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Glossary

API	Application Programming Interface
AQC	Advanced Quality Control
CF	Cumulative Frequency
CMEMS	Copernicus Marine Environment Monitoring Service
CNR-ISMAR	National Research Council - Institute of Marine Science
CODAR	Coastal Ocean Dynamics Applications Radar
CTF	CODAR Tabular Format
CUI	Coastal Upwelling Index
EOOS	European Ocean Observing System
EU	European Union
EuroGOOS	European Global Ocean Observing System
FAIR	Findable, Accessible, Interoperable, Reusable
GOOS	Global Ocean Observing System
HFR	High Frequency Radar
HOORT	HFR Online Outage Reporting Tool
IT	Information Technology
KPPI	Key Platform Performance Indicator
LERA	Least Expensive Radar
MySQL	My Structured Query Language
NRT	Near Real Time
OSR	Ocean State Report
PUM	Product User Manual
QC	Quality Control
REP	Delayed Mode
REST API	Representational State Transfer Application Programming Interface
SOCIB	Balearic Islands Coastal Observing and Forecasting System
US	United States of America
WERA	WEllen Radar
WMWare ESXI	Virtual Machine Ware Elastic Sky X integrated
WMOP	Western Mediterranean OPerational model

Executive summary

The EuroSea project brings together key European actors of ocean observation and forecasting with key end users of ocean observations, responding to the Future of the Seas and Oceans Flagship Initiative. The present deliverable summarizes the innovative tools developed by EuroGOOS High Frequency Radar Task Team, to support the HF Radar community, as part of the “Task 3.6 HF Radar”.

WP3 (Network integration and Improvement) supervises key aspects of integration of European observing technology for its optimal use in EOOS and global initiatives. Moreover, WP3 is dedicated to increasing the efficiency and effectiveness of operation and use of in-situ ocean observing technologies by improving and integrating observing networks and improving their coordination.

The development of open tools to be shared by the whole HFR community is essential for the efficiency and effectiveness of the HFR technology and the integration of the networks. In this sense, different tools have been developed inside the “Task 3.6 HF Radar” to be shared with the HFR community and they are detailed in this deliverable.

Open tools for the operational NRT/REP (Near Real Time / Delayed Mode) workflow are crucial for the integration of HFR networks. Those tools have been generated among Task 3.6 and made available for the whole HFR community. They are currently being re-coded from Matlab to Python (open source) to make them even more accessible for the whole HFR community. These tools allow the HFR community to easily process and share their data. The development of these tools has become essential for the efficiency and effectiveness of HFR technology and the integration of networks.

To enhance the use of HFR surface current data, tools for advanced QC for REP products and HFR Online Outage Reporting Tool (HOORT) have also been developed. Those tools not only help for the understanding of the surface currents and their quality and availability, but they also help to understand the outages that occur to the hardware and data workflow.

Coastal upwelling occurs when along-shore winds and the Coriolis effect combine to drive a near-surface layer of water offshore, inducing the vertical uplift of cold enriched waters that fertilize the uppermost layer, impacting on water quality and fisheries. Coastal Upwelling Index from HFR has been developed to enhance the use of added value products from HFR systems and a contribution has been recently sent to the 7th edition of the Copernicus Ocean State Report (OSR#7¹).

1. Introduction

EuroSea works to improve the European ocean observing and forecasting system in a global context. Our vision is a truly interdisciplinary ocean observing system that delivers the essential ocean information needed for the wellbeing, blue growth and sustainable management of the ocean. EuroSea will strengthen the European and Global Ocean Observing System (EOOS and GOOS) and support its partners.

¹ <https://marine.copernicus.eu/access-data/ocean-state-report>

WP3 (Network integration and Improvement) oversees key aspects of integration of European observing technology for its optimal use in an EOOS and global initiatives (e.g. GOOS) and, in parallel, addressing national interests. Moreover, WP3 is dedicated to increasing the efficiency and effectiveness of operation and use of in-situ ocean observing technologies by improving and integrating observing networks and improving their coordination. “Task 3.6 HF Radar” is part of the tasks in WP3. It is focused on High Frequency Radar (HFR) and it aims to:

1. Enhance the use of HFR surface current data and added-value products.
2. Improve the availability of FAIR HFR data and implement Best Practices of HFR operations and maintenance.
3. Work towards a governance structure that ensures long-term sustainability.
4. Guide the development of the network with a prioritization performed at Sea-basin scale.

Besides, “Task 3.6 HF Radar” includes two deliverables:

1. “D3.4 HF-Radar Governance”, which describes a proposed governance structure and roadmap of the HF Radar Network, and was submitted in May 2021
2. “D3.14 HF-Radar Tools”, which describes the innovative tools developed to support the HF Radar community and it is the goal of this document. This deliverable will be submitted by December 31st, 2022.

The development of open tools to be shared by the whole HFR community is essential for the efficiency and effectiveness of the HFR technology and the integration of the networks. In this sense, different tools have been developed inside the “Task 3.6 HF Radar” to be shared with the HFR community and they will be detailed in the next section:

1. Tools for the operational NRT/REP (Near Real Time/Delayed Mode) workflow
2. Tools for advanced QC for REP products
3. HOORT: HF radar Online Outage Reporting Tool
4. CUI generated from HFR
5. Ongoing work line: North Atlantic Regional Validation (NARVAL) web tool

2. HF Radar Tools developed/improved in Task 3.6 HF Radar

The EuroGOOS High Frequency Radar Task Team² acts since 2014 for promoting the coordinated development of HFR technology in Europe. The HFR Task Team efforts followed up on many initiatives in Europe (EU H2020 Jerico-Next, EU H2020 SeaDataCloud, EU H2020 EuroSea, EU H2020 Jerico-S3, Copernicus Marine Environment Monitoring Service Evolution INCREASE) and enabled the building and strengthening of the European HFR community by establishing broad international collaboration, promoting scientific and

² <http://eurogoos.eu/high-frequency-radar-task-team/>

technological synergy among European ocean observing infrastructures, raising awareness of European HFR activities and boosting stakeholder engagement.

One of the more meaningful achievements of the HFR Task Team was the harmonization of system requirements and design, data quality, and standardization of HFR data management (Mantovani et al., 2020; Corgnati et al., 2018). This allowed the building of an operational HFR European network based on coordinated governance and data management for the development of operational ocean monitoring via HFR systems.

The European HFR Node was established in 2018 by AZTI, CNR-ISMAR (National Research Council, Institute of Marine Science) and SOCIB (Balearic Islands Coastal Observing and Forecasting System), under the coordination of the EuroGOOS HFR Task Team as the focal point and operational asset in Europe for HFR data management and dissemination, also promoting networking between European infrastructures and the Global HFR network. The European HFR Node is fully operational since December 2018 in distributing tools and support for standardization to the HFR providers as well as standardized NRT and REP HFR radial and total currents data to the major platforms for marine data distribution.

2.1. Tools for the operational NRT/REP workflow

At present, the European HFR Node manages data from 16 European HFR networks (built by 53 radar sites) and integrates US (United States of America) HFR network data (173 radial stations, grouped in 5 networks).

For both NRT and REP workflow, the European HFR Node implements the following functions:

- Data acquisition and harvesting
- Quality Control (QC)
- Conversion to the European standard data format for HFR current data
- Validation/assessment
- Delivery of NRT and historical HFR current data with different reprocessing levels

The operational NRT and REP workflows are based on a centralized MySQL database containing updated metadata of the HFR networks and the information needed for processing and archiving the data. The database is fed and kept updated by the HFR operators via a web form³.

As a joint effort of EU H2020 Jerico-S3, Copernicus Marine Service In Situ Ocean TAC and EU H2020 EuroSea projects, the hardware infrastructure, the IT architecture and the processing tools for the operational NRT workflow of the European HFR Node were redesigned and reimplemented in order to improve the performances of the services and the FAIRness of the products.

The hardware infrastructure was rebuilt based on hyper convergent computing infrastructure and virtualization servers.

The IT architecture was rebuilt within the VMWare ESXI virtualization environment where specific virtual machines were installed per each service (data access and collection, processing, database, dissemination, etc).

³ <https://webform.hfrnode.eu>

The processing tools for the operational NRT workflow are in the process of being ported into Python3 language (the current ones are written in Matlab), in order to avoid the use of licensed products (thus enhancing the usage of the tools by the HFR operators) and to take advantage of the open-source benefits related to the continuous expansion and improvement of the language capabilities.

Concerning the routines for the operational processing, they are in the process of being reimplemented for refining the underlying science and for managing both files written in CODAR Tabular Format (CTF) and files written in the WERA and LERA crad_ascii and cur_asc native formats, and to perform for both data types the weighted least square combination of radial currents into total currents as defined in (Gurgel, 1994). The use of classes made this homogenization possible even at the processing low level.

When completed, the ensemble of the new routines will be published as a general-purpose Python3 toolbox for treating all HFR data.

The new processing tools are available via the GitHub repository⁴.

Specific actions were also carried out for supporting the HFR Online Outage Reporting Tool (HOORT) described in Section 2.3.

The application EU_HFR_NODE_db4HOORT was developed in Python3 language for feeding the database with information about last available data and radial delay from each HFR system connected to the Node. This information is used by the API of the HOORT tool for the operational recognition and management of system outages.

For this scope, the radial_delay_tb table was added to the database with the following fields:

- registration_date: date and time (in UTC) of the programmed execution of the application. It is recommended to run the application on hourly basis at o'clock time.
- station_id: ID of the HFR station.
- last_data_available: date and time (in UTC) of the last available radial file received from each HFR station (ie. time of the last measurement).
- radial_delay: time interval (in hours) between registration_date and last_data_available.
- creation_date: date and time (in UTC) of the effective run of the script launched via the cron-hourly.

The application EU_HFR_NODE_db4HOORT is available via the GitHub repository⁵ and it is published with all release versions accessible with the DOI⁶.

2.2. Tools for advanced QC REP

REP HFR current data are processed with the NRT QC tests as the first step. Furthermore, Advanced Quality Control (AQC) procedure is applied to the REP datasets, summarized in individual reports for each radial site and each total system. Data series are organized in a standard system/time folder tree and the historical HFR data time series are screened by means of yearly plots in order to allow the inspection of human experts for

⁴ https://github.com/LorenzoCorgnati/EU_HFR_NODE_pyHFR

⁵ https://github.com/LorenzoCorgnati/EU_HFR_NODE_db4HOORT

⁶ Doi: 10.5281/zenodo.7324253

assessing the effective quality of HFR datasets. The following plots are produced by year and site/system for each of the individual reports:

1. Time series of the spatial average of the current velocity module, its standard deviation, and the total coverage (see example in Figure 1).
2. Time series of the QC flags for all the grid nodes with data.
3. Maps of the mean value of QC flags for the target year and maps of the mean velocity module and its standard deviation for the target year.
4. Spatial (x-axis) vs. temporal (y-axis) coverage 80/80 annual. It allows checking if the system reached the goal of providing surface currents over 80% of the area during 80% of the time (Figure 2)
5. Map of the mean velocity field in the area of 80% temporal coverage (Figure 2).

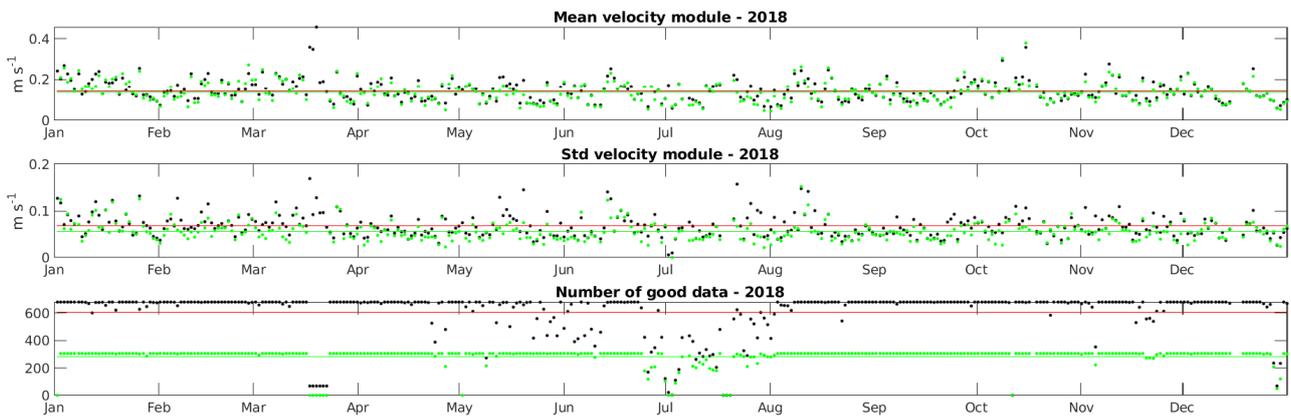
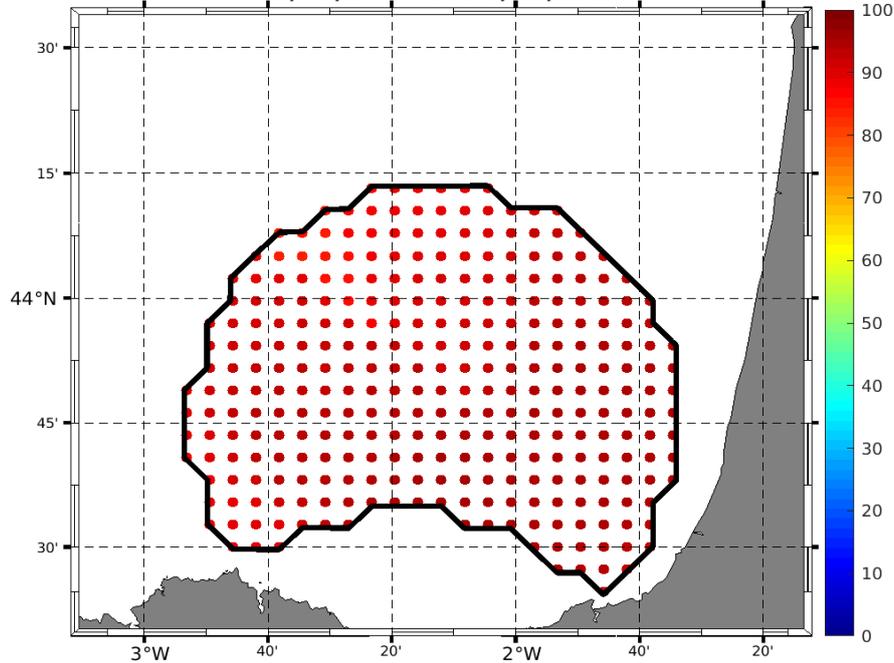


Figure 1. (From top to bottom) Time series of the spatial average of the current velocity module, its standard deviation, and the number of grid points of the total coverage for the HFR-EUSKOOS system in 2018. Black dots are the values obtained considering all the data in the domain, in green those considering only data with QC flag =1 (good data).

**HFR-EUSKOOS: Percent Total Vector Coverage (contour showing >80%)
01/01/2018 to 30/12/2018**



**HFR-EUSKOOS: Spatial Coverage vs. Temporal Coverage
01/01/2018 to 30/12/2018**

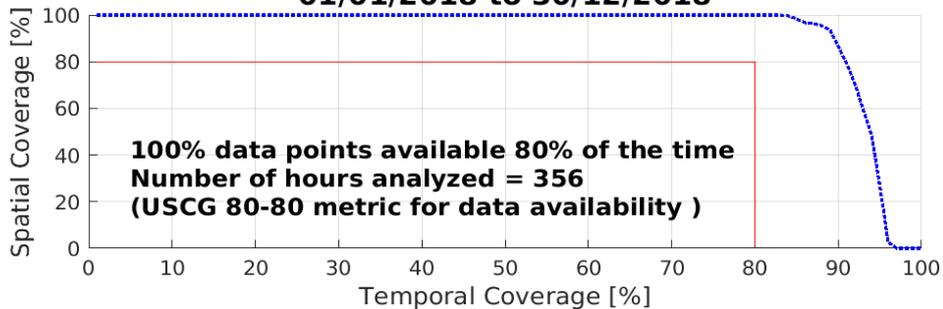


Figure 2. (top) Map of the % of availability of data in each grid point and contour showing the area of temporal availability >80%. (bottom) Temporal (x-axis) vs. spatial (y-axis) coverage 80/80 annual metric recommended by Roarty et al., 2012.

Based on the screening of the previous plots an AQC report by system is produced, where the performance is analysed year by year, and periods for reflagging (expert but subjective analysis) are proposed. In addition, possible changes in the processing of the data (namely in the thresholding strategy) are proposed too, if any anomaly is detected in the data or in the QC, for ensuring the effective quality of HFR data. Once the report is generated, it is sent to the HFR data provider for its validation and agreement or feedback on the comments and the reflagging/reprocessing proposed. After the provider's feedback, changes in the original data series (reflagging or reprocessing) are indicated (Figure 3). A final version of the report is produced and shared in a public repository⁷ and through CMEMS In Situ TAC documentation. Reports have been redesigned to give more visibility and credits to the data providers.

⁷ <http://dSPACE.azti.es/>

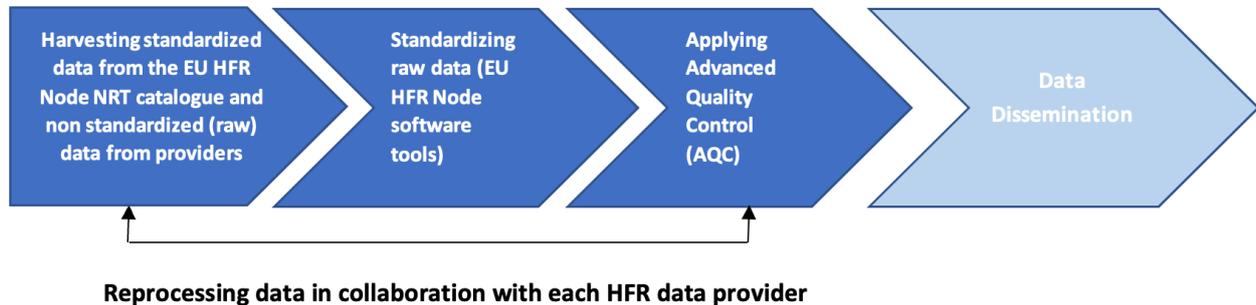


Figure 3. Schema of the Advanced Quality Control (AQC) procedure before data dissemination.

All the tools allowing data processing and corresponding report on historical datasets have been transferred to the European HFR Node to allow the improvement of data products in the main European data aggregators.

Furthermore, the European HFR Node has recently also opened a discussion inside the HFR community to decide about the possibility to assign a DOI to each HFR system to reinforce the visibility and credits to the data providers, following the goal of the Findability of the FAIR datasets (Tanhua et al., 2019) of the “Task 3.6 HF Radar” of the EuroSea project. This topic was discussed in the Annual meeting of the EuroGOOS HF Radar Task Team, held in Florence from November 21st to 22nd, 2022 and it will be followed in the next community meetings.

2.3. HOORT: HF radar Online Outage Reporting Tool

HOORT stands for HFR Online Outage Reporting Tool: it is a web-based application to aid High-Frequency Radar (HFR) operations and maintenance and keep operators more aware of common problems, helping them to report them. The main characteristics of the tool are summarized in the following lines:

- **What is HOORT?**
 - HOORT serves as:
 - a forum for troubleshooting.
 - a database of outage records per each HFR station.
 - an aid to operations and maintenance.
 - a tool to report ongoing and past outages and to provide metrics about the HFR station's performance.
 - HOORT is a free and open web-based application available online⁸
 - HOORT has been developed by SOCIB in collaboration with CNR-ISMAR, AZTI, Spanish Port System, MARACOOS (Mid-Atlantic Regional Association Coastal Ocean Observing System) and the European HFR data providers.
- **What is HOORT for?**
 - The main objectives are threefold (Detect-Alert-Report) (Figure 4).
 - 1) automatically detect the outage.

⁸ <https://hoort.hfrnode.eu/>

2) automatically alert the HFR operator.

3) provide an interface to manually report the outage following defined best practices for HFRs operation and maintenance.



Figure 4. Summary of the description, objectives, and target audience of HOORT.

• **How does it work?**

HOORT is connected by means of a REST API⁹ to the European HFR Node Database (Figure 5).

- The station outage enters automatically into the database of HOORT when the last radial file from the station is older than 12 hours.
- At the same time, HOORT will send an alarm notification by email to the operator(s) so they are definitely aware of station outages sooner.
- For the outage reporting, the intervention of the HFR operator is needed. So thus, once the alarm is received, the operator can later log in to HOORT and provide the outage details.

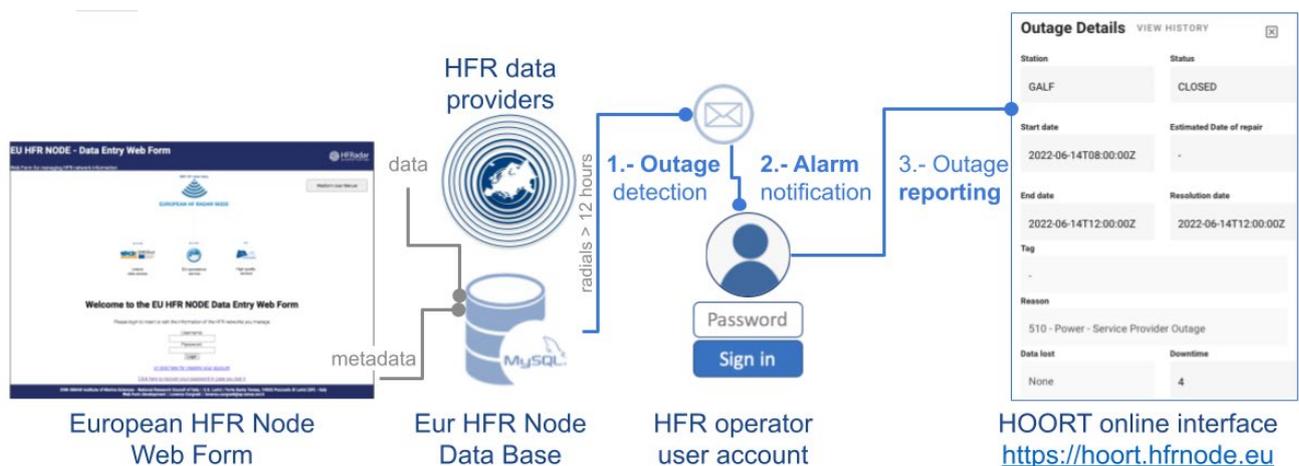


Figure 5. Scheme showing how HOORT works.

⁹ <https://api.hfrnode.eu>

With just few clicks, HOORT enables the HFR operators:

- to daily monitor the performance of her/his HFR stations, by using the Dashboard.
 - to know the Station Status of her/his HFR stations.
 - to manage and to be aware of the most recent Open Outages of her/his HFR stations.
 - to add Data Annotations (for radials and totals) of her/his HFR stations and be kept updated about the replies from other HFR operators.
- **Target audience:**
 - HFR operators (access to all functionalities), and end users & decision-makers (guest users)
 - **Main sections of HOORT:**
 - Login Page (Figure 6):
 - In order to log in to HOORT the user must have its credentials (username and password), which are the same ones as for the Web Data Entry Form¹⁰ of the European HFR Node.
 - The Terms and Conditions govern all use of HOORT and all content available at or through the web application.
 - Our Privacy Policy explains the way we handle and protect your personal data in relation to your use and browsing of HOORT. By agreeing to the terms and conditions and to be able to use HOORT, you also agree to our Privacy Policy.
 - In the login page, the password recovery functionality 'Forgot your password?'¹¹ is also available.
 - In case you need an account¹², you are required to visit the Web Data Entry Form of the Node.

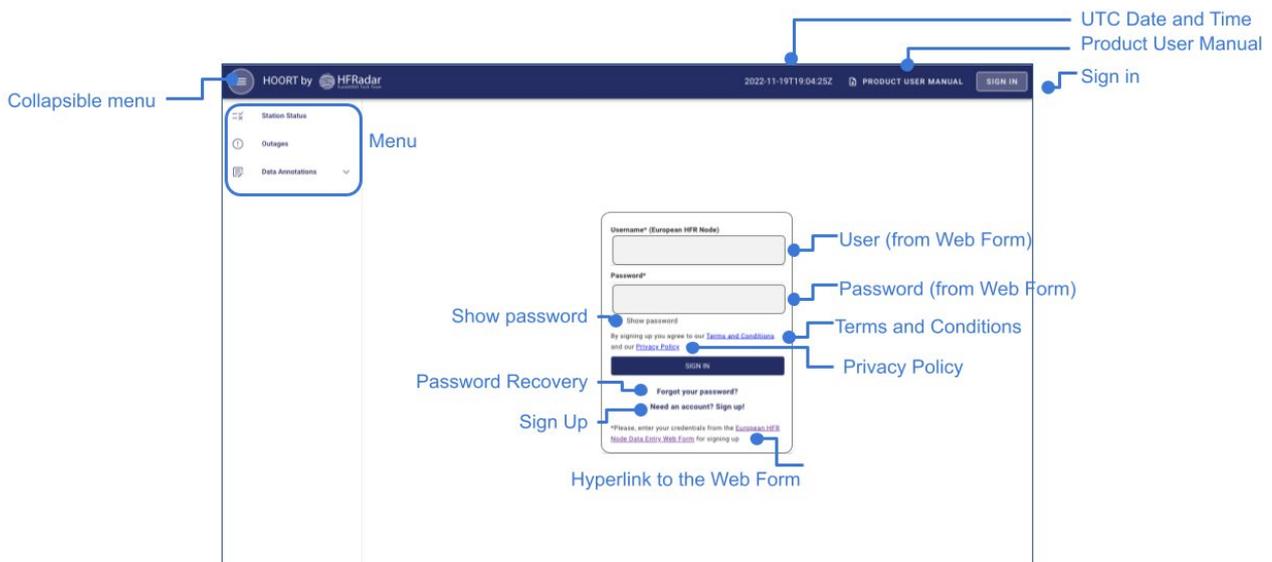


Figure 6. Login page of HOORT showing the different functionalities.

¹⁰ <https://webform.hfrnode.eu/>

¹¹ https://webform.hfrnode.eu/psw_recovery.php

¹² <https://webform.hfrnode.eu/registration.php>

○ Dashboard:

- It is designed to be used as a Daily Activity Monitoring.
- The Dashboard is based on the following premises:
 - The user wants to know the Station Status and to be aware of the most recent Open Outages of her/his stations. In addition, the user wants to create and follow all Data Annotations that he/she has made (regarding his/her stations or from others).
- All computations of the Dashboard need the following user settings:
 - Selection of network, station (a specific one or all) and the period of interest (higher than 2 months but shorter than 12 years)
- The dashboard is divided into 3 blocks: KPIs, charts and list of open outages and open threads for data annotations.
 - KPIs (Figure 7): including the %uptime, %maintenance stops, and %closed outages as defined in the framework of JericoS3 for all mature platforms.

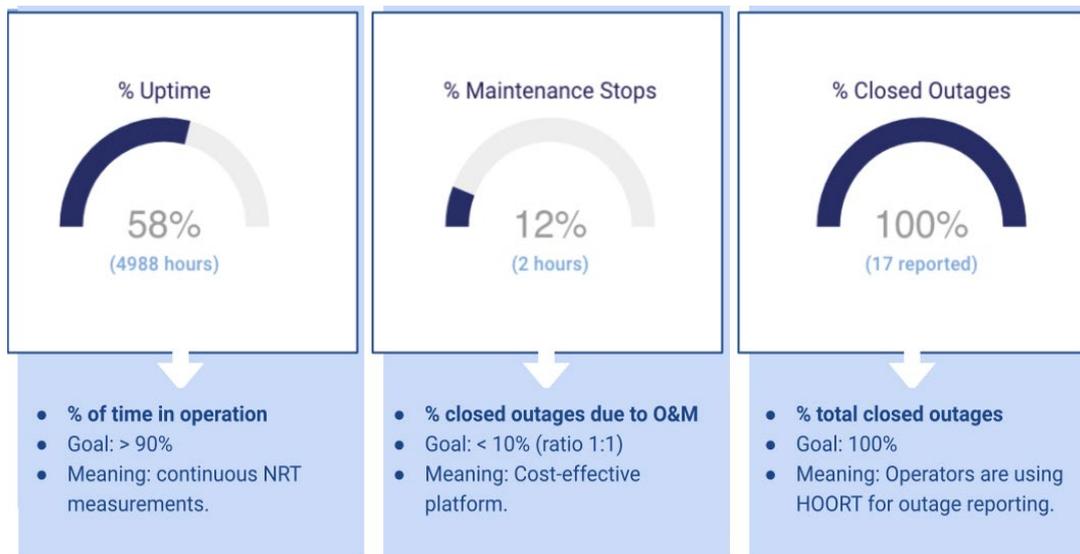


Figure 7. Key Platform Performance Indicators available in the Dashboard.

- Charts: of different styles (time series, histograms, pie charts) (Figure 8)

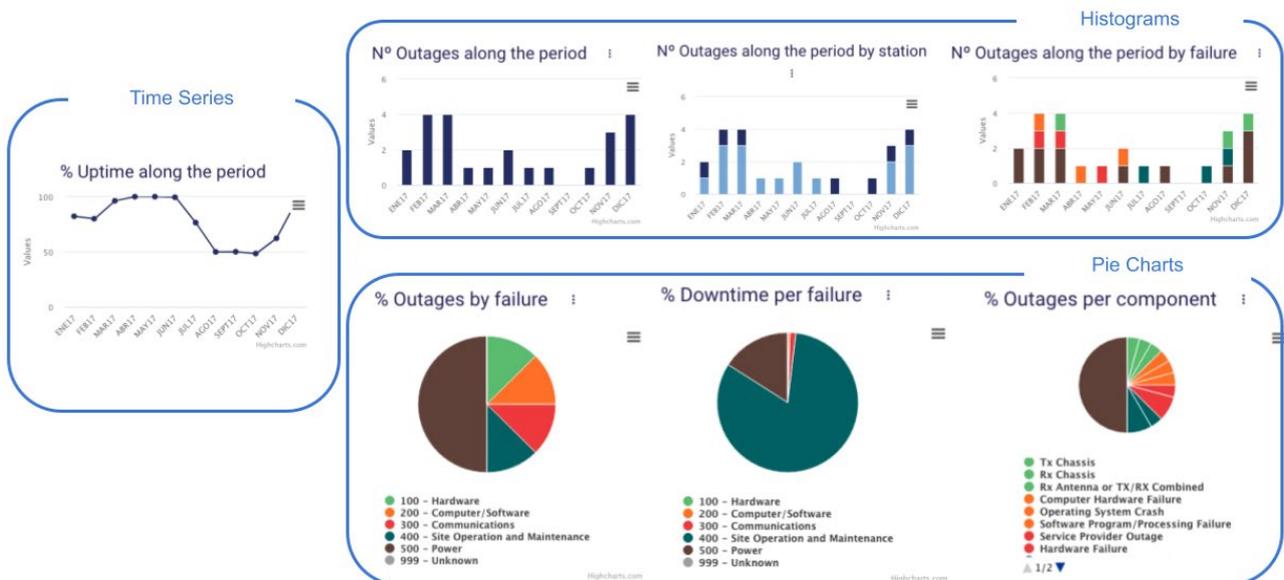


Figure 8. Type of charts available in the Dashboard.

- Open Outages and Open Threads of Data Annotations from the user. This table includes all open outages (i.e. new, in progress, resolved) from the HFR station(s) assigned to the HFR operator that should be tracked. By clicking on each of the rows of the table of “my outages”, the HFR operator is redirected to the specific section of HOORT where he/she can manage the outage.
- Station Status (Figure 9):
 - It includes a catalogue of HFR radial stations, metadata and status (red, yellow, and green based on the date of the delay of the latest native file received from the stations at the European HFR Node, grey for historical and white for future ones).
 - Filters are available for Station, Network, CF range, Start/End Date, etc. The user can access directly to his/her stations at one click using the filter options.

Station	Network	CF (MHz)	Direction of Arrival	Calibration Type	Latitude	Longitude	Latest File Date
CSAP	HFR-NASCUM	25	DIRECTION FINDING	APM	45.4899	13.491	2022-11-18T22:55:01Z
CSMR	HFR-Granitola	16.1	BEAM FORMING	FULL	37.4856	13.0175	2022-11-18T22:55:01Z
CSTB	HFR-GoN	24.6	DIRECTION FINDING	APM	40.6929	14.4643	2022-11-18T22:55:01Z
CZUB	HFR-NASCUM	25	DIRECTION FINDING	APM	45.2982	13.5691	2022-11-19T17:55:01Z
FISI	HFR-Dardanos	13.5	BEAM FORMING	FULL	39.8105	25.3709	2011-06-24T00:00:00Z
FIST	HFR-Galicia	4.463	DIRECTION FINDING	APM	42.88	-9.27	2022-11-18T21:55:01Z
FORM	HFR-Ibiza	13.5	DIRECTION FINDING	APM	38.6662	1.3887	2022-11-19T18:00:00Z
FRUH	HFR-Finmark	4.453	DIRECTION FINDING	APM	71.094	23.982	2022-11-19T19:55:02Z
GALF	HFR-Ibiza	13.5	DIRECTION FINDING	APM	38.9519	1.21915	2022-11-19T19:00:00Z
GAR	HFR-IROISE	12.377	BEAM FORMING	INTERNAL	48.5028	-4.77556	2022-09-08T17:19:29Z

Figure 9. Station Status window showing the list of stations and filter options.

- Station details can be visualised (side-by-side) on user click on rows (Figure 10).

Station Details (side-by-side view)

Station	Network	CF (MHz)	Direction of Arrival	Calibration Type	Latitude	Longitude	Latest File Date
PIRO	HFR-Galicia	4.463	DIRECTION FINDING	APM	43.568	-8.314	2022-11-19T08:40:03Z
POZZ	HFR-CALYPSO	13.5	DIRECTION FINDING	APM	36.7105	14.8298	2022-11-19T17:40:03Z
PIRA	HFR-Nadr	24.525	BEAM FORMING	FULL	45.53	13.566	2022-11-19T11:40:03Z
PFIN	HFR-TirLig	13.5	DIRECTION FINDING	APM	44.2987	9.21836	2022-11-19T02:40:03Z
PERR	HFR-WHub	12	BEAM FORMING	FULL	50.338	-5.17721	2022-11-19T12:40:03Z
PEND	HFR-WHub	12	BEAM FORMING	FULL	50.1645	-5.66994	2022-11-19T04:40:03Z
PCOR	HFR-TirLig	26.275	DIRECTION FINDING	APM	44.1435	9.6593	2022-11-19T17:40:03Z
OLD	HFR-MATROOS	16.173	BEAM FORMING	INTERNAL	51.8203	3.87694	2022-11-19T06:40:03Z
NEJO	HFR-Cotentin	13.5	BEAM FORMING	FULL	49.391	-1.7	2022-11-19T08:40:03Z
MTIS	HFR-IrelandWestCoast	25	DIRECTION FINDING	APM	53.2539	-9.0547	2022-11-19T06:40:03Z

Station Details (side-by-side view)

Station: PIRA

Station Long Name: PIRAN

Start Date of operation: 2015-01-10

End Date of operation: Ongoing

Institute Name: NIB - Nacionalni inštitut za biologijo

Institute Website: <https://www.nib.si/mbp/en/oceanographic-data-and-n>

NRT Connection: Yes

REP Connection: Yes

Figure 10. Station Status window showing the station details side-by-side.

- Outages (Figure 11 and Figure 12):
 - It includes a list of outages from the HFR stations displaying their different status (i.e. new, in progress, resolved, closed), showing their key information.

- The user can directly access the Open Outages of his/her HFR stations at one click using the filters available “Show only: My stations” and “Show only: Open Outages”. Other filters are available for selecting the: Station, Status, Reason for the outage, Period, and Reporter (i.e. HFR operator that reported any detail about the outages).

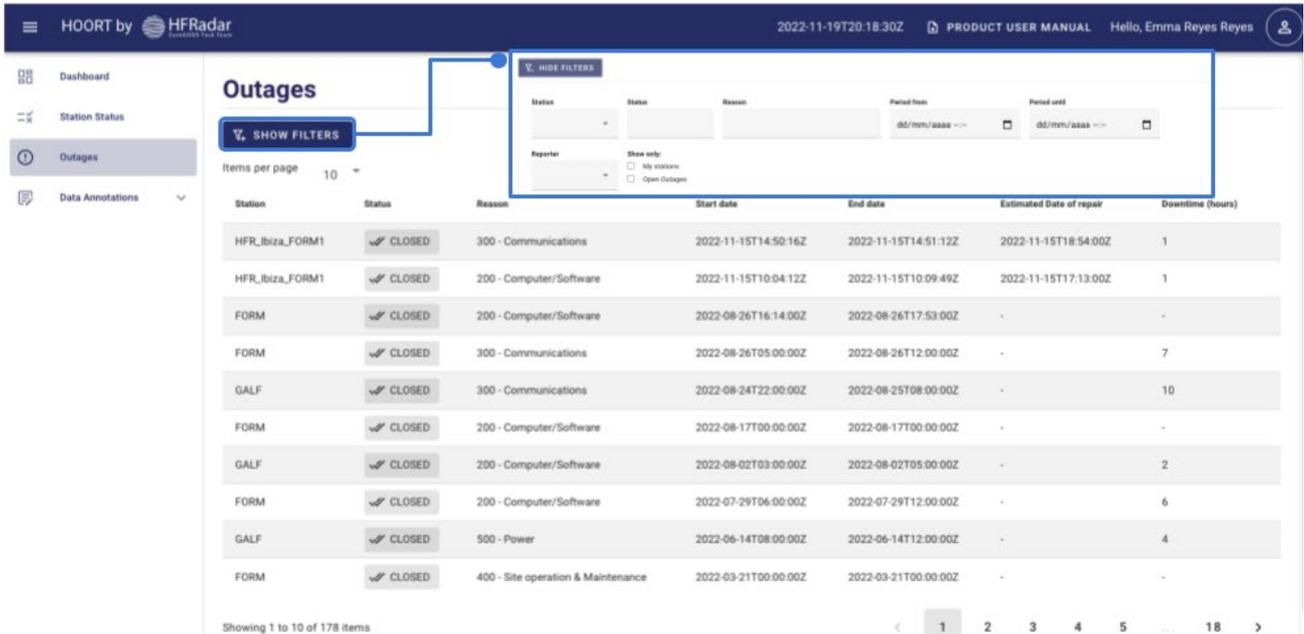


Figure 11. Outages window showing the list of outages and filter options.

- Outage details are provided (side-by-side) on user click on rows.

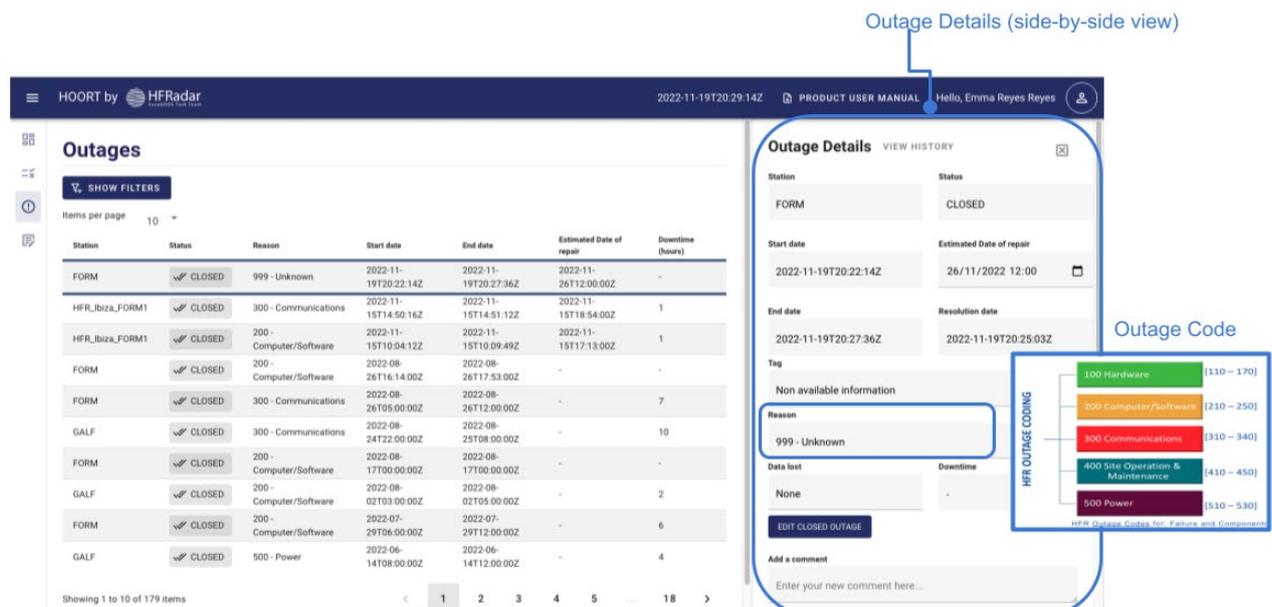


Figure 12. Outages window showing the outage details side-by-side.

- For each outage, the HFR operator has the possibility to track (Figure 13):
 - “State Changes” or “Comments” or “All events together”.

- “View History”, which will allow us to audit any change made.

HOORT: what and how?

The screenshot displays the 'Outages Audit' interface. On the left, a table lists various outage events with columns for Station, Status, Reason, Start date, End date, Estimated Date of repair, and Downtime (hours). The table shows several 'CLOSED' events with reasons like 'Unknown', 'Communications', and 'Computer/Software'. On the right, a detailed view of an event is shown, including a 'Comments' section with a list of events and their descriptions, and a 'Settings for enable or disable notifications' panel with options for real-time, daily, and disabled notifications. A 'SAVE CHANGES' button is also visible.

Figure 13. Outages window showing all events of the outage.

o **Data Annotations (Figure 14)**

- It includes notes about data quality as a complement to the outages.

The screenshot shows the 'Radials Annotation' window. It features a 'NEW DATA ANNOTATION' button and a 'SHOW FILTERS' button. The main content area displays details for a specific annotation titled 'GALF - Connection issues', including the author, date, and a description. Below this, there is a 'Replies' section with a list of responses. On the right side, there is a 'New Data Annotation' form with fields for Station, Visibility (Public/Private), Type, Start date, End date, and Annotation, along with a 'SEND DATA ANNOTATION' button.

Figure 14. Data annotation window for radials showing the details and the new data annotation functionality.

- It is designed as a discussion forum, where the operators can exchange comments.

- The operator can create 'New Data Annotation' for radial or totals and can make them public or private (just for him/her).
 - Once sent the data annotation, the same HFR operator or others can reply to the annotation, edit, or close the thread.
- **Alarm notification** (Figure 15) system via e-mail. HOORT will send an alarm notification by email to the operator(s) so they are definitely aware of station outages sooner.
 - Notification types: For each outage, the operator will receive 2 emails:
 - The first one for reporting the outage.
 - The second one, once the outage is resolved.
 - In the email, further indications on how to proceed at each step will be provided.



Figure 15. Example of alarm notification sent by email for the station of FORM and detail of the information to be provided.

- Trigger of the alarm: The station outage enters automatically into the database of HOORT when the last radial file from the station is older than 12 hours.
 - Setting of the notifications: The operator can enable or disable the notifications.
- **HOORT Product User Manual:** the manual of the tool, currently being developed, is available in the header of the tool. The PUM will have a DOI assigned pointing to a landing page where all versions will be available. It includes several appendices for providing further details of the:
 - Outages codes and useful information to report an outage
 - Glossary
 - Outage status flow
 - Filter types
 - KPIs name, description, computation and goals.
 - File Naming Convention of exported figures and tables.
- **Scheme of elements and developments needed:** in addition to the documentation described in the previous point, supplementary elements required for HOORT have been developed in the framework of JericoS3. These elements will be further detailed in the deliverable of Jerico-S3, entitled "Report

on the functional homogenization tools that will support the implementation of best practices within the JERICO-RI" (Figure 16).

- The API for the European HFR Node¹³ is a RESTful Application Programming Interface (API) - also referred to as RESTful web service- that facilitates Machine-to-Machine (M2M) discovery of metadata from the European HFR stations, networks, and users.
- End- points to report and resolve outages.
- The API for HOORT and the HOORT database.

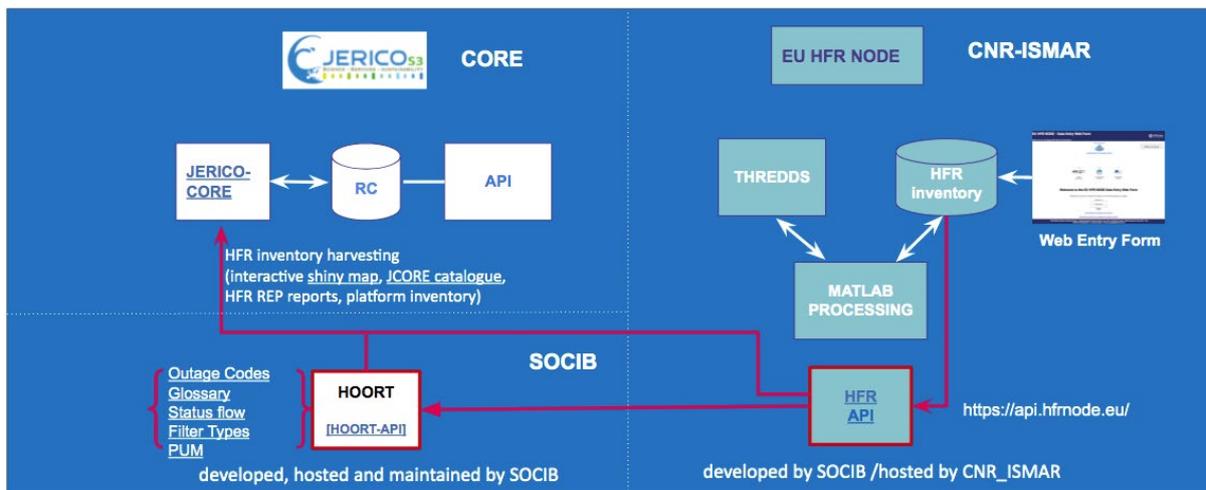


Figure 16. Scheme of the additional elements (with a red box) developed in the context of HOORT.

2.4. CUI generated from HFR

A contribution has been recently sent to the 7th edition of the Copernicus Ocean State Report (OSR#7¹⁴), which is an international peer-review initiative aimed at providing a summary of the variations in the ocean over the past decades, with emphasis on relevant met-ocean processes and coastal hazards. The submitted work (Lorente et al., in review, 2022) focuses on the development of a novel Coastal Upwelling Index (CUI), generated from remote-sensed hourly surface current estimations provided by an HFR in order to quantify the spatiotemporal variability of this phenomenon.

Coastal upwelling occurs when along-shore winds and the Coriolis effect (due to Earth's rotation) combine to drive a near-surface layer of water offshore, inducing the vertical uplift of cold enriched waters that fertilize the uppermost layer, impacting water quality and fisheries. The consistency of the proposed index (CUI-HFR) is assessed in two different oceanographic areas during two distinct time periods: in the North-western Iberian Peninsula for 2021 and in the Bay of Biscay for 2014, respectively. To this end, CUI-HFR was compared against a traditional CUI based on hourly wind observations (CUI-WIND) provided by two in-situ buoys moored within each HF radar area coverage and a CUI-GLOBAL . Likewise, the skill of CUI-HFR to categorize upwelling (upward motion) and downwelling (downward motion) events were also qualitatively evaluated. Results obtained in these two pilot areas revealed a noticeable agreement between CUI-HFR, CUI-WIND and CUI-GLOBAL, derived from the surface currents predicted by the GLOBAL analysis and forecast system (Lellouche et al., 2018), with correlation coefficients above 0.67 (Figure 17), highlighting their

¹³ <https://api.hfrnode.eu/>

¹⁴ <https://marine.copernicus.eu/access-data/ocean-state-report>

potential applicability for direct upwelling monitoring over any coastal area of the global ocean. The methodology proposed in this work could be also applied to analyse long-term seasonal trends in both study areas as extremely active and persistent upwelling-downwelling episodes might negatively impact coastal ecosystems.

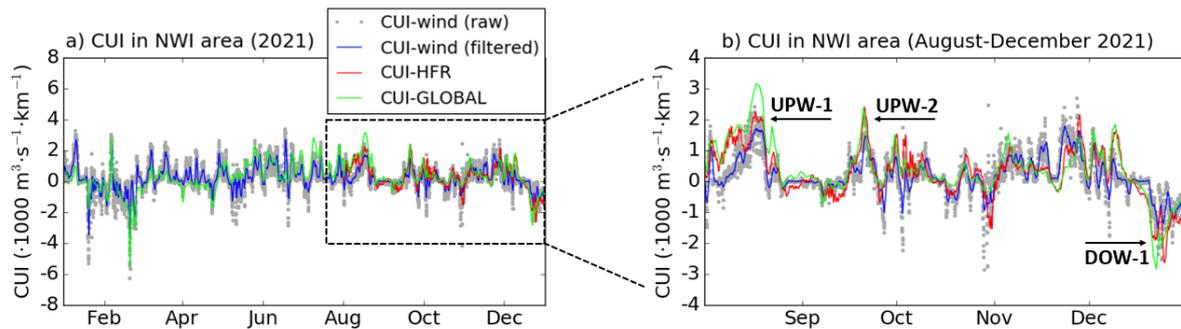


Figure 17. Time Series of diverse hourly Coastal Upwelling Index (CUI) in the North-Western Iberia (NWI) region (a) for the entire 2021 and (b) for August-December 2021, as derived from wind observations from Silleiro Buoy (CUI-WIND) -product ref. 3-, from HFR surface currents (CUI-HFR) - product ref. 1 and 2 - and from modelled surface currents (CUI-GLOBAL) -product ref. 4-, respectively. CUI-WIND raw (grey dots) was filtered by applying a 24 h moving mean (blue line). Some of the most relevant upwelling (UPW) and downwelling (DOW) events are denoted in b)

2.5. Ongoing work line: North Atlantic Regional Validation (NARVAL) web tool

NarVal: an ongoing work line is the implementation of a new module in the North Atlantic Regional Validation (NARVAL) web tool in order to validate ocean models against a number of HF radar systems deployed within their spatial coverage and here used as reference field or “ground-truth” observation. Hourly surface currents provided by WMOP model and diverse HF radars are compared on a monthly basis to infer strengths and weaknesses of the former. Skill metrics will be routinely computed to quantify the prognostic capabilities of WMOP, which will be useful for modellers to identify those aspects where there is still room for improvement.

2.6. Maintenance and future of the developed tools

HFR tools described in sections 3.1 to 3.5 are dynamic tools that should remain accessible to the whole HFR community in the future. They should not only be accessible but also updated according to the needs and requirements of the HFR community and final users.

As with all the tasks of WP3, the targeted milestones have been defined based on the requirements provided by the EuroGOOS Task Teams. The operational maintenance and evolution of those tools is part of the commitment of the European HFR Node, created in 2018, and defined as a key element in the governance of the community (see Eurosea D3.14 European High Frequency Radar network governance¹⁵).

The requirements for developing new capacities of the European HFR Node will be defined by the HFR community through the EuroGOOS HFR Task Team, and by the interaction with other observing networks through EuroGOOS or through the EOOS Operation Committee.

¹⁵<https://eurosea.eu/download/eurosea-d3-4-hfr-governance/?wpdmdl=3585&refresh=639c64a28bd5e1671193762>

3. Conclusion

The present deliverable (D3.14-HF-Radar Tools) summarizes the innovative tools developed by EuroGOOS High Frequency Radar Task Team, to support the HF Radar community, as part of the “Task 3.6 HF Radar”, inside the WP3.

As noted, the development of open tools to be shared by the whole HF Radar community is essential for the efficiency and effectiveness of the HFR technology and the integration of the networks. In this sense, open tools for the operational NRT/REP workflow have been generated and made available for the whole HFR community and they will be re-coded from Matlab to Python (open source) by mid-2023 to make them even more accessible for the whole HFR community. These tools allow the HFR community to easily process and share their data.

To enhance the use of HFR surface current data, tools for advanced QC for REP products and the HFR Online Outage Reporting Tool have been developed. Those tools help not only to understand of the surface currents and their quality and availability but also help to understand the outages that occur to the hardware and data workflow.

Finally, the CUI index from HFR has been developed and it is being currently reviewed by the OSR#7. This index will help to enhance the use of added-value products from HFR systems.

All the actions developed inside the Task 3.6 HF Radar have contributed to the efficiency and effectiveness of the HFR technology and the integration of the networks.

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