THE EUROPEAN HF RADAR INVENTORY

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Foreword

The inventory of the different HF radar systems operating in Europe has been gathered thanks to the survey launched by the EuroGOOS HFR Task Team, in the framework of INCREASE and JERICO-NEXT projects. We are very grateful to all the people who kindly provided the information of their radar and related activities.

This publication summarizes the main results of the European HF radar survey. EuroGOOS HFR Task Team will keep it as living document to be updated each time new information concerning existing or future systems is made available. Please do not hesitate to contact jmader@azti.es if you detect any necessary update on the current contents.

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1 Introduction

The accurate monitoring of ocean surface transport, which is inherently chaotic and depends on the details of the surface velocity field at several scales, is key for the effective integrated management of coastal areas, where many human activities concentrate. This has been the main driver for the growth of coastal observatories along the global ocean coasts.

Among the different measuring systems, coastal High Frequency Radar (HFR) is the unique technology that offers the means to map ocean surface currents over wide areas (reaching distances from the coast of over 200km) with high spatial (a few kms or higher) and temporal resolution (hourly or higher). Consequently, the European HFR systems are playing an increasing role in the overall operational oceanography marine services. Their inclusion into CMEMS is crucial to ensure the improved management of several related key issues as Marine Safety, Marine Resources, Coastal & Marine Environment, Weather, Climate & Seasonal Forecast.

The main potential of HFR resides in the fact that these systems can offer high temporal and spatial resolution current maps, matching the need for operational monitoring/forecasting of ocean transports and their applications to several Marine Strategy Framework Directive's (MSFD) objectives.
Around 400 HFR sites have been already installed worldwide, and used in a diverse range of applications (see Paduan and Washburn, 2013, and Roarty et al., 2016). In Europe, the number of HFR systems is growing with over 50 HFR sites currently deployed and a number in the planning stage.

In Europe, the use of HFR systems is growing with over 50 HFRs currently deployed and a number in the planning stage. In order to build an up-to-date inventory of operational HFR systems and operators the EuroGOOS HFR TaskTeam in close collaboration with the INCREASE and JERICO-Next projects, launched a European survey to diagnose the present status of different HFR systems available in Europe.

The survey consisted in 46 questions oriented to provide information on four areass:

- Contact people for each network or system
- Technical information on the network, number, names, locations, working parameters of the sites (including questions on maintenance procedures and experience of interference problems)
- Technical information about the data formats, sharing protocols and policies, QA/QC and processing
- Areas of application of the data and identified users (including specific questions related to data assimilation)

The survey was launched in June 17th and was set to the EuroGOOS HFR Task Team expert's mail-list, including JERICO-Next collaborators and other identified key actors. It was closed July 27th, gathering responses from 28 European institutions and information on more than 70 HFR systems.

The complete survey can be consulted in Annex 1.

2 Overview to the European HFR systems

The INCREASE EU HFR survey gathered information from 28 institutions, 23 of whose are operators of ongoing or past HFR networks. A total of 72 sites (conforming 28 networks) were listed from the survey results, 52 of those sites are ongoing (20 networks). Within the remaining sites there are 9 past installations (3 past networks) and 12 future installations (5 new networks). The information provided in the following describes several aspects of the ongoing and past HFR networks (N=23) and their corresponding sites (N=60). Although we believe this survey provides a very complete view of the HFR activity in Europe we are aware of some additional past HFR installations which were not listed here, because they were very short term or experimental installations or they have been not identified by the users of the survey (e.g. two HFRs were operated close to the Rhone river mouth, NW Mediterranean, at least from June 2006 to January 2007, see Schaeffer et al. 2011).

2.1 General view of EU HFR systems

Based on the responses provided, 92% (48) of the ongoing installations (52) are meant to be permanent. The remaining systems are temporary, with undefined dates of end of use. Figure 1 shows the location of the systems listed by the survey, with a graphical representation of the footprint areas for each antenna.

The distribution of the identified ongoing and past networks (N=23) amongst the ROOS areas is: 52% (12) in MONGOOS, 26% (6) in IBIROOS and 22% (5) in NOOS. In terms of number of sites MONGOOS is again the most densely populated, it contains 31 sites (52%). While IBIROOS and NOOS contain 17 sites (28%) and 12 sites (20 %), respectively.

Figure 2 shows the evolution in time of the number of HFR systems in Europe, following the current inventory. The number of systems is growing with time and the plans show the increase to continue in the next year.

In addition to the general statistics presented here, a complete characterization of the existing systems has been performed, and it is presented in the corresponding tables of Annex 2. Most of the EU HFR networks are (or have been) operated for several years and are built of 2 sites, on average. The used systems range from very high frequency systems like the one in Ria de Vigo, working at frequencies of 46.5 MHz (thus providing horizontal resolution for total currents coarser than 200 m) to long range systems working at 4.5 MHz (providing horizontal resolution of 5 km) used in Spain or UK. They offer typically temporal resolution of 1 hour or less and variable spatial coverage depending on their working frequency (see Figure 1).

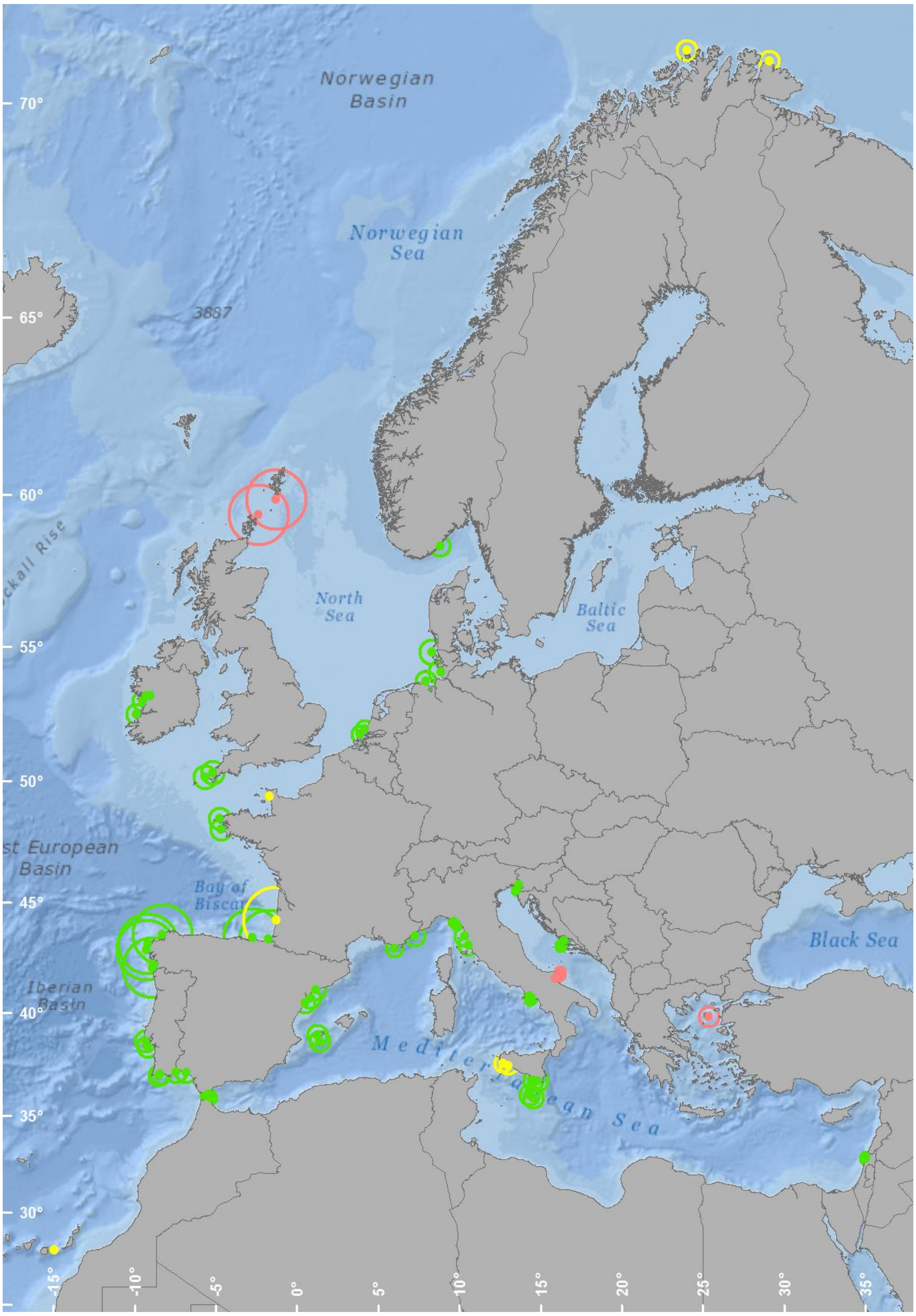

FIGURE 1: MAP WITH THE LOCATION OF THE 72 EU HFR SITES LISTED IN THE SURVEY, AND THEIR RADIAL COVERAGE (REPRESENTED BY THE CIRCLES SCALED TO TYPICAL RADIAL RANGE ASSOCIATED TO THE FREQUENCY OF OPERATION OF EACH OF THE SYSTEMS) . GREEN: ONGOING; RED: PAST; YELLOW: FUTURE INSTALLATIONS.

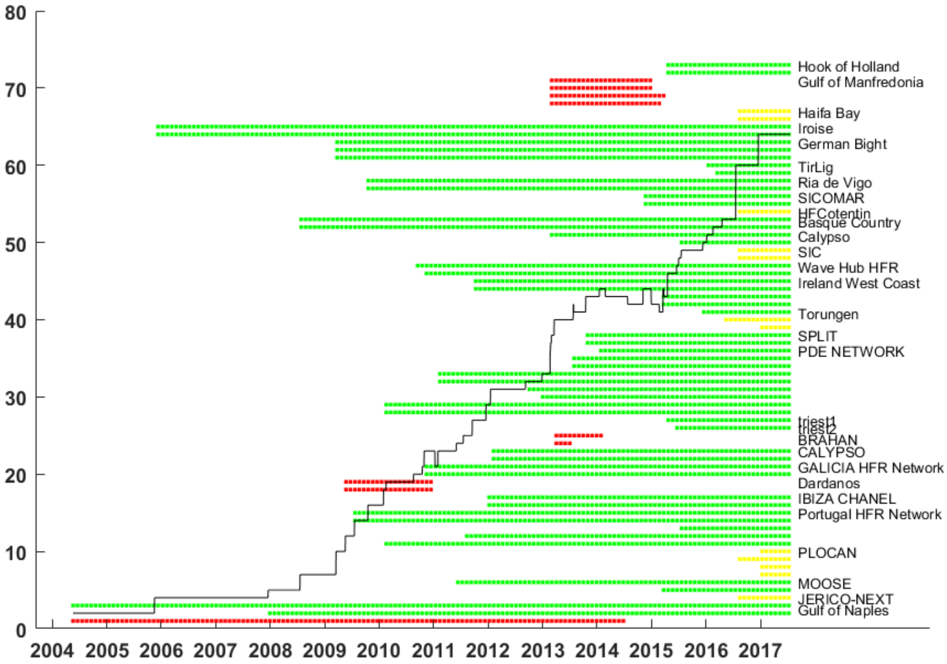

FIGURE 2: EVOLUTION OF THE NUMBER OF EU HFR OPERATIONAL RADARS WITH TIME. THE BOLD BLACK LINE SHOWS THE NUMBER OF OPERATIONAL SYSTEMS PER YEAR (Y AXIS). THE TIMELINE OF THE EU SYSTEMS, FOLLOWING THE INVENTORY, IS PROVIDED BY THE DISCONTINUOUS LINES. PAST SYSTEMS ARE PLOTTED IN RED, FUTURE SYSTEMS IN YELLOW AND PRESENT SYSTEMS IN GREEN. THE NAME OF THE NETWORKS AS PROVIDED IN THE SURVEY IS GIVEN BESIDE THE CORRESPONDING SITES' TIMELINES.

Only 28 % of the systems are connected to European Data System - EMODnet Physics (Figure 3). Some of them through other national networks like Puertos del Estado and some other are also included in other National and International Networks like: MOOSE Network: www.moose-network.fr; GEO Global High Frequency Radar Network: http://marine.rutgers.edu/~hroarty/GEO/ESRI and IBERORed: www.iberoredhf.es.

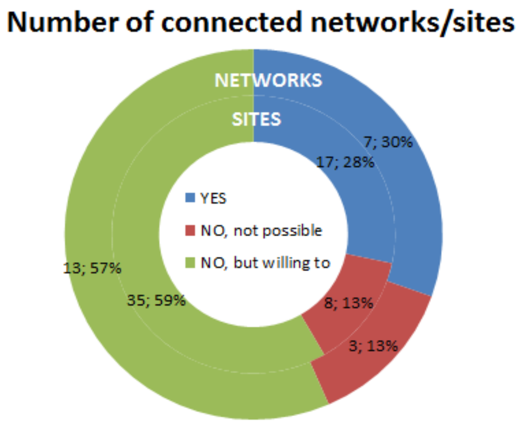

FIGURE 3: PERCENT OF NETWORKS AND SITES CONNECTED TO THE EUROPEAN DATA SYSTEM

The most interesting is that the majority of the institutions whose systems are not connected express the will to do it in the future. 35 new sites are potentially being added to the list of 17 sites already connected in the next months, provided the correct tools and needed guidance are produced.

2.2 HFR systems operation and maintenance

78 % of the EU HFRs (N=60) are being or have been operated using direction-finding (DF) and 20 % using beam-forming (BF) in a phased array. One system follows in the middle of these two categories, using DF on eight receiving antenna. The two main manufacturers identified are CODAR and WERA, HELZEL Messtechnik.

The systems are operated by different kind of institutions, from Academy to technological centers and meteorological agencies to governmental organizations. The frequency of in situ technical maintenance operations is variable. Most part of the systems (74%) are controlled in situ periodically (every 3-6 months or yearly). For 20% of the systems in-situ operations are sporadic; they are performed after changes at the antennae arrays, if technical issues appear or when possible. For several of the systems additional remote check is performed in a monthly basis or even daily.

The occurrence of interferences is also variable with around 30% of the systems experiencing interferences at some level. These are observed to reduce the range of the data and/or to reduce the signal to noise ratios (SNRs). In the cases where there is continuous interference, it is observed mostly in 13.5 MHz systems, during the afternoon. These interferences are skipped in some cases by changing the system operation bandwidth. Occasional interferences seem to be related to ambient noise at different times during the day or to the ionosphere effect during the evenings (and especially in summer time).

2.3 Existing data formats and QA/QC protocols

Data formats and QA/QC protocols in use by the EU HFR operators (N=23) are diverse (Figure 4). Most of the operators are using Manufacturer's data formats for radial data, although around a 26% of the systems are already using netcdf format for radials. In the case of total data the number of networks already using netcdf formats in addition to that of the manufacturer's is much higher (around 70%). Other include basically ASCII formats defined by the institution producing the data. NetCDF for radial data in use are those defined by RITMARE standards and proposed as standard for the EU network. In the case of NetCDF for total data, they follow different standards, with data files following CF-1.3, CF-1.4 and CF-1.6 conventions, ACDD, INSPIRE, Unidata Dataset Discovery v1.0 and or NOAA GNOME format compliant to NetCDF formats without compliance.

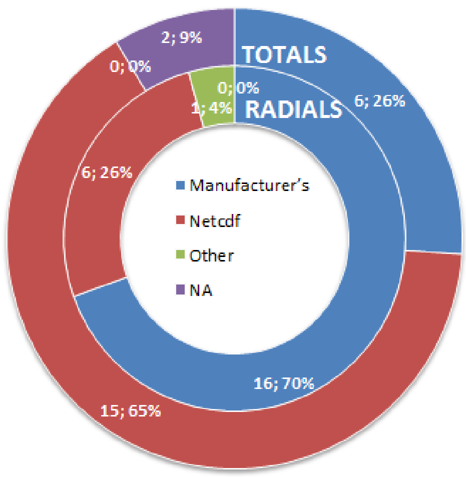

FIGURE 4: DATA FORMAT IN USE FOR RADIAL AND TOTAL DATA BY THE EU HFR OPERATORS (N=23).

Following the survey responses, represented in Figure 5, QA/QC are mostly applied jointly to both total and radial data (35%), but several operators also apply QA/QC at the three levels: total, radial and spectral (19%). Other choices exist, for instance applying QA/QC only at total or radial levels or those, including AdHoc QA/QC procedures (as indicated by one of the operators).

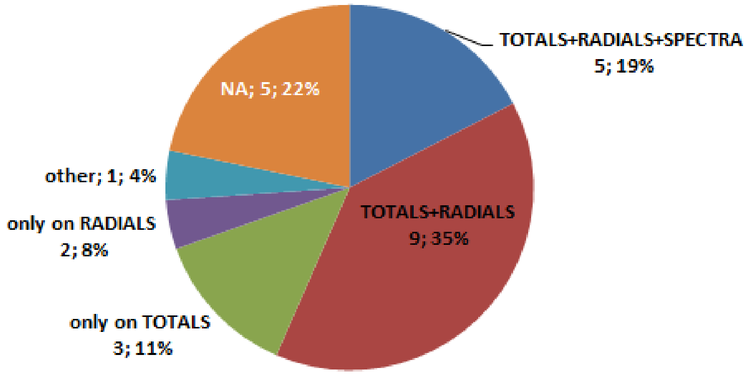

FIGURE 5: DATA LEVELS USED FOR QA/QC PROCEDURES BY THE EU HFR OPERATORS (N=23).

Most of the operators (N valid answers= 14) use the Least Square Method (>90%) to produce totals, but other methods like OMA (Kaplan & Lekien, 2007) are also quite extended (around 30% of the responses). The most common software used for combining radials into totals is the one provided by the manufacturers (in around 68% of the cases, N valid answers= 19) although other tools like the matlab HFR_toolbox (26%) and specific software developed by the operators (19%) are used in other cases in addition or as alternative to manufacturer's software.

2.4 HFR surface ocean current data sharing protocols

The most part of the networks (70%) are applying an open data policy with no restrictions of use (Figure 6). From those, 14 operators are providing free and open data under no specific licensing. Two networks, operated by CNR-ISMAR, are offering their data under Creative Commons Attribution 4.0 International License (see http://creativecommons.org/licenses/by/4.0). The remaining 30% of the data are not all fully restricted. For some networks there is free access to the data depending on the final user (for instance, data is open for academic use or), or the resolution of the product (so only high resolution products are restricted and only available upon request). Other data are only available upon request and in one case data are restricted but near-real time visualization and validation of the current maps are available at the institution web.

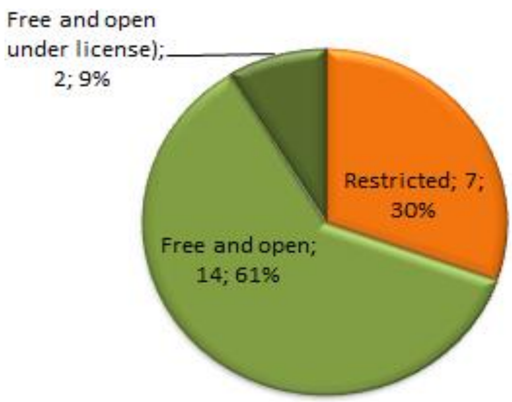

FIGURE 6: DATA POLICY (N=23)

Concerning the online availability of the data from the listed networks, while the 75% of the real time data are online, only the 51% of the historical data are (Figure 7). The most used protocol to put the data online is the THREDDs, although other possibilities coexist (e.g. using WMS-Web Map Service through the operator webpage, or other protocols like ftp; Some data are available through the institutions' data server or portals).

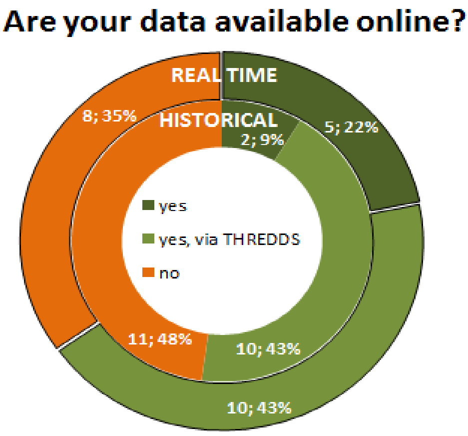

FIGURE 7: DATA AVAILABILITY AND DATA SHARING PROTOCOLS (N=23)

3 HFR current data uses and users in Europe

As revealed by the increasing literature in Europe concerning HFR reflects ongoing efforts towards the applications in different sectors: oils spill management (Abascal et al. 2009; Bellomo et al., 2016), marine litter (Basurko et al. 2016), search and rescue (Orfila et al. 2015, Solabarrieta et al. 2016) and data assimilation (e.g. Marmain et al, 2014; Barth et al. 2008, 2011; Iermano et al., 2016; Stanev et al. 2015).

Following the information gathered from the HFR networks participating in the INCREASE survey, several additional applications of HFR data to different sectors in Europe are in progress and there is a number of well-established users (Figure 8). 20 of 23 operators chose at least one option between the listed users of their data among different activity sectors. The most popular identified user is the Academia, followed by European or National Maritime Safety Agencies and Weather Services. Some specific users were by Spanish operators: the Spanish Maritime Safety Agency SASEMAR and Ports Authorities through Puertos del Estado networks.

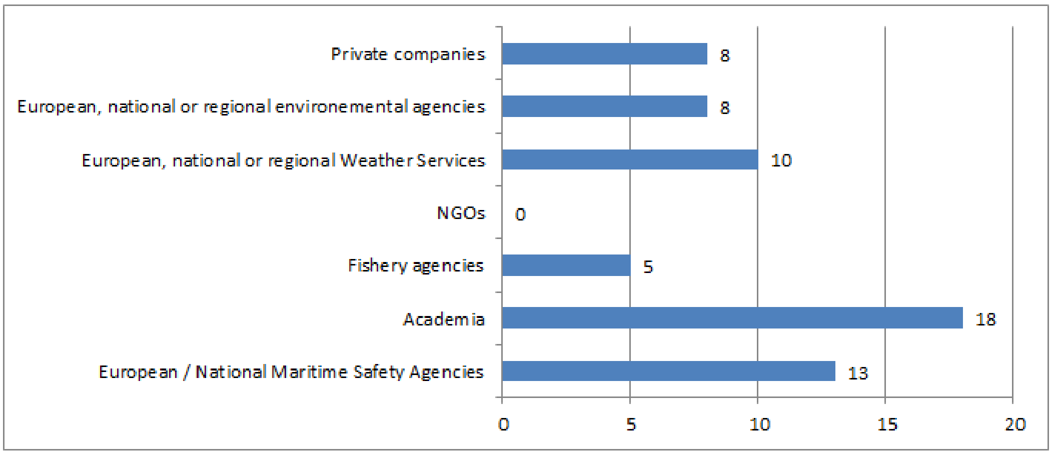

FIGURE 8: EU HFR IDENTIFIED USERS. FROM THE 23 NETWORKS 20 CHOSE AT LEAST ONE OPTION. MULTIPLE CHOICE WAS ENABLED, SO MORE THAN ONE USER COULD BE IDENTIFIED BY THE SAME OPERATOR.

More information on current HFR applications was collected through multiple choice questions related with five activity sectors: Marine Safety, Marine Resources, Coastal and marine environment, Weather, Climate and Seasonal Forecast and Research (Figure 9). It was asked to the survey contributors to mark only applications that were actually exploited by identified users.

The most popular sector of application of EH HFR data is the Marine Safety. 14 of 23 operators identified at least one category within this sector, being the applications for oil spill response and search and rescue operations the most frequent. Among the specifications provided by the operators some applications consist of both HFR and a 3D hydrodynamic modeling (The currents measured by the HFR will be assimilated into the 3D model to provide the best forecast) but also on the indirect use of data by users (coastal guards, offshore plant and ship routing) that use both radar and model data entries, delivered in the form of reports and bulletins. In the Basque Country HFR data were used recently to update the Basque Country Contingency Plan, in the design of characteristic current scenarios. Finally the data from several of Puertos del Estado systems are directly distributed to Spanish MArine Safety agency to Search and Rescue operations SASEMAR.

Regarding Marine Resources much less applications are identified, only 7 of 23 operators identified applications in this section in the categories of Fishery research (one specific example concerning the applications of larval transport and distribution for the sustainable fishing of bluefin tuna was provided), ecosystem based approach and renewable energies.

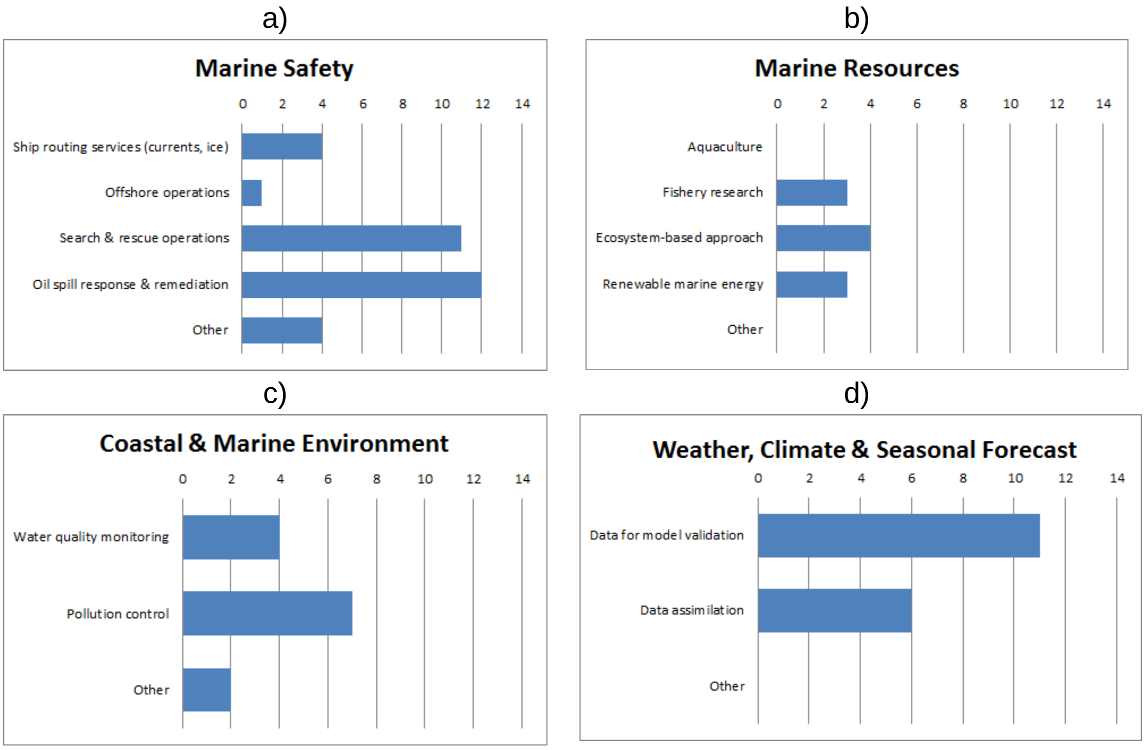

FIGURE 9: EU HFR APPLICATIONS WITHIN FOUR ACTIVITY SECTORS: A) MARINE SAFETY, B) MARINE RESOURCES, C) COASTAL AND MARINE ENVIRONMENT AND D) WEATHER AND CLIMATE FORECAST. FROM 23 OPERATORS 14,7, 11 AND 12 CHOSE AT LEAST ONE OF THE AVAILABLE OPTIONS FOR A), B), C) AND D), RESPECTIVELY. MULTIPLE CHOICE WAS ENABLED, SO MORE THAN ONE APPLICATION WITHIN THE SAME OR DIFFERENT SECTORS COULD BE IDENTIFIED BY THE SAME OPERATOR.

In addition to water quality monitoring and pollutions control other two applications in the sector of Coastal and Marine Environment were identified: Leisure activities (sail and swimming competitions) and indirect use of data for estimating marine litter concentrations that may be accumulated by local hydrodynamic conditions (for Universities and National/Regional Environmental Agencies). 11 of 23 operators identified at least one application in this field, being the use of HFR data for pollution control de most popular.

In the field of weather forecast almost all of those operators that identified at least one application in this sector (12 of 23) were referring to the use of data for model validation and half of them to the use of the data for data assimilation.

Finally, concerning HFR related research, the most popular research lines are those related to Lagrangian approaches to surface transport and connectivity, the research on data assimilation and small scale and mesoscale ocean processes (figure 10). The most part of the categories presented are related with HFR surface current data, one user added an additional research lines related with the spatial wave measurements for research and marine renewable energy application.

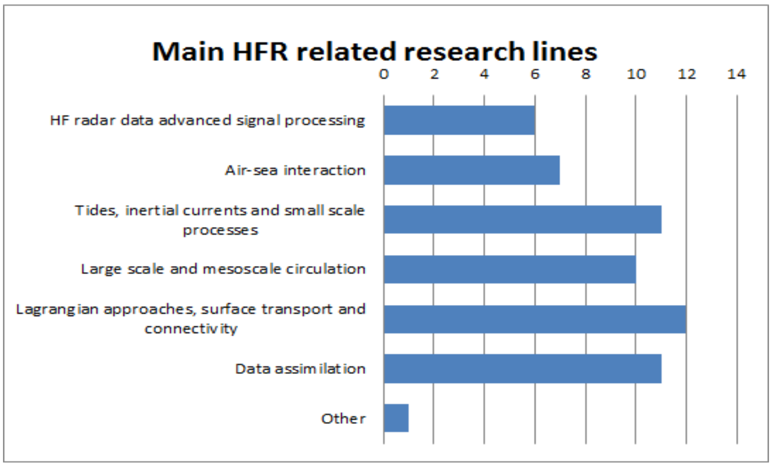

FIGURE 10: HFR RELATED RESEARCH LINES LISTED BY EU OPERATORS CONTRIBUTING TO THE SURVEY. FROM 23 OPERATORS 15 CHOSE AT LEAST ONE OF THE AVAILABLE OPTIONS. MULTIPLE CHOICE WAS ENABLED, SO MORE THAN ONE APPLICATION WITHIN THE SAME OR DIFFERENT SECTORS COULD BE IDENTIFIED BY THE SAME OPERATOR.

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5 Acknowledgments

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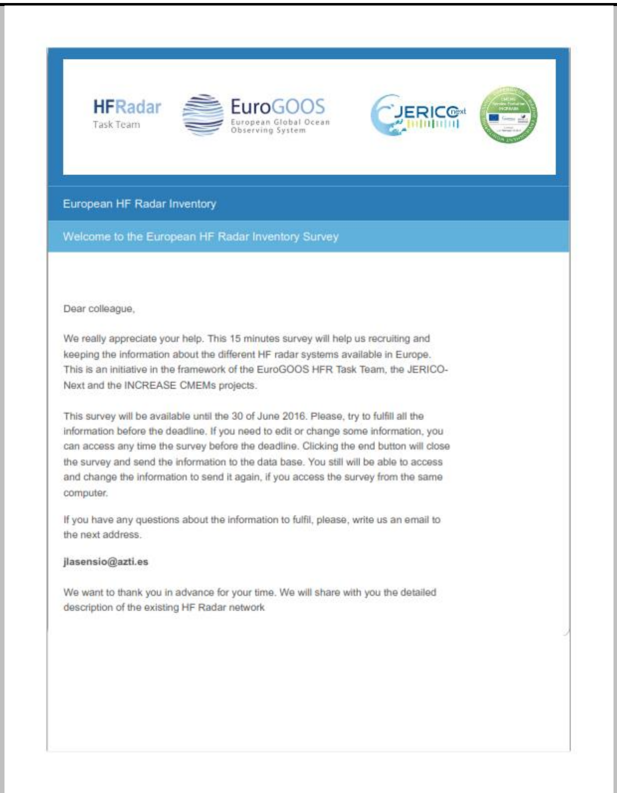
ANNEX 1 – The HFR survey

PAGE 1 - INTRODUCTION	PAGES 2-3 CONTACT INFORMATION	PAGES 4-7 HFR NETWORK SITES



HFRadar Task Team

EuroGOOS European Global Ocean Observing System

JERICO-NEXT

European HF Radar Inventory

Welcome to the European HF Radar Inventory Survey

Dear colleague,

We really appreciate your help. This 15 minutes survey will help us recruiting and keeping the information about the different HF radar systems available in Europe. This is an initiative in the framework of the EuroGOOS HFR Task Team, the JERICO-Next and the INCREASE CMEMs projects.

This survey will be available until the 30 of June 2016. Please, try to fulfill all the information before the deadline. If you need to edit or change some information, you can access any time the survey before the deadline. Clicking the end button will close the survey and send the information to the data base. You still will be able to access and change the information to send it again, if you access the survey from the same computer.

If you have any questions about the information to fulfil, please, write us an email to the next address.

jlasensio@azti.es

We want to thank you in advance for your time. We will share with you the detailed description of the existing HF Radar network

HFRadar Task Team

EuroGOOS European Global Ocean Observing System

JERICO-NEXT

European HF Radar Inventory

General Information

Complete the contact information relative to the Observing Network.

* 1. Contact person

Name

Institution

Address

Address 2

Country

Email Address

Phone Number

2. Owner or responsible for the network (if different from previous)

Name

Institution

Address

Address 2

Country

Email Address

Phone Number

HFRadar Task Team

EuroGOOS European Global Ocean Observing System

JERICO-NEXT

European HF Radar Inventory

Information of the Networks: Site N. 1

This page includes all technical information specific to the different sites of your networks. You can add up to 10 sites if necessary.

* 4. Site name

* 5. Name of the network

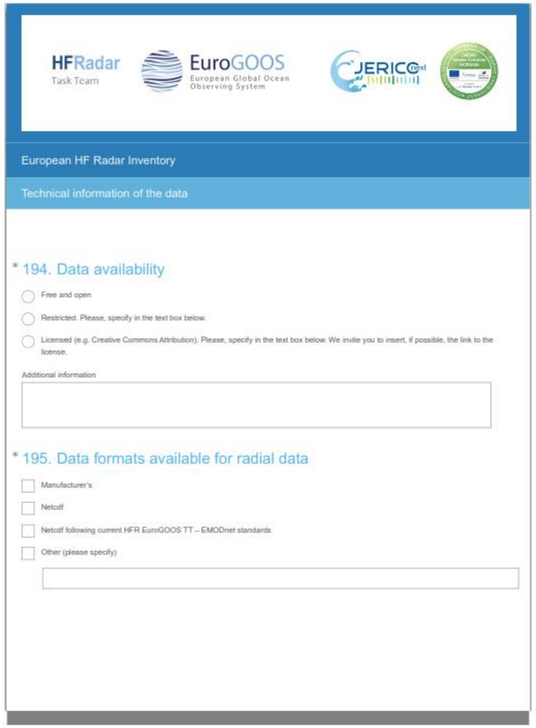
* 6. Latitude (decimal format)

* 7. Longitude (decimal format)

8. Manufacturer

PAGES 4-7 HFR NETWORK SITES	PAGES 4-7 HFR NETWORK SITES	PAGES 4-7 HFR NETWORK SITES (up to 10 sites)
* 9. System type Direction Finding Phased Array Other (please specify) 10. Resolution of radial data: Angular resolution (in degrees) 11. Resolution of radial data: Range cell resolution (in meters) 12. Resolution of radial data: Temporal resolution (in minutes) 13. Spatial resolution of total velocity grid (in meters) * 14. Transmit frequency (in MHz) * 15. Transmit Bandwidth (in KHz) * 16. Start date of use DD MM YYYY Date / Time / /	* 17. End date of use or ongoing Ongoing Ended (Please enter the end date in DD/MM/YYYY format) * 18. "Permanent" or temporary installation Permanent installation Temporary installation * 19. Is this HF radar site subjet to regular interference? never occasionally periodically always Other If you answered occasionally, periodicalle or always, specify please, in which bandwith. If Other, should be explained here too. 20. Which is the periodicity of system maintenance? Bi-yearly Yearly Other (please specify)	21. Which is the frequency of the antenna patterns calibration (APM) campaigns? Bi-yearly Yearly Other (please specify) * 22. Do you need to add another site to the network? YES NO

PAGES 8-11 DATA TECHNICAL INFORMATION



European HF Radar Inventory

Technical information of the data

* 194. Data availability

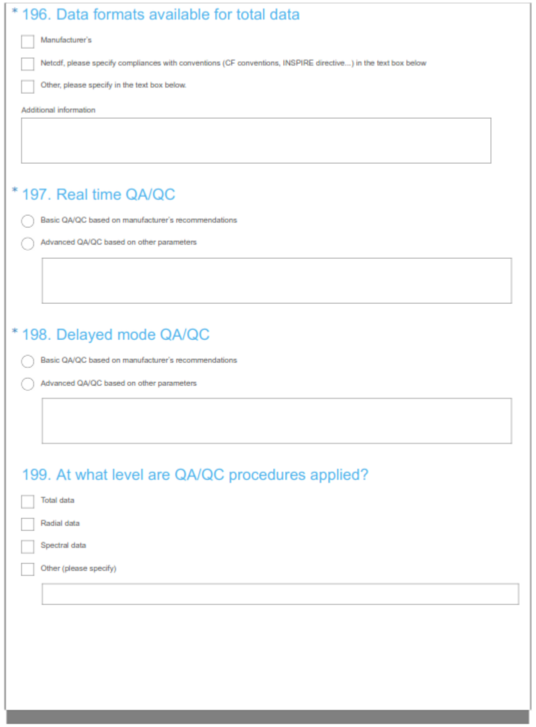
- Free and open
- Restricted. Please, specify in the text box below.
- Licensed (e.g. Creative Commons Attribution). Please, specify in the text box below. We invite you to insert, if possible, the link to the license.

Additional information

* 195. Data formats available for radial data

- Manufacturer's
- Netcdf
- Netcdf following current HFR EuroGOOS TT – EMODnet standards
- Other (please specify)

PAGES 8-11 DATA TECHNICAL INFORMATION



* 196. Data formats available for total data

- Manufacturer's
- Netcdf, please specify compliances with conventions (CF conventions, INSPIRE directive...) in the text box below
- Other, please specify in the text box below.

Additional information

* 197. Real time QA/QC

- Basic QA/QC based on manufacturer's recommendations
- Advanced QA/QC based on other parameters

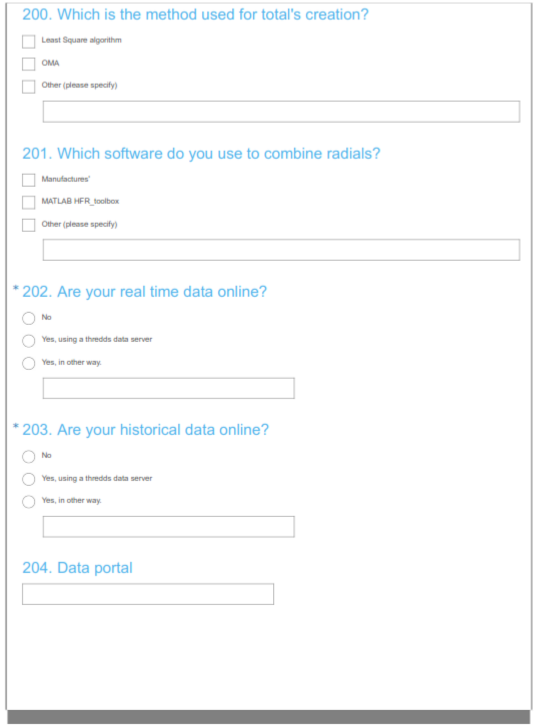
* 198. Delayed mode QA/QC

- Basic QA/QC based on manufacturer's recommendations
- Advanced QA/QC based on other parameters

199. At what level are QA/QC procedures applied?

- Total data
- Radial data
- Spectral data
- Other (please specify)

PAGES 8-11 DATA TECHNICAL INFORMATION



200. Which is the method used for total's creation?

- Least Square algorithm
- OMA
- Other (please specify)

201. Which software do you use to combine radials?

- Manufactures'
- MATLAB HFR_toolbox
- Other (please specify)

* 202. Are your real time data online?

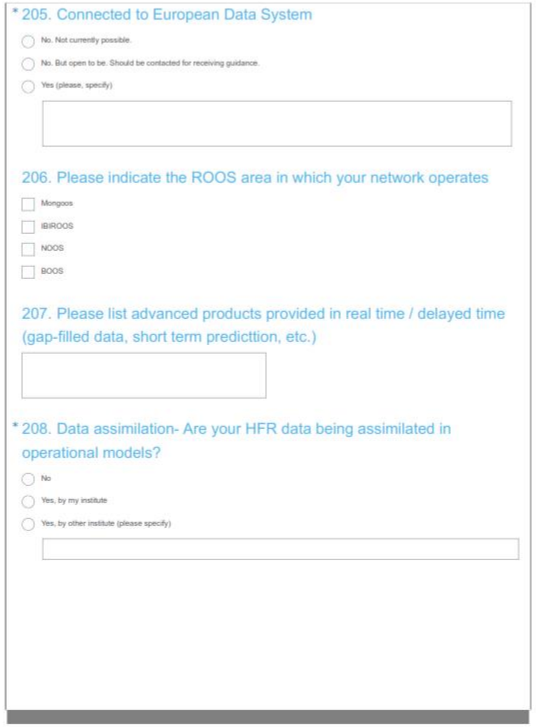
- No
- Yes, using a thredds data server
- Yes, in other way.

* 203. Are your historical data online?

- No
- Yes, using a thredds data server
- Yes, in other way.

204. Data portal

PAGES 8-11 DATA TECHNICAL INFORMATION



* 205. Connected to European Data System

- No. Not currently possible.
- No. But open to be. Should be contacted for receiving guidance.
- Yes (please, specify)

206. Please indicate the ROOS area in which your network operates

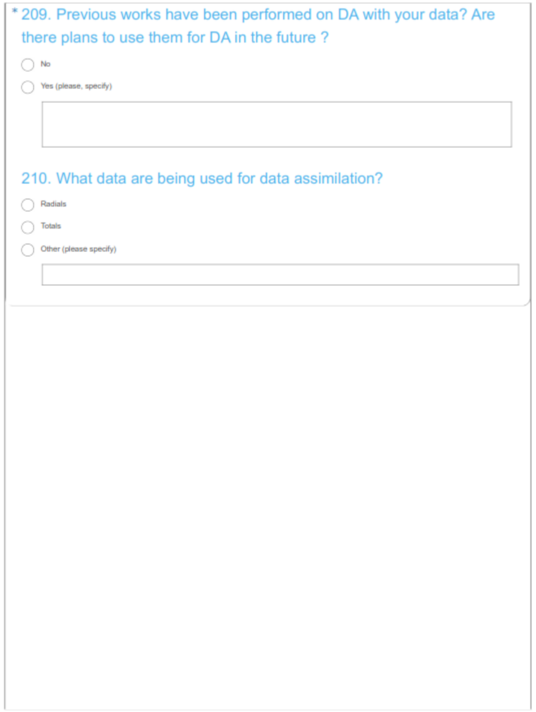
- Mongoos
- IBIROOS
- NOOS
- BOOS

207. Please list advanced products provided in real time / delayed time (gap-filled data, short term predicttion, etc.)

* 208. Data assimilation- Are your HFR data being assimilated in operational models?

- No
- Yes, by my institute
- Yes, by other institute (please specify)

PAGES 8-12 DATA TECHNICAL INFORMATION



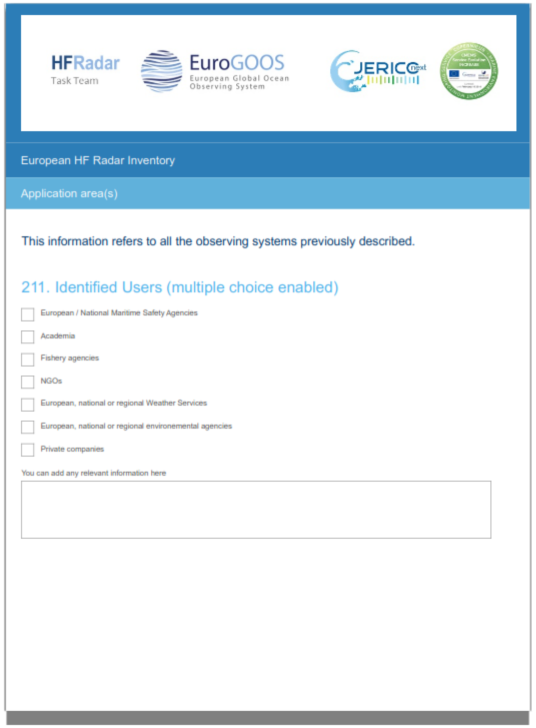
* 209. Previous works have been performed on DA with your data? Are there plans to use them for DA in the future ?

- No
- Yes (please, specify)

210. What data are being used for data assimilation?

- Radials
- Totals
- Other (please specify)

PAGES 13-15 APLICATIONS



European HF Radar Inventory

Application area(s)

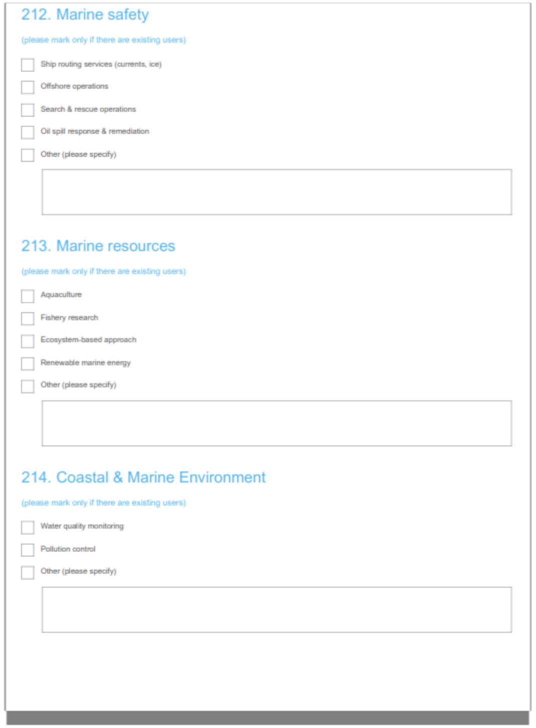
This information refers to all the observing systems previously described.

211. Identified Users (multiple choice enabled)

- European / National Maritime Safety Agencies
- Academia
- Fishery agencies
- NGOs
- European, national or regional Weather Services
- European, national or regional environemental agencies
- Private companies

You can add any relevant information here

PAGES 13-15 APLICATIONS



212. Marine safety

(please mark only if there are existing users)

- Ship routing services (currents, ice)
- Offshore operations
- Search & rescue operations
- Oil spill response & remediation
- Other (please specify)

213. Marine resources

(please mark only if there are existing users)

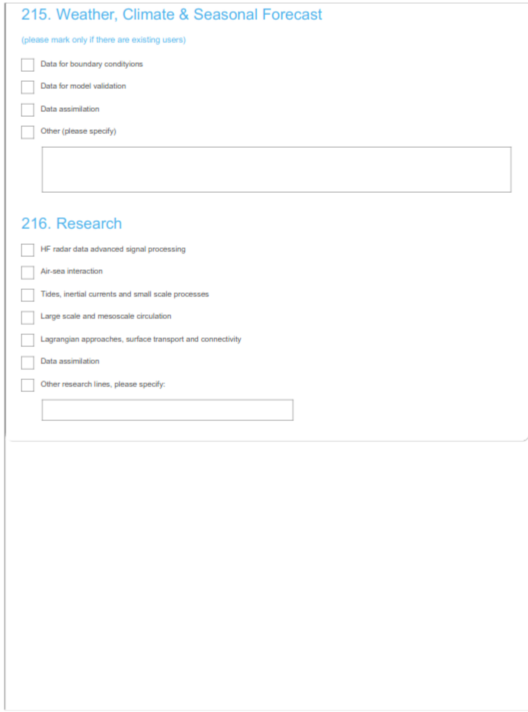
- Aquaculture
- Fishery research
- Ecosystem-based approach
- Renewable marine energy
- Other (please specify)

214. Coastal & Marine Environment

(please mark only if there are existing users)

- Water quality monitoring
- Pollution control
- Other (please specify)

PAGES 13-15 APLICATIONS



215. Weather, Climate & Seasonal Forecast

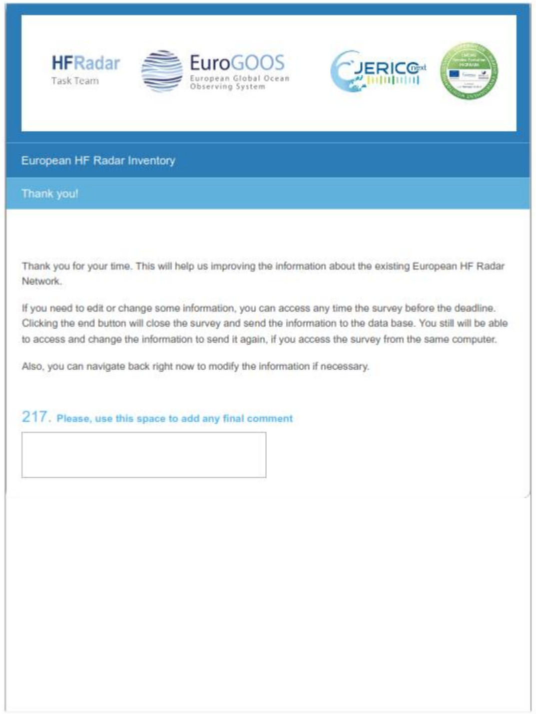
(please mark only if there are existing users)

- Data for boundary conditiyons
- Data for model validation
- Data assimilation
- Other (please specify)

216. Research

- HF radar data advanced signal processing
- Air-sea interaction
- Tides, inertial currents and small scale processes
- Large scale and mesoscale circulation
- Lagrangian approaches, surface transport and connectivity
- Data assimilation
- Other research lines, please specify:

PAGE 16 CLOSING INFORMATION



HFRadar Task Team EuroGOOS European Global Ocean Observing System JERICO-next

European HF Radar Inventory

Thank you!

Thank you for your time. This will help us improving the information about the existing European HF Radar Network.

If you need to edit or change some information, you can access any time the survey before the deadline. Clicking the end button will close the survey and send the information to the data base. You still will be able to access and change the information to send it again, if you access the survey from the same computer.

Also, you can navigate back right now to modify the information if necessary.

217. Please, use this space to add any final comment

ANNEX 2 – Main characteristics of European HFRs

TABLE A1-1. MAIN CHARACTERISTICS OF THE EU HFR NETWORKS. WERA*= WERA, HELZEL MESSTECHNIK; DF= DIRECTION FINDING; PA= PHASED ARRAY.

HFR NETWORK	Hook of Holland		German Bight			Gulf of Naples			TirLig		Gulf of Manfredonia				SICOMAR		Calypso		Joe Doe	CALYPSO		SPLIT	
COUNTRY	***THE NETHERLANDS***		***GERMANY***			***ITALY***													**SLOVENIA**	**MALTA**		***CROATIA***	
OPERATOR	Rijkswaterstaat		Helmholtz-Zentrum Geesthacht			University of Naples			CNR-ISMAR						Consorzio LaMMA - CNR		University of Palermo		National Institute of Biology	University of Malta		Institute of Oceanography and Fisheries	
Numbser of SITES	2		3			3			2		4				2		2		1	2		2	
Name of sites	Ter Heijde	Ouddorp	Wangerooge	Büsum	Sylt	Portici	Castellammare di Stabia	Sorrento	MONT	TINO	VIES	PUGN	MATT	MANF	Livorno Accademia	Marina di San Vincenzo	POZZ	MRAG	Piran 1	Barkat	Sopu	Razanj	Stončica
Sites lat , lon coordinates	52,03	51,82	53,79	54,12	54,82	40,81	40,69	40,63	44,15	44,03	41,89	41,78	41,73	41,62	43,53	43,10	36,71	36,78	45,53	35,88	36,06	43,32	43,07
	4,17	3,88	7,92	8,86	8,28	14,34	14,46	14,34	9,65	9,85	16,18	16,19	16,12	15,93	10,31	10,54	14,83	14,55	13,57	14,56	14,31	16,41	16,25
Date of 1st deployment	01/10/2015		30/08/2009			01/11/2004 and 01/06/2008		11/01/2004	20/06/2016 and 01/08/2016		08/05/2013			08/08/2013	20/04/2015		14/08/2013 and 15/12/2015		01/10/2015	01/07/2012		01/04/2014	
Status	Ongoing		Ongoing			Ongoing		Ended on 06/01/2015	Ongoing		Ended on 13/06/2015		Ended on 06/09/2015	Ended on 06/08/2015	Ongoing		Ongoing		Ongoing	Ongoing		Ongoing	
Permanent installation?	yes		yes			yes			no		no				yes		yes		yes	yes		yes	
Manufacturer	WERA*		WERA*			CODAR			CODAR		CODAR				CODAR		CODAR					WERA*	
Type of radar	PA		PA			DF			DF		DF				DF		DF		PA	DF		PA	
Temporal resolution (minutes)			20			60			60		60				60		60					30	
Spatial resolution of total velocity grid (m)						1000			1500		1500				3000		3000					5000	
Tansmit Fequency (MHz)	16,1		13,5	10,8	10,8	24,6		25,2	26,275		24,53	26,275			13,5		13,5		25	13,5		26,275	
Tansmit Bandwidth (KHz)	150		100	100	100	150			150		150				100		100		150	49,6		150	

TABLE A1-1. MAIN CHARACTERISTICS OF THE EU HFR NETWORKS. WERA*= WERA, HELZEL MESSTECHNIK; DF= DIRECTION FINDING; PA= PHASED ARRAY(cont.)

HFR NETWORK	IBIZA CHANEL		DELTA DEL EBRO			ESTRECHO DE GIBRALTAR			GOLFO DE CÁDIZ	GALICIA				Ria de Vigo		Basque Country	
COUNTRY	*SPAIN*																
OPERATOR	SOCIB		Puertos del Estado									INTECMAR		University of Vigo		AZTI	
Numbser of SITES	2		3			3			1	2		2		2		2	
Name of sites	FORM	GALF	SALOU	ALFACADA	VINAROZ	CEUTA	PUNTA CARNERO	TARIFA	MAZAGÓN	SILLEIRO	FISTERRA	Vilán	Prior	Ria de Vigo	SUBR	Matxitxako	Higer
Sites lat , lon coordinates	38,67	38,95	41,06	40,67	40,46	35,90	36,08	36,00	37,13	42,10	42,88	43,16	43,57	42,20	42,25	43,45	43,38
	1,39	1,22	1,17	0,83	0,48	-5,31	-5,43	-5,61	-6,83	-8,90	-9,27	-9,21	-8,31	-8,80	-8,86	-2,75	-1,78
Date of 1st deployment	01/06/2012		01/07/2014	07/01/2014		15/07/2011		21/02/2013	11/06/2013	15/07/2010		13/04/2011		01/04/2010		01/01/2009	
Status	Ongoing		Ongoing			Ongoing			Ongoing	Ongoing		Ongoing		Ongoing		Ongoing	
Permanent installation?	yes		yes			yes			yes	yes		yes		yes		yes	
Manufacturer	CODAR		CODAR			CODAR			CODAR	CODAR		CODAR		CODAR		CODAR	
Type of radar	DF		DF			DF			DF	DF		DF		DF		DF	
Temporal resolution (minutes)	60		60			60			60	60		60		30		60	
Spatial resolution of total velocity grid (m)	3000		3000			1000			1500	6000	5000	6000		187		5000	
Tansmit Fequency (MHz)	13,5		13,5	13,5	13,5	26,275	26,275	26,275	13,5	4,463		4,463		46,5	46,8	4,525	
Tansmit Bandwidth (KHz)	90,069		90	90	90	150	150	150	100	50		29,4	29	800,2	800	40	

HFR NETWORK	National HF Network				
COUNTRY	*PORTUGAL*				
OPERATOR	Instituto Hidrografico				
Numbser of SITES	5				
Name of sites	São Julião	Espichel	Sagres	Alfanzina	Vila real de Santo
Sites lat , lon coordinates	38,67	38,41	36,99	37,08	37,18
	-9,33	-9,21	-8,55	-8,44	-7,44
Date of 1st deployment	01/01/2010		01/01/2016	01/01/2012	01/08/2010
Status	Ongoing				
Permanent installation?	yes				
Manufacturer	CODAR				
Type of radar	DF				
Temporal resolution (minutes)	60				
Spatial resolution of total velocity grid (m)	1400		1500		
Tansmit Fequency (MHz)	12,43	12,923	13,5		12,4698
Tansmit Bandwidth (KHz)	80,878	69,849	80,878		99,259

TABLE A1-1. MAIN CHARACTERISTICS OF THE EU HFR NETWORKS. WERA*= WERA, HELZEL MESSTECHNIK; DF= DIRECTION FINDING; PA= PHASED ARRAY (cont.)

HFR NETWORK	MOOSE HF radar		Iroise		Torungen	Wave Hub HF Radar		BRAHAN		Ireland West Coast_Radars			
COUNTRY	*FRANCE*				*NORWAY*	*UK*				IRELAND			
OPERATOR	MIO, AMU-CNRS-IRD-UTLN		SHOM		Norwegian Meteorological Institute	Plymouth University		Marine Scotland Science		National University of Ireland			
Numbser of SITES	2		2		1	2		2		4			
Name of sites	ANTARES	DYFAMED	Pointe de Garchine	Pointe de Brézellec	Torungen	Pendeen	Perranporth	SUMB	NRON	Mutton Island	Spiddle	Inish Oirr	Loop Head
Sites lat , lon coordinates	42,95	43,50	48,50	48,07	58,40	50,16	50,34	59,85	59,39	53,25	53,24	53,06	52,56
	6,00	7,25	-4,78	-4,66	8,79	-5,67	-5,18	-1,28	-2,38	9,05	9,30	9,52	9,92
Date of 1st deployment	15/11/2011	01/09/2015	01/05/2006		25/05/2016	01/02/2011 and 01/04/2011		01/09/2013		01/03/2012		01/09/2015	
Status	Ongoing	Ongoing	Ongoing		Ongoing	Ongoing		Ended on 09/08/2014	Ended on 09/01/2014	Ongoing			
Permanent installation?	yes	yes	yes		yes	no		no		yes			
Manufacturer	WERA*	CODAR	WERA		CODAR	WERA*		CODAR		CODAR			
Type of radar	DF on 8 receiving antenna	DF	PA		DF	PA		DF		DF			
Temporal resolution (minutes)	60	90	10		60	60		60		60			
Spatial resolution of total velocity grid (m)	3000	0	2000			1000		5000		300		2000	
Tansmit Fequency (MHz)	16,175	13,45	12,4		13,5	12		4,5		25		13,5	
Tansmit Bandwidth (KHz)	50	50	100		75	350	375	36,8		500		49,6	