections/HF7KYXVN).

While the contribution of all the listed projects has been valuable, we can highlight a few of them because of the value of their outputs to the community: EMODnet Physics, INCREASE and INSTAC projects (CMEMS), and JERICO-NEXT and JERICO-S3 projects (H2020).

In the period 2016-2018 the **INCREASE** (http://www.cmems-increase.eu/) project worked to establish a plan for the inclusion of HFR data into the European Copernicus Marine Environment Monitoring Service (CMEMS, http://marine.copernicus.eu/), as a crucial step to ensure the improved management of several related key issues as Marine Safety, Marine Resources, Coastal and Marine Environment, Weather, Climate and Seasonal Forecast. INCREASE was partially built on the first pilot action coordinated by **EMODnet Physics**, with the support of the HFR TT, which in 2013 started to develop a strategy of assembling HFR metadata and data products within Europe in a uniform way to make them easily accessible, and more interoperable. EMODnet Physics proactively worked on HFR data stream management, presenting their data and data products in an organized and harmonized view, while data had different formats and QA/QC protocols at their origin. INCREASE, in addition to technical outputs related to the establishment of standards for data, metadata and Quality Control procedures, widened by the collaboration with EMODnet Physics, had an important role in (i) structuring the HFR community by promoting several expert workshops, (ii) creating the first inventory of European HFR systems (Rubio et al. 2017), the first THREDDS European HFR community data catalog, laying the bases of the European HFR Node and (iii) ensuring the connections with the Global Network. INCREASE managed to prove the need of offering real-time and coordinated pan-European access to HFR surface current data and opened the door to integrate HFR data in the new INSTAC portfolio. The **INSTAC** project in the period 2018-2021 set the bases for the establishment of the HFR European NODE for operational data and metadata management in real and delayed-time modes. The efforts in archiving historical data and data interoperability were done in collaboration with SeaDataCloud (https://www.seadatanet.org/About-us/SeaDataCloud).

HFR was one of the new technologies introduced in **JERICO-NEXT,** together with cabled observatories; the outcomes of the project concerning this technology in the period 2015-2019 were significant and showcased the multiple benefits of the **JERICO-RI** environment for an emerging observing community, boosting the developments of new products, methods, and applications of the HFR data. Among them, the homogenization of data and metadata formats and Quality Assessment/Quality Control (Mantovani et al. 2020). The HFR standards and best practices set in JERICO-NEXT have been transferred to other EU-funded regional projects like those in the INTERREG Italy-France "Marittimo" Programme. These efforts have enabled the entry into service of HFR data distribution within the Copernicus CMEMS-INSTAC in April 2019. Moreover, collaborations among different groups within JERICO-NEXT have enabled significant steps forwards in methodologies for the processing, analysis and integration of HFR data with other observing and modelling methodologies, increasing the uses of the data and unlocking the data potential for science and society. Some examples are: (i) the work developed using jointly HFR and glider data by Berta et al. (2018); (ii) the combination of HFR with satellite altimetry, ADCP, gliders and models by Manso-Narvarte et al. (2018, 2020 and 2021), (iii) the efforts towards bio-phys integration in the Gulf of Manfredonia by Corgnati et al. (2018), Sciascia et al. (2018), Berta et al. (2020) and in the Bay of Biscay by Dávila et al. (2021 -under review), (iv) The study of mesoscale processes by Rubio et al. (2018); or the works on methods for gap-filling and short term prediction techniques by Hernández-Carrasco et al. (2019), Barth et al., (2021) and Solabarrieta et al. (2021). Several tasks related to the use and dissemination of HFR technology and data are ongoing in JERICO-S3. HFRs are an important component of several regions working in strategy building and demonstration of innovative coastal observation approaches. In addition, HFR-related tools (standardization, QC) and direct access to HFR data are offered through the Virtual Access to JERICO-RI resources.

Table 3. Non-exhaustive list of the most relevant projects in the recent achievements of the European HFR Community

ACRONYM (Project name)	Funding body (dates)	HFR - related activities
EMODnet Physics (European Marine Observation and Data Network) www.emodnet-physics.eu	UE DGMARE (2013-2016)	Testing the concept and organising the European HF Radar community and data.
JERICO-NEXT (Joint European Research Infrastructure network for Coastal Observatory – Novel European eXpertise for coastal observaTories)	INFRAIA - H2020 (2015-2019)	Harmonization of best practices Harmonization of data formats Improve current estimates by advanced quality control and analysis. Applied research based on current data: along & cross-shelf transport, connectivity, data blending Virtual access to the data
INCREASE (Innovation and Networking for the integration of Coastal Radars into EuropeAn marine Services) http://www.cmems-increase.eu/	CMEMS-SE 21 CALL (2016-2018)	Community building. Basis for the management of NRT and historical data and methodologies for NRT and advanced delayed mode quality-control techniques. Enable an HFR European operational node to ensure the link with operational CMEMS.
SeaDataCloud https://www.seadatanet.org/About-us/SeaDataCloud	UE (2016 - 2020)	Basis for interoperability in archiving historical data

MyCOAST (A Coordinated Atlantic Coastal Operational Oceanographic Observatory) http://mycoast-project.org/	Interreg Atlantic Area (2017-2020)	Implementation of data interoperability standards for HFR systems. New products (HFR + models) for maritime safety and coastal pollution risks. Estimation of wave parameters. Develop transnational observation with HFRs.
INSTAC (Copernicus Marine Service In Situ Thematic Assembly Centre) https://www.marineinsitu.eu	UE (2018-2021)	Integration and operation of HFR data in NRT and REP UV products. Support to the HFR European operational node.
JERICO-S3 (Joint European Research Infrastructure of Coastal Observatories: Science, Service, Sustainability) https://www.jerico-ri.eu/	H2020-INFRAIA-01-2019 (2020-2024)	Harmonization of best practices Improve current estimates by advanced quality control and analysis. Applied research based on current data. Virtual access to the data
SHAREMED (Sharing and enhancing capabilities to address environmental threats in mediterranean sea) https://sharemed.interreg-med.eu/ & https://sharemed.capemalta.net/index.php	INERREG-MEDITERRANEAN (2019-2022)	Community building: ShareMed HF Radar Group. Enhance the quality and use of HF radar observations and merging to other data sources. operational combined data delivery syste.m HFR added value products targeting users needs (merging HF radar, EO and models).
EUROSEA (Improving and Integrating European Ocean Observing and Forecasting Systems for Sustainable use of the Oceans) https://eurosea.eu/	H2020-BG-2019-1 (2020-2024)	Coordination and governance structure. Implementation of best practices of operations (FAIR principles). Tools supporting the advanced delayed mode QC of HFR and added value products (integration HF-radar, in-situ and EO data). Outage online reporting database. Implementing the standardized NRT data flow through the European HFR Node, and guide standardized quality assessment and data management.

The main milestones of the HFR TT community in the last 5 years are summarized in the table 4 and the timeline is schematized in Fig. 5.

Table 4.- EuroGOOS High-Frequency Radar community: Key milestones from the last 5 years

When?	What?
JUNE 2016	**FIRST INVENTORY OF EUROPEAN HF RADARS**
The first survey to diagnose the status of different HFR systems available in the EU was launched in the framework of INCREASE project, and has been maintained up to date (Mader et al., 2017). The survey gathered responses from 28 European institutions and information on more than 70 HFR systems. It also allowed to make a first diagnostic on the most popular identified users of the European HFR data, the	

most popular research lines and resulted in a community paper entitled "HF Radar Activity in European Coastal Seas: Next Steps toward a Pan-European HF Radar Network" (Rubio et al., 2017). Inventory published in the HFR TT Website and later on in the form of a Community paper - The map of HF radars is kept alive in the HFR TT Website (https://eurogoos.eu/high-frequency-radar-task-team/)	
SEP 2016	**INCREASE WORKSHOP - La Spezia**
Attendants: HF Radar experts (45 people) from EU and USA + Copernicus representatives **Main aim:** HF Radar expert workshop to discuss the main issues concerning data format and QA/QC procedures in order to meet the needs of both the HFR community and CMEMS operational services. In particular, four main points were analyzed for achieving a common consensus and set up a roadmap for the implementation activities expected within the project: data format; metadata structure; QC flagging scheme; QC tests. A roadmap was defined for each of the points. In addition, the state of the art of the corresponding products and the interest for CMEMS (INSTAC, MFC…) of each of these products were reviewed/discussed to build a catalog of «advanced» products that could be developed to offer an idea of the roadmap to make the way for HFR products into CMEMS (data gap filling and refined grid products, Short term prediction, Lagrangian products).	
OCT 2018	**HFR STANDARD ESTABLISHED**
A common data and metadata model was defined and was progressively implemented to become the official EU standard for real-time HFR surface current data and to ensure efficient and automated HFR data discovery and interoperability. The model was defined according to the Copernicus-InSituTAC-FormatManual-1.41, the Copernicus-InSituTAC-SRD-1.5 and the Copernicus-InSituTAC-ParametersList-3.2.0, and to the standards of Open Geospatial Consortium (OGC) for access and delivery of geospatial data, is compliant with the Climate and Forecast Metadata Convention CF-1.6, the Unidata NetCDF Attribute Convention for Data Discovery (ACDD), the OceanSITES convention and the INSPIRE directive. It follows the guidelines of the DATAMEQ working group and the Radiowave Operators Working Group (ROWG). It specifies the file format (*i.e.* netCDF-4 classic model), the global attribute scheme, the dimensions, the coordinates, data and QC variables and their syntax, the QC procedures and the flagging policy. A battery of mandatory QC tests ensured the delivery of high-quality data. All the software tools for the production of HFR data according to the common model and performing the QC tests have been implemented and freely shared at the links: https://github.com/LorenzoCorgnati/HFR_Node__Centralized_Processing https://github.com/LorenzoCorgnati/HFR_Node_tools	
OCT 2018	**HFR data standardization WORKCAMP**
The **HF radar Workcamp on HFR data** held in Bilbao, Spain, aimed to take a major step forward in the standardization of the European HF radar data by offering a practical and effective training to the attendees on the use of free software tools for data conversion. The main agenda points were: (i) to introduce and describe the European HFR Standard, detailing the metadata scheme, the Quality Control procedures and the data format; (ii) to provide training for the use of the software tools that allow the transformation of radial and total HFR data from CODAR and WERA native formats to the European HFR Standard.	
DEC 2018	**NODE ESTABLISHMENT**
The **European HFR Node** distributes tools and support for standardization to the HFR providers as well as standardized Near Real Time (NRT) and delayed-mode HFR radial and total current data to CMEMS-INSTAC, EMODnet Physics and SDC Data Access. Within the European framework, the European HFR Node	

is now **managing** data from **14 European HFR networks** (made of 44 radar sites), representing 8 countries included in 3 different ROOSes (NOOS, IBIROOS, MONGOOS), operating with both **Direction Finding and Phased Array** systems, and is expected to manage 17 networks (for a total of 50 radar sites) by the end of 2021. Furthermore, the European HFR Node integrates and distributes **US HFR data** (from 5 regional networks, made of 173 radar sites) to CMEMS-INSTAC and EMODnet Physics since June 2020 (EMODnet Physics integrated global data from US and Australian HFR data since 2018). In particular, the European HFR Node implements the functions of data acquisition and harvesting, QC, validation/assessment, NRT data delivery and historical data distribution with different reprocessing levels.	
May 2019	**START OF CMEMS DATA INGESTION**
First version of NRT total velocities dataset was delivered for CMEMS April 2019 catalogue release, the work in 2019 then focused on the delivery of NRT radial velocities and on increasing the number of HF radars connected into the node and to offer additional available systems for April 2020. A first version of REP (total velocities) was delivered in June 2020. Second version of REP total velocities and update of NRT was delivered by November 2020, for its inclusion in the December 2020 catalogue, it included update in the aggregation of the total files and the addition of 6 additional systems (including 5 US networks). Processing of the new data set, REP radial velocities (30 radial stations) have been included in the May 2021 release. Link to the CMEMS product containing NRT and REP HFR datasets: https://resources.marine.copernicus.eu/?option=com_csw&view=details&product_id=INSITU_GLO_UV_NRT_OBSERVATIONS_013_048 https://resources.marine.copernicus.eu/?option=com_csw&view=details&product_id=INSITU_GLO_UV_L2_REP_OBSERVATIONS_013_044 along with the main documentation pieces: PRODUCT USER MANUAL: https://catalogue.marine.copernicus.eu/documents/PUM/CMEMS-INS-PUM-013-048.pdf https://catalogue.marine.copernicus.eu/documents/PUM/CMEMS-INS-PUM-013-044.pdf QUALITY INFORMATION DOCUMENT: https://catalogue.marine.copernicus.eu/documents/QUID/CMEMS-INS-QUID-013-048.pdf https://catalogue.marine.copernicus.eu/documents/QUID/CMEMS-INS-QUID-013-044.pdf	
Oct 2020	**HISTORICAL HFR DATA STANDARDIZATION FOR SEADATACLOUD**
A common data and metadata model was defined and was progressively implemented to become the official EU standard for historical HFR surface current data to be distributed via SeaDataNet. The model was defined according to SeaDataNet_1.0 manual (CF extension) and to the standards of Open Geospatial Consortium (OGC) for access and delivery of geospatial data, is compliant with the Climate and Forecast Metadata Convention CF-1.6, the Unidata NetCDF Attribute Convention for Data Discovery (ACDD), the OceanSITES convention and the INSPIRE directive. It follows the guidelines of the DATAMEQ working group and the Radiowave Operators Working Group (ROWG). It specifies the file format (*i.e.* netCDF-4 classic model), the global attribute scheme, the dimensions, the coordinates, data and QC variables and their syntax, the QC procedures and the flagging policy. A battery of mandatory QC tests ensured the delivery of high quality data. All the software tools for the production of HFR data according to the common model and performing the QC tests have been implemented and freely shared at the link: https://github.com/LorenzoCorgnati/HFR_Node__SDC_Processing	

Figure 5.- Timeline of HFR projects and milestones since the launching of the EuroGOOS HFR Task Team.

3.2.2- Quantitative framework

Since 2016, date of the first inventory, the network of HFR systems continues to rapidly expand in Europe (at a rate of 7 new systems per year), and to gain relevance in the integrated management of coastal zones, with over 81 sites currently running and a number in the planning stage. The present map showing the distribution of the European HFR systems to the date is provided in Fig. 6. The inventory and map are updated periodically and can be consulted here (https://eurogoos.eu/high-frequency-radar-task-team/).

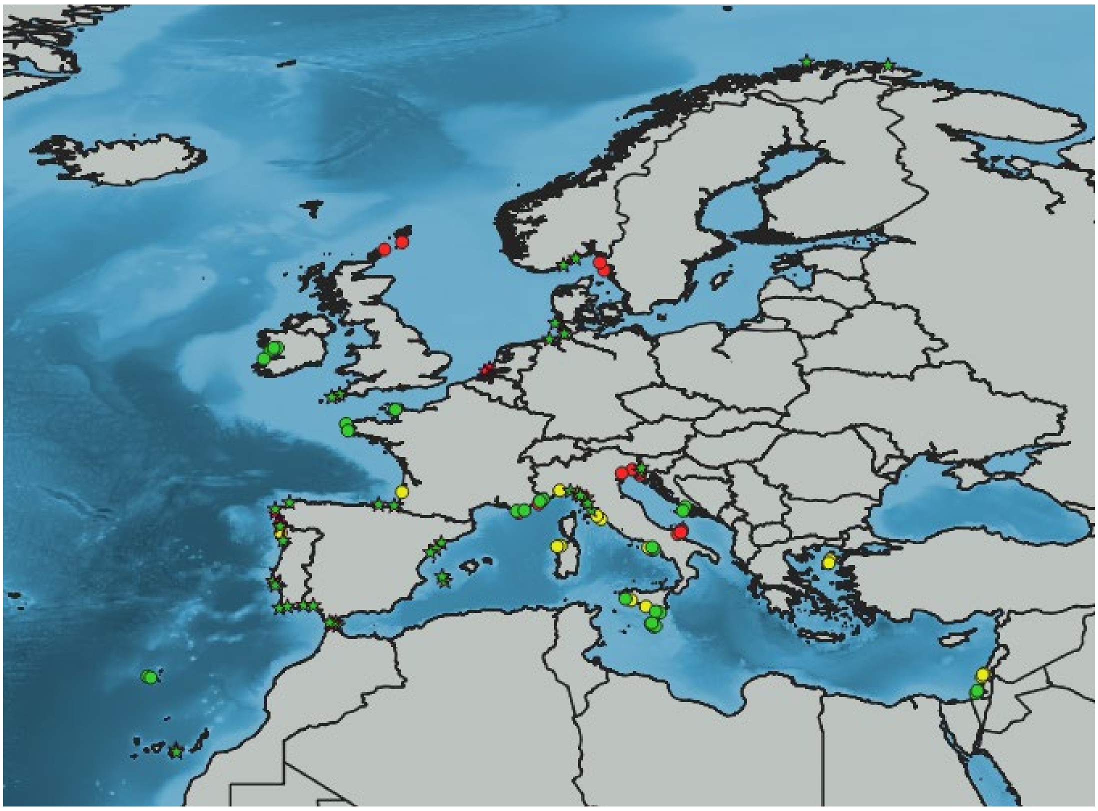

Figure 6 - European HFR networks listed in the European HFR inventory. Green stars: operational HFRs whose data are integrated in the operational European HFR NODE data flow. Green dots: operational HFRs whose data are not integrated in the operational European HFR NODE data flow. Yellow dots: future installations. Red stars: past installations or installations no-longer operational, whose data are integrated in the reprocessed European HFR NODE data flow. Red dots: past installations or installations no-longer operational whose data are not integrated in the European HFR NODE data flow.

- The temporal evolution of the number of HFRs is provide in Fig. 7

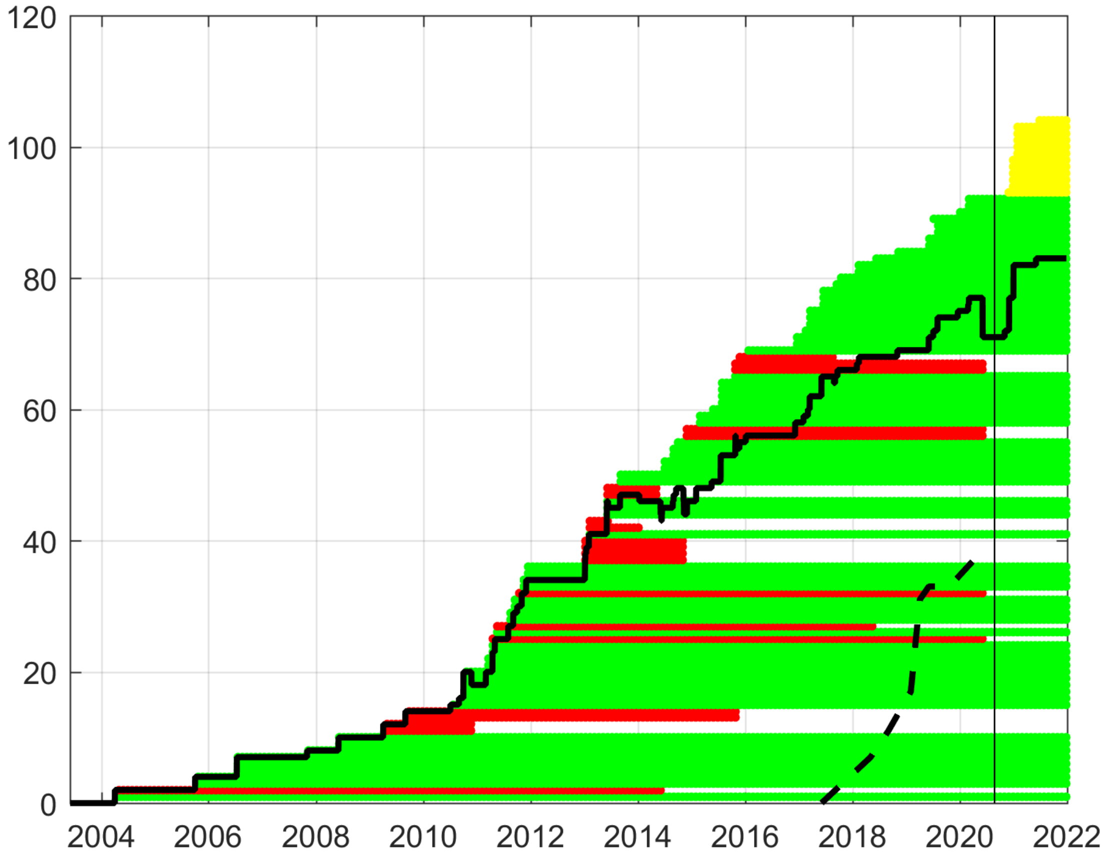

Figure 7 - Evolution in time of (bold line) number of HFR sites in EUROPE and (dashed line) the number of European HFR sites connected into the operational European HFR NODE data flow. Vertical line: day of the inventory update. Green lines: operational HFRs. Yellow lines: future installations. Red lines: past installations or installations no-longer operational.

A **quantitative framework** of key performance indicators (KPIs) has been established to evaluate the HFR network impact and to track its progress. Different KPIs have been considered and they are shown in the following figures and tables:

- **Number and percentage of European HFR sites** in terms of status (operational, historical, future deployments); permanence (permanent or temporary); type of system (direction finding or phase array); manufacturer (CODAR, WERA); ROOSes; central frequency (standard, medium, long) and integration of the HFR data in NRT and REP into the European HFR Node (Fig. 8)

Figure 8. Examples for network KPIs. Pie charts showing the percentages of HFR systems in terms of status, permanence, type, manufacturer, central frequency, range and ROOS.

- **Number and percentages of European HFR networks**, sites, ongoing and future installations, HFR sites connected in near real-time (NRT) and historical (REP), per each one of the ROOSs (Table 5)

Table 5.- EuroGOOS High-Frequency Radar inventory: numbers and percentages of the main quantitative indicators

Metric	Number
Number of HFR Networks	*43*
Number of HFR Sites	*109*
Number of Ongoing installations	*68 [62%]*
Number of Future installations	*15 [14%]*
Number of HFR Sites Connected in NRT	*44 [40%]*
Number of HFR Sites Connected in REP	*32 [29%]*
Number of HFR Sites per ROOSes	*60 [55%] MonGOOS* *32 [29%] IBIROOS* *13 [12%] NOOS* *4 [4 %] MonGOOS/IBIROOS*

- Number of models assimilating European HFR data:
  - WMOP model: The Western Mediterranean OPerational Forecasting System from SOCIB (more information here) is assimilating daily averaged total velocities.
  - GETM model: The General Estuarine Transport Model from the Coastal Observing System for Northern and Arctic Seas (COSYNA) (more information here) is assimilating hourly surface current data from HF Radars.

- Number of Public/private institutions integrating HFR data at operational basis
  - For example: the Spanish Maritime Safety and Rescue Agency has 6 HFR systems from the Iberian Peninsula (HFR-Galicia; HFR- Ebro; HFR-Gibraltar; HFR-Ibiza; HFR-EUSKOOS; HFR-Cadiz) integrated in its Environmental Data Server.

- Number of publications with HFR data:

In December 2020 a repository using the open source software Zotero : **eurogoos_hfradar_taskteam GROUP** was created in order to build a list of publications from the group and the European community on different HFR-related R&D issues. The publications were then classified by a set of established scientific/technical categories and by the use of three tags to define the work frame of the authors of the listed publications (HFR Task Team, Europe, Global). The tool allowed to import personal and group libraries and allowed the collection of more than 200 publications, most of them in the form of peer review papers. Although the list of publications is still in progress, this action allowed us to list and elaborate a first analyse on the group contributions to different issues, the most popular issues, the ones that will need consolidation (Fig. 9). In general, the contribution of the HFR Task Team members and the EU community to all the classified R&D issues are significant. The evolution in time of the publications show for almost all the R&D categories a positive tendency, and it is remarkable the growth in the number of community papers in the last three years (Fig. 10).

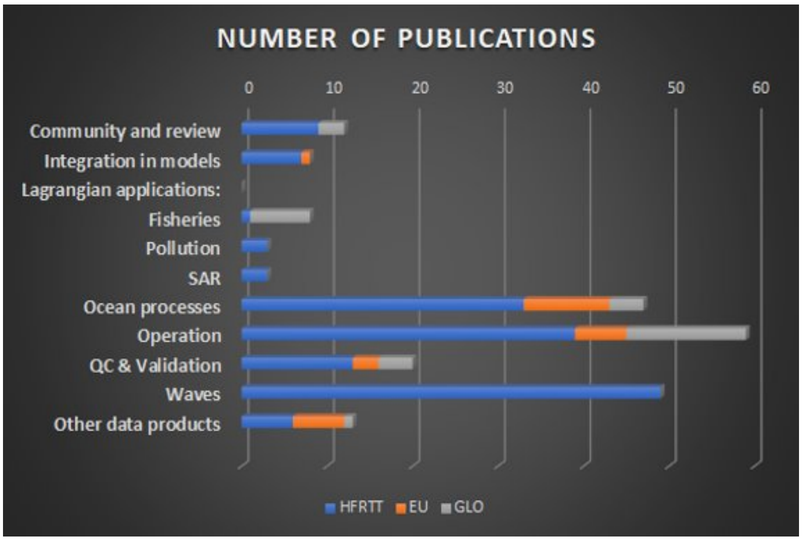

Figure 9.- Number of publications on HFR-related R&D issues extracted for the group's Zotero library and the three considered work frames of the authors in the listed papers: HFR Task team (blue), Europe (orange) and global (grey).

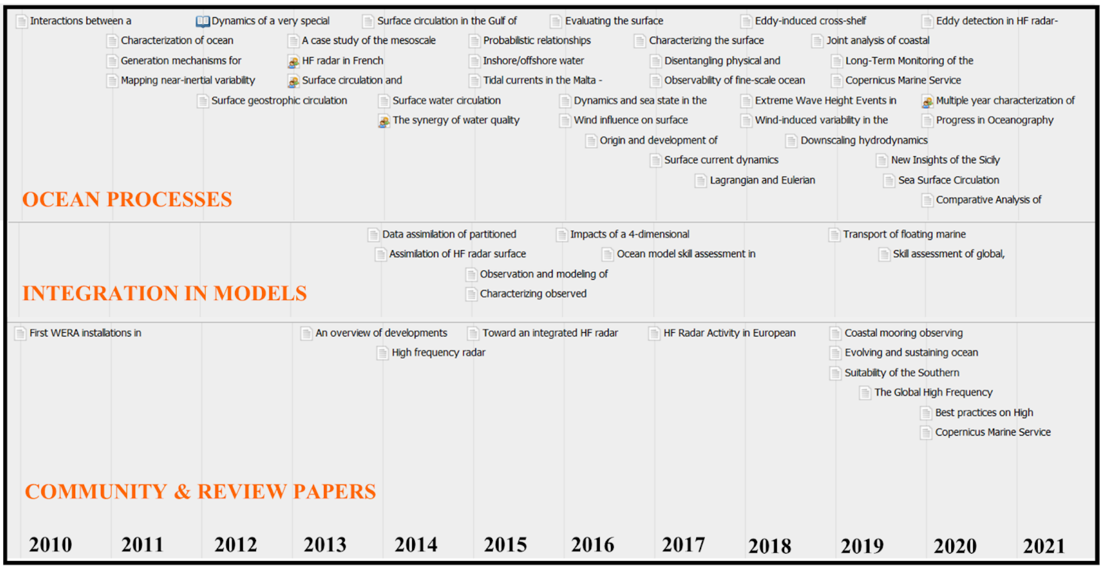

Figure 10.- Timeline of HFR publications on Ocean Processes, Integration in Models and Community and Review Papers extracted for the group's Zotero library

- Number of HFR sites integrated at CMEMS In Situ TAC, EMODnet-Physics, SeaDataNet (table 6)

Table 6.- Number of HFR sites/networks available in European and Global Marine Data Portals and Institutions

MARINE DATA PORTAL	HFR SITES	LINK TO INFORMATION
CMEMS	44	https://atlas.mercator-ocean.fr/s/cHgK7bQPeAeDSFt http://atlantos.emodnet-physics.eu/kibana/ https://nrt.cmems-du.eu/erddap/griddap/index.html?page=1&itemsPerPage=1000
EMODnet-Phys	40 (from 16 systems)	http://thredds.emodnet-physics.eu/thredds/HFRADARCatalog.html https://erddap.emodnet-physics.eu/erddap/search/index.html?page=1&itemsPerPage=1000&searchFor=HFR
Sea Data Net	26 (based on EDIOS ID)	http://seadatanet.maris2.nl/v_edios_v2/search.asp
Global HFR network	173	https://marine.rutgers.edu/~hroarty/GEO/ESRI/

- Number of HFR datasets with DOI assignation
  - For example: SOCIB HFR http://apps.socib.es/data-catalog/#/data-products/hf-radar-ibiza

4. Future strategy & tactics

4.1 Long-term Strategy 2021-2030

The long-term strategy of the European HFR community is divided according to the five high-level objectives of EuroGOOS as above-mentioned in section 2.2.2:

(i) Stimulate communities of practice

To empower the contribution of the HFR community in ocean observation, fostering global, European and regional connections, sharing and adopting Best Practices, contributing to the implementation of user-oriented FAIR data products.

(ii) Advocate for coordinated and integrated European ocean observing and operational oceanography

To advocate the need for a sustained fully implemented HFR network integrated within a coastal observing system. The effective monitoring of the dynamics and fluxes in a land-sea continuum coastal area requires the best technology available fully implemented. The final long-term goal in terms of implementation should be stated based on requirements for resolving the relevant space-time scales along the European coastline, combining different radar frequencies. Furthermore, the progress of this implementation should be monitored.

To ensure the best quality required by all the relevant European data aggregators (CMEMS, EMODnet, SeaDataNet) and marine downstream services.

(iii) Strengthen and expand partnerships

To advocate the benefits of a pan-European coordination of the resources dedicated to ocean observations in order to (1) obtain a fully implemented, connected and interoperable HFR network along the European coastline, (2) speed the development of scientific knowledge and operational services for a sustainable and healthy ocean.

Foster the use of HFR data in more operational marine services, together with Ocean Health and Climate services, through more integration between disciplines, coastal and open ocean observing platforms, land based and satellite remote systems, observations and modelling capabilities.

(iv) Promote sustainability across the value chain of operational oceanography and ocean observing

To involve all the key actors in the governance structure of the HFR network aiming to the common goal of implementing and sustaining a fit-for-purpose coastal observing network: stakeholders, end-users, operators, scientists, technological developers and providers.

To avoid individual strategy and favour a collective approach within a sustained coastal observing system.

(v) Mobilise the public on the importance of the ocean and oceanographic services

To disseminate the role of the HFR technology in ocean observation improving the involvement of industry, next generations of scientists, and the general public.

4.2. Roadmap 2020-2023

The work plan for 2020-2023 was set up during the annual meeting of the European HFR community in San Sebastian, November 2019 after a session of presentation of the status of different ongoing actions, a joint review of the ToR and a brainstorming session. The brainstorming session was developed using a specifically designed group work session (Fig. 11) starting from a set of initial questions:

- How to enhance HF radar related science? Ideas on joint R&D from historical or NRT datasets (multi-observation) around? What are the research needs, hot research topics?

- How to enhance HF radar-related products and services? Ideas on joint products /services; How to improve the co-creation, sharing and transfer of products/tools around the main application fields (Security, Resources and environmental management)

- What should be the next actions/ contributions of the HF radar TT and/or the community? Best Practices, standardization, community building, promotion/communication, sustainability of the network...

Figure 11– Illustration of the brainstorming session

Four main areas of actions were identified: 1-Management and community building; 2-Sustainability, 3-Product and services and 4-Research & Development. For each area, one working group by task was created, with one task leader, a set of specific objectives, a calendar and a list of expected outcomes.

The main mid-term milestones (3 years) for each of these tasks and their main outcomes up to date are detailed in Table 7.

Table 7.-- Task, mid-term milestones and main outcomes the HFR community roadmap for 2020-2023

TASK	MID TERM MILESTONES	MAIN OUTCOMES
Management & Community building		
Projects mapping and roadmap	(i) To share mid-term objectives and strategy linked to ongoing projects; (ii) To make visible and transparent the landscape of projects/initiatives to the community (iii) To promote benefits for the whole HFR community; (iv) To emphasize the outreach of our outcomes and contributions in the coastal Operational Oceanography.	First listing of projects started (see ***Monitoring R&D community activities action - community library includes a list of past and ongoing projects)***

Biannual newsletter	(i) Keep the community updated on the latest findings, ongoing initiatives, projects; (ii) Boost interaction & collaborations (internally and externally)	Two published newsletters: June 2020 February 2021
Sustainability		
Communication with stakeholders	(i)Harmonize the list of stakeholders of different past and ongoing projects under the same classification; (ii) Establish whether or not they know the HF radar technology or if they are end-users (power/interest); (iii)Define possible HF-derived products that could be of interest to each stakeholder in order to establish a specific communication strategy.	Template to collect stakeholders list and first list of stakeholders (> 160)
Good practices in stakeholder commitment	(i) Focus on stakeholders: Install awareness, build understanding, and create buy-in before commitment; (ii) Build bidirectional commitment between HFR operators (we create a tailored product) and stakeholders (we will definitely use what you create); (iii) Tracking and keeping commitments: upgrade in case of new needs; (iv) Promotion of successful synergies to attract new stakeholders (pre-existing o new-born)	Detailed work plan built
Endorsement	To receive endorsement from EuroGOOS and other European infrastructures to support the importance of the role of local operators and the sustainability of the observing system	(i) Common letter from CMEMS-EMODnet-EuroGOOS to all HF Radar operators; (ii) To share the support letter made for supporting SOCIB HFR Infrastructure (English template created) (iii) Certificates delivered to members.
New opportunities for joint proposals	(i)Promote networking & cooperation.; (ii) Share available funding opportunities.; (iii) Address common HFR challenges/interests; (iv) Exploit past efforts (e.g. ETN, COST).; (v) Strengthen the funding process.	(i)Competence Matrix to build a group CV; (ii)Identification of calls through the Newsletter (see task "biannual newsletter")
Products and Services *Two technical working groups created around the main technical challenges identified to establish a state of the art of the data and methods, work towards joint development and exploitation of the data/ data products at European scales (EMODnet, CMEMS…)		

Data gap filling working group	(i) Make a Census of gap filling techniques applicable to HFR data; (ii) Found a standardized procedure; (iii) Write a paper on gap filling methods review	(i) List of data gap filling techniques applied also to other data; (ii) List of data gap filling techniques applied to HFR data
Wave data working group	(i) Establish where we are now with HF radar waves in Europe; (ii) Determine accuracy requirements and parameters needed for different applications and users; (iii) Where are the gaps/uncertainties and how to address these; (iv) Decide on netcdf structure; (v) Provide data through EMODnet/CMEMS …	(i) Circulated a questionnaire to gather information on the state of the art concerning wave data production and exploitation; (ii) Built a bibliography on waves data from HFR (transfer to the community library set in task "Monitoring R&D community activities".)
Research & Development		
Monitoring R&D community activities	(i) Assessing R&D community activities and outcomes; (ii) Enhancing R&D joint activities and outcomes.	Set up of a community library in zotero (with papers and research projects metadata)
Promote the opportunities for joint contribution	(i) Boost HFR team interaction & collaborations; (ii) Provide support in launching initiatives and providing opportunities, upon request.	(i)Promotion of opportunities through the newsletter (see task "biannual newsletter"); (ii) Launched joint contribution on MONGOOS-HFR Network (in the context of the Ocean Science Special Issue, EGU and 9th EuroGOOS International Conference)

For the management of this work plan, two specific tasks deal with ensuring effective internal communication and the continuity in the implementation of actions:

- For the internal communications a Microsoft TEAMS environment was set (June 2020) to improve the communication inside the HF Radar TT, ensure all the members have access to common documentation and enhance the active participation of all the members in ongoing actions.
- Then to coordinate the different working groups and the continuity in the implementation of actions quarterly progress meetings were planned. Since then, two TT meetings have been held. A first one (June 2020) to set the objectives and calendar of the actions and following (January and March 2021) to share progress on the ongoing actions and propose needed adjustments.

5. Proposed model of Governance structure

We have begun to evaluate the capability and resources that will be required to implement the EuroGOOS HFR Task Team strategy over the forthcoming years and the way to be governed.

5.1 Structure, roles and responsibilities

The **European HFR network governance** structure will comprise **5 units**: Executive Steering Committee (ESC), the European HFR Node (NODE), the HFR Operators & Manufacturers Working Group (HFR-WG), the Stakeholder Panel (SP) and the Advisory Board (AB).

While all units are composed of **members** from institutions involved in the **European HFR network**, the **Advisory Board (AB)** will be formed by external international **EU and non-European HFR experts**.

Chair of the Executive Steering Committee (ESC), as it is also the chair of the EuroGOOS HFR TT, will be elected following the nomination and election rules from the EuroGOOS Task Teams. The **AB members** will be nominated by the ESC. Nevertheless, the **nomination and election processes** of the members from the different elements of the HFR governance framework that can better contribute towards an effective performance are still not completely defined. In the same way, the procedures to launch the nomination calls, to receive the candidatures, the outside advisors role in first locating and then selecting the suitable candidates, the voting process, the criteria to review and evaluate the candidates with due consideration of gender, diversity, and geographic balance considering the specific needs of the governance's elements and the way to inform about the composition will also be discussed and agreed at a more mature stage of the governance implementation.

The governing structure is schematized in Fig. 12 and the composition, tasks, meetings and strategy to achieve the implementation is detailed in Table 8 below.

Table 8.- Governance structure of the European HFR network:

GOVERNANCE STRUCTURE
Executive Steering Committee (ESC)
● <u>Composition:</u> - Chair: spokesperson for the network, designated representative. - NODE coordinator: 1-2 representatives of the NODE - Task leaders: 5-7 members nominated to include gender and geographical balanced representation of the HFR operators Working Group (HFR-WG). - SC representatives: from academic and non-academic sectors ● <u>Tasks:</u> in charge of the network **planning and oversight** including: vision, advice and guidance on the main 4 key areas (e.g. 1-Management and community building; 2-Sustainability, 3-Product and services and 4-Research & Development), the attraction of new HFR operators, the support the network maintenance (ie. making sure the community follows the common European HFR network objectives and recommendations), the national and international coordination and the sustained uninterrupted funding. More specifically: - Chair: ➔ To report/link to the OCG-GEO HFR Global ➔ To report/link to the EOOS Operation Committee ➔ To coordinate the objectives and manage the network-wide activities in the 4 key areas. ➔ To manage the day-to-day activities of HFR TT. ➔ To establish and oversight the development and implementation of the actions from each working group of the 4 key areas. ➔ To set agendas and organize meetings. ➔ To support and advice: impact, redundancy, representativeness and efficiency of existing, planned of potential new HFR installations. ➔ To establish links with other observing platforms, with the modelling and satellite community. - NODE Technical Coordinator: ➔ To coordinate the design and development of the node's architecture with the final objective of satisfying the Certified Oceanographic Data Centre requirements. ➔ To support the definition of common protocols, instrumentation, standardization. ➔ To inform about standard operation procedures. ➔ To ensure the BPs convergence within the network. ➔ To implement standardized performance metrics. - Task leaders: ➔ To coordinate the actions included in the 4 priority areas (further detailed in <u>section 4.2</u>)

- To implement strong and efficient communication strategy
- To provide scientific oversight
- To initiate strategic activities
- To develop synergies between all members, enhancing international cooperation and linking to other relevant initiatives and projects in HFR, also identify sources of financial support.

- SC representatives

- Meetings:
  - 3 Progress meetings per year by videoconference.
  - Annual general meeting with all members from the European HFR network.
  - Yearly rounds of review and consultations
  - One 2-days meeting every 5 years with the Advisory Board (around 25-30 persons);
  - Face-to-face meetings on an ad-hoc basis and in dedicated workshops
- Strategy: moving governance to the level of people's day-to-day job responsibilities, from strategic planning to day-to-day operations, from contributions in the context of ongoing projects or joint initiatives or even on a voluntary basis, to specify functional accountabilities at the European HFR network who work on the ESC.
  - HFR network needs to be led by an authoritative international body with the mandate to coordinate HFR observations in Europe. EuroGOOS HFR TT has a meaningful role to play.
  - The top board must include European leading HFR science and technology institutions, whose expertise, experience and infrastructure provide the unique and long term capability to design, build, operate and innovate the HFR network

European HFR NODE (NODE)

- Composition:
  - Technical coordinator
  - Data curator(s) (managers)
  - IT staff(s)
- Tasks: it constitutes the Data Management Team of the network being responsible to overseeing the day-to-day **management of HFR data**, ensuring that the data flow from the HFR available sites towards in common format and are made publicly available in different European data integrator infrastructures (e.g. CMEMS, EMODnet-Physics, SeaDataNet), guaranteeing data standardization, the long-term usability, the archival and the quality checking of the HFR data.

  More specifically, the NODE is in charge of:
  - Acquisition: data harvesting (from EU HF radar operators)
  - Quality Control and Harmonization: QC and data formatting or data format checking, guaranteeing the appropriate data documentation with metadata.
  - Data archiving and distribution: assessment and delivery
  - Service management (key performance indicators, Infrastructure monitoring, updated inventory of the HFR stations)
  - Support harmonization of methodologies

- Meetings:
    - Monthly meetings to oversee the data management
    - Quarterly meetings: in conjunction with the ESC via videoconferences.
- Strategy: The supporting functionality of the European HFR Node is being provided by organizations involved in the European HFR network. Future plans aim to raise the funds to support people at the European HFR network who work on the NODE**.**
    - Apply and operate (when the procedures for doing so are established) as IODE (IOC Committee on International Oceanographic Data and Information Exchange) GDAC (Global Data Assembly Centre), as a structural element of IODE.
    - Check the possibility to operate as a component of the CMEMS In Situ TAC Global Production Unit
    - Integrate a Service Desk to handle single requests
    - Apply for being accredited as a trusted data repository (Core Trust Seal Certification) through FAIRsFAIR project funding, aiming to implement the FAIR principles for scientific data management.

HFR Operators & Manufacturers Working Group (HFR-WG)

- Composition:
    - HFR operators from the European HFR network
    - Engineers and technicians from the manufacturers
- Tasks: Overseeing the day-to-day **management of HFR operations and maintenance**, including:
    - To deploy new HFR systems.
    - To manage the day-to-day activities of HFR maintenance following accepted guidelines and best practices.
    - To actively participate in the actions included in the 4 main areas.
    - To enhance the HFR technology, to promote the know-how exchange and the interaction between manufacturers and operators in diverse issues (e.g. platform design and improvement, sensor testing and selection, reliability, software-hardware compatibility, maintenance best practices, etc)
    - To adopt the open data policy being agreed to open and free sharing of HFR data, whenever possible making data available in NRT; to provide the necessary metadata; to submit their data to the NODE (in their role of data providers)
- Meetings:
    - Yearly/Bi-annual meetings: at venues (e.g. ROW or ROWG context, dedicated workshops). Meeting attendance should be funded via institutions that operate the sites.
    - Occasional meetings via videoconference if needed and/or requested.
- Strategy: Installation and maintenance of the HFR sites have been supported and funded by organizations (most of them public bodies responsible for ocean observation) involved in the European HFR network.
  EU funding supporting sustained HFR observations at wide coastal areas will be requested.

Stakeholder Panel (SP)
● <u>Composition:</u> - Representatives of the most influential and intersectoral stakeholders. - Representatives of policy makers - European HFR network members (including scientists, operators, IT staff) and external people with special expertise in stakeholder engagement, particularly task leaders from Products & Services [PS] and from Research & Development [RD] and members from other observing platforms ● <u>Tasks:</u> Connection with stakeholder communities and leveraged engagement, identification of societal needs, defining user requirements and co-designing products and services. - To provide advice to ensure the fit-for-purpose of the HFR observations. - To provide feedback about their day-to-day needs to ensure the uptake of the HFR derived added value products and services. - To ensure the science-policy-society interactions in marine resources management and planning. - To discuss the risks and impacts of projects and operations ● <u>Meetings:</u> - Annual stakeholder meetings: at venues dedicated sessions. - Theme-focused workshops - Individual/groups interactions - Yearly rounds of review and consultations (ie. surveys) lead by the ESC ● <u>Strategy:</u> - Creation and further integration of stakeholder into annual general meetings and definition of the stakeholder engagement as a core value. - Include engagement in projects budget and work plan. - Invite key stakeholder representatives and policy makers to participate on the Task Team. - Prepare for a long-term commitment - Expand functionality as requested - Evaluate the products and services on regular basis - Include societal awareness mechanisms in the communication strategy
Advisory Board (AB)
● <u>Composition:</u> External experts' members from European and non-European coordination bodies, as elected by the ESC: - Project office representatives from European and Global observing programmes: e.g. GOOS / OceanOPS, EuroGOOS / EOOS, ROOSs (ambassadors), JERICO-RI

- Nominated representatives of international coordinating network: GLOBAL HFR network (including most of the world's leading HFR science and technology institutions)
- Nominated representation of national/regional coordinating networks

- Tasks: Overarching **guidance for defining the strategy** aligned with global strategies to ensure the uptake
  - To support the European HFR network, develop and maintain highly competitive planning in HFR technology and its applications, by sharing best practices, knowledge, significant experiences and functional expertise.
  - To review the status of actions and provide recommendations by means of a report
  - To promote new ideas and external export advice, counsel and guidance to the ESC
  - To promote collaborative alignment of communities and networks
  - To reflect international context and advise the SEC about changes in the ocean observation landscape, programme, funding, new drivers and feasibility and scientific foresight.
  - To reinforce the internationalization of the European HFR network ensuring the link with GEO Global network and OCEANOPS.
- Meetings:
  - Annual meeting: online, or at venues (e.g. ROW meetings, workshops, etc)
  - Yearly rounds of review and consultations (ie. surveys) led by the SEC in which the Advisory Board members would submit detailed responses to the SEC.
  - Videoconferences when requested.
- Strategy:
  - Implementation of the member solicitation process to fill the Panel and further vacancies.
  - Election of the members of the AB, considering the diversity of expertise, geography, intersectoral (public and private sectors), career level (early, mid-, senior) and gender.
  - Creation and evolving into a more permanent structure.

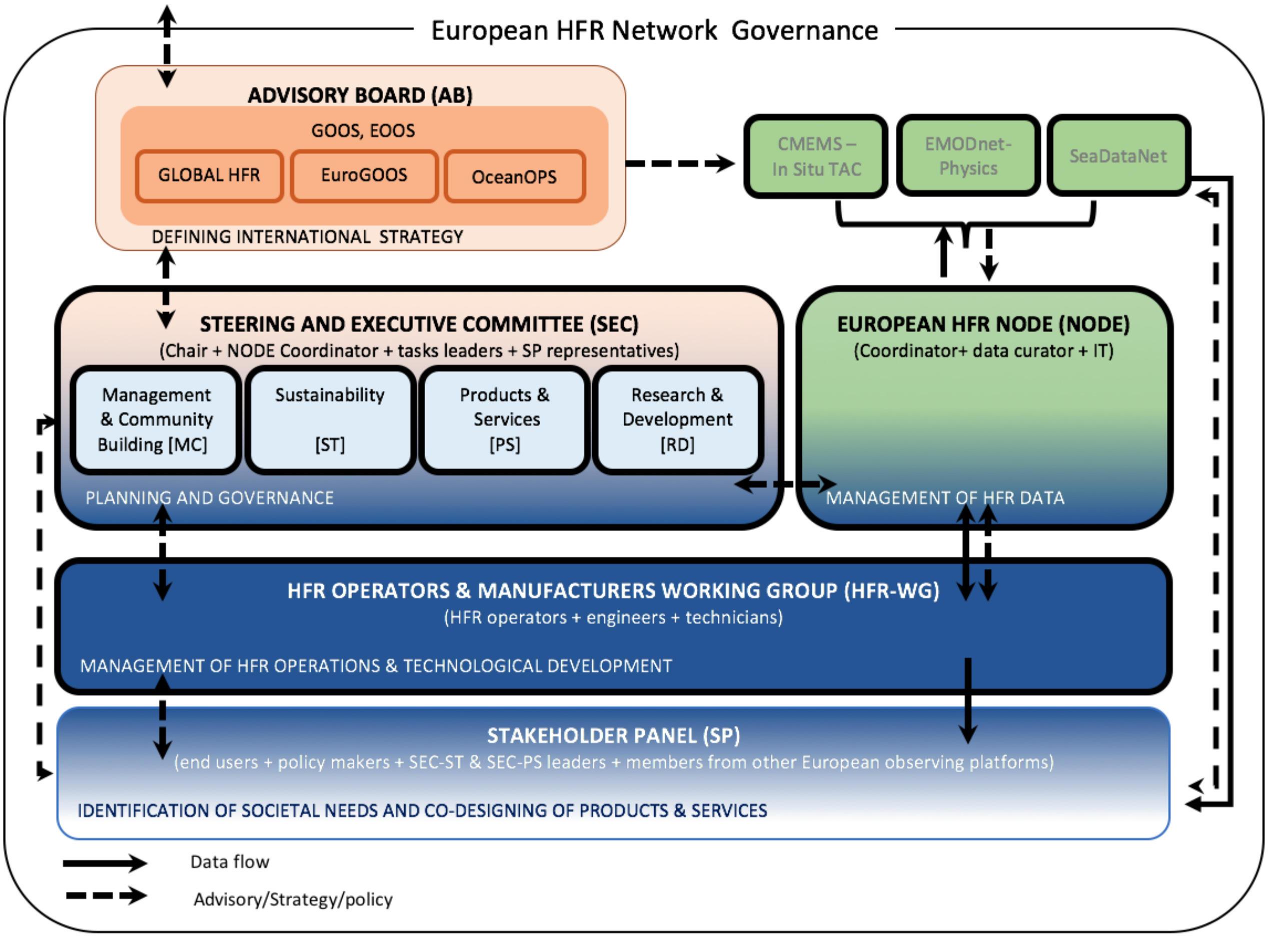

Figure 12.- European HFR network governance structure. Boxes with thick black lines are the elements already in place.

5.2. Human resources and infrastructure

HFR Task Teams activities in the recent years have been supported on a volunteer basis and costs have been covered by projects or own resources from the institutions involved. Strong coordination effort was needed due to resources fragmentation.

Aiming at regular long term financial support, it can be useful to provide an estimation of the resources needed to sustain governance activities including central HFR Node operations, according to the proposed model of governance and building on the experience gained. Also, information from the US HFR Network management plan has been considered, as well as the Euro-Argo ERIC Office report as an example of infrastructure with a well-established Global Data Assembly Center (GDAC).

5.2.1 - Resources for coordination

For coordination activities, a minimum amount of resources should be allocated in order to guarantee regular meetings and documents editing / communication. Required resources are identified as person months, travel costs, workshop / conferences organization costs, publication costs.

Considering the present Covid-19 pandemic situation, an increased number of virtual meetings is expected for the forthcoming years, instead of in-person meetings.

However, face-to-face meetings are recommended with reasonable frequency, for instance:

- one 2-days meeting per year could be considered for the Executive Steering Committee, jointly with the Advisory Board (around 25-30 persons) every 5 years;
- one 2-days meeting every one and half years (could be a joint event with ROWG) could be considered for HFR Operators & Manufacturers group (around 60 persons);
- one 1-day meeting every year could be considered for Stakeholder Panel (around 50 persons);

A total amount of 2 person months has to be considered annually for coordination and reporting activities.

5.2.2 - Resources for the HFR Node

An estimate of **the annual effort** needed for maintenance and development of the European HFR Node, including Near Real Time (NRT) and Reprocessed (REP) data as currently disseminated to CMEMS In Situ TAC, could be described as follows:

- man power (24 person months) dedicated to Data Server Operation and Management, Data Management, Data & Radar Hardware Quality Assurance/Quality Control, Quality Control Enhancement Development. (e.g. 1 full-time junior technician/developer, 1 part-time senior technical coordinator/system architecture designer, and 2 part-time HF radar experts).
- direct costs of the HFR node infrastructure, e.g. computational power, storage, data traffic, maintenance, periodic hardware replacement and upgrade, software licenses, energy. Such costs range between 10% and 20% of the total needed resources.

Forecasting an increasing number of HFR data producers connected with the node in the upcoming years, an increasing amount of data processing, QC improvements, new products delivery (also independently from CMEMS INSTAC or EMODnet Physics) and the establishment of a proper European GDAC, the number of tasks and responsibilities will increase with consequent need of increasing man and infrastructure power.

A structured, state-of-the-art GDAC cannot be sustained in the long term with the current voluntary contribution model. A more stable support should be sought in parallel, on the one hand in the synergy with Pan-European data and marine services and on the other hand in the framework of the ESFRI Roadmap for the JERICO Research Infrastructure.

Those costs may also be reduced by deeply involving the National operators in the application of the standards and publishing FAIR and M2M data (e.g. ERDDAP) so the HFR Node should concentrate the effort on data flow monitoring and on quality, reprocessing and specific products.

6. Concluding remarks

Significant progresses have been performed during the last 7 years in structuring a network of HF Radar systems in Europe. The proposed governance aims to pave the way towards the consolidation, the expansion and optimization of an ambitious and coordinated HF Radar network along the European coastline, aligned with the global and European ocean observing strategies of the Ocean Decade.

From the surrounding framework described in this document, the available options for the implementation of the proposed governance will be:

Keep as we are, under the umbrella of the EuroGOOS Task Team:

- Advantages
  - A network with wide participation from key European actors given the 44 EuroGOOS members and more than 100 contributors of the ROOSs.
  - The structure of the Task Team is flexible enough to host the proposed governance in coordination with other components of the EuroGOOS organization.
- Disadvantages
  - Very loose structure based on volunteering of the members.
  - Infrequent fund support through projects or temporary contribution of members.

A dedicated ERIC (similar to EuroArgo)

- Advantages:
  - The HFR community is fully in line with the definition of an ERIC described in section 2.2.2: “RI are facilities, resources and services that are used by the research communities to conduct research and foster innovation in their fields”.
  - The commitment of the involved countries is expressed on the long term.
- Disadvantages:
  - There is a need to go through the long way and complex ESFRI roadmap.
  - The participation is only by the members whose ministries sign into the ERIC with possibly many actors being left out.

A structure inside JERICO ERIC

- Advantages:
  - There is no need to go through the whole ESFRI roadmap but contributing to achieve a suitable design for the targeted objective of the HF Radar network.
- Disadvantages:
  - HFR will be one of the several coastal platforms inside the JERICO-RI; this could make difficult to have a HFR-specific governance inside the JERICO governance.
  - Again, the participation is only by the members whose ministries sign into the ERIC.

A **mixed solution** could be the appropriate approach: The EuroGOOS HF Radar Task Team may evolve and assume the implementation of the different components of the proposed governance, in coordination with the overall EuroGOOS structure, and under the umbrella of JERICO-RI.

Targeted infrastructures like the pioneering open ocean EuroArgo or EMSO European RI Consortiums, conceived at single-platform level, could be considered for the HFR community. However, an increasing number of isolated marine infrastructures is neither advisable nor feasible in the current ESFRI roadmap. The building of an integrated coastal infrastructure, where HFRs will play a significant role and benefit from the complementarities between different platforms, arises as an added-value solution for the European coastal community. In our view, the HFR community should contribute to the design of a distributed JERICO-RI that may combine different structural elements focused in supporting essential pan-European coastal observational networks.

This integrated approach, within the coastal community and widely within EOOS, is consistent with strong observational platform federations that will highly benefit from a community of practices, globally and within GOOS Regional Alliances like EuroGOOS.

A close link with global organizations like OceanOPS, OBPS, or the platform specific OCG-Global HFR Network will contribute to monitor the European contribution at global level and foster capitalization from international good practices.

Community building between an extensive network of HF Radar operators will stay the basement for a more efficient, sustainable, and fit-for-purpose joint observational network, where key actors like industry (technological suppliers, operations, services) and stakeholders will play an increasing role in the governance structure.

The progress made in the last years, thanks to the activities of the Task Team and the endorsement of different EU projects has been considerable, however it is not granting the longer-term sustainability of the network. First, the promotion of the impact generated by HF Radars across the value chain of operational oceanography will be a priority through the above-mentioned higher connection with industry and stakeholders. Then, joint commitments from the Nations should be enhanced by the implementation of EOOS and through the pursuit of the support of a sustained structuring solution like an ERIC.

Among the different components of the governance, the major role of the Node as a Data Assembly Centre and interface with European Data Aggregators should be consolidated. The impact of the mutualization and value-added of the Node role applying FAIR principles should be monitored in order to feedback the national systems operators and stakeholders.

Finally, this work has been led by a core group of the EuroGOOS HF radar Task Team integrating the outputs from different workshops. However, the proposed governance will need to be further discussed, in the extended HFR community, in the EuroGOOS framework, in the context of EOOS Operation Committee and with other key actors of the Ocean Observation in Europe. This work and its extension can also modestly contribute to the EuroSea Strategic Vision, guidelines for a strategic European Vision of Ocean Observing Integration (Deliverable D3.8 expected for September 2022).

7. Authors contribution

JM, AR, ER, CM, LC contributed to define the Table of Content; ER made substantial contributions to sections 1, 2.3.1, 2.3.2, 3.2.2 and 5.1; prepared figures 5, 6, 9 and 13 based on the deliverable contents, and with input of all authors and conceived the initial idea for Table 8; AR and LS made substantial contributions to sections 2.3.2, 3 (all subsections) and 4.2, prepared figures 3,4,7 and tables 7,8,10,11,12. JM defined the general scope of the document and made substantial contributions to sections 2.3, 3.1, 4.1 and validated the general proposal of 5. LC made substantial contributions to sections 3 and 5. CM made substantial contributions to section 5.2. PB made substantial contributions to section 1.

All authors and contributors discussed and contributed to the writing and review of the final version of the deliverable.

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