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1. Executive Summary

The JERICO network is constantly working to improve its core functionality, which is the ability to provide comprehensive observations of Europe's coastal seas and oceans. This means integrating new, promising observing technologies that can expand its spatial and temporal reach. This effort must include a specific data management fully committed to inform end-users and stakeholders about the quality and reliability of the data routinely delivered. While building the JERICO-Next project, High Frequency Radar (HFR) systems were identified as particularly attractive technology to complete the JERICO network. HFR technology offers the means to gather information on surface currents and sea state over wide areas with relative ease in terms of technical effort, manpower and costs.

There are twelve HFR sites, operated by five JERICO-Next partners. Together, they constitute 23.5% of the HFRs currently operating in Europe. Although some countries have started to implement operational data management for HFR systems, a unified implementation is needed for allowing their integration in the JERICO network. Task 5.6 of JERICO-Next deals specifically with defining common formats and Quality Control (QC) procedures for HFR data. The present deliverable is a first recommendation at European level to achieve the harmonization of HFR data management including the following points: data format, metadata structure, QC flagging scheme and QC tests.

This deliverable gathers recommendations that have been established taking into account: (1) the characteristics of HFR monitoring, considering that HFR surface current velocity data are somewhat unique in the oceanographic observation world since they are: i) two-dimensional ocean surface measurement; ii) derived from a fixed land-based remote sensor and iii) they are placed on a fixed grid; (2) the existing standards in non-EU networks (in particular in IOOS); (3) the existing standards in Europe for Marine Data Management (EuroGOOS ROOSes, EuroGOOS HFR Task Team, CMEMS, SeaDataNet's NODC network, EMODnet and its thematic portals, JCOMMOPS in-situ Observing Platforms).





2. Introduction

HFR is a unique technology in that it offers mapping of ocean surface currents and wave fields (along with other variables) over wide areas with high spatial and temporal resolution. This technology has been applied to many different sectors such as: basic and applied research in coastal oceanography and the marine environment, safety and exploitation of the seas (Paduan and Wahsbrun, 2013, Rubio et al, 2017).

Integrated HFR networks providing real-time information with unified quality control have been operating in the United States (US-IOOS, <http://www.ioos.noaa.gov/hfradar/>) and in Australia (ACORN, <http://www.ees.jcu.edu.au/acorn/>), providing key information for scientific and societal needs. In Europe, although some countries have started to implement operational HFR systems in the coastal area, a unified HF coastal radar network has not been implemented yet.

In order to assess the implementation of a distributed system providing a research and operational access to HFR data, Task 5.6 (Definition of Quality Control procedures for HFR data, M1-M42) was planned to define: (i) a standardized data model for different levels of data products (suitable temporal and spatial scales for the provided data need to be defined; for HFR data implementation in European marine data infrastructures, a data model will be defined taking into account specificities of the systems and uses); (ii) a standard QC procedure established for the evaluation of delayed-mode and near real time HFR data.

Two steps of recommendations will be successively provided: the first one (this document) partially based also on the harmonization task performed in WP2, task 2.3, and the second one at the end of the project taking into account Joint Research Activities performed in Task 3.2 of WP3. Effect of specific unfavorable conditions (low energy Bragg waves, storms...) will be considered.

The work in Task 5.6 is being done in close cooperation/contact with other major projects and existing marine data infrastructures dealing with coastal HFR data:

- SeaDataCloud for building historical products for reanalysis purposes and for standard improvements.
- EMODNet-Physics to be interoperable with the EMODNet portal and contribute to unlocking access to private data.
- EuroGOOS: for enhancing link with in situ observing system operators and downstream users (Task Teams and Working Groups) and following general recommendations of EuroGOOS DATAMEQ.
- CMEMS and the INCREASE (SE¹ 2016 call) project, which aims to the integration of existing European HFR operational systems into the CMEMS

¹ CMEMS- Service Evolution 21-SE-CALL1





and to the promotion of the use of HFR data for improving CMEMS numerical modelling systems.

The first part of this document (Sections 3 and 4) provides background information on the present status of JERICO-Next HFRs related to data formats and sharing protocols, and on how JERICO-Next task is encompassed with the present efforts of the European community towards the constitution of a pan-European HFR network. Recommendations to constitute the European Common data and metadata model for real-time HFR data are provided in Section 5. Section 6 is focused on the interoperability of the data, allowing the operational access to HFR data, data exchange and re-used between researchers, institutions, organisations and countries. Finally, conclusions and next steps to implement the HFR data management are in the last section.

3. JERICO networking and international context

Networking is essential to ensure that the potential of HFRs is fully exploited in the development of operational ocean monitoring systems in Europe. Although HFR is routinely used for real-time monitoring of ocean currents in many places along the European coasts, Europe still needs to develop the infrastructure to coordinate efforts to reach the added-value achieved by other HFR networks (i.e. US network), like: central archiving, homogenized protocols for data distribution, development of standards for quality assurance, control and data structures.

JERICO-Next is working at different levels towards the coordinated development of the coastal HFR technology and its products, mainly based on the observation of surface ocean currents. As a first very significant milestone reached in 2016 it is worth to highlight the JERICO-Next Transversal Workshop on HFR developments that was held in San Sebastian on March 9th to 11th, 2016 (MS9-1, http://www.jerico-ri.eu/download/JericoNext-HFR-workshop-Minutes_vf.pdf).

This very successful meeting joined the main partners dealing with HFRs in JERICO-Next, with participation of 22 people and 12 different Institutions from 7 European countries. The two main outcomes of the Workshop were (i) a joint review of the state-of-the-art of these observing systems (in terms of technology, procedures, maintenance, data processing, format, quality and management, identification of limitations and difficulties, applications, dissemination, site maintenance and main operational issues etc.), and (ii) the coordinated planning of work in the different task related to HFRs. These tasks involve all JERICO-Next WPs: WP2 on the harmonization of new network systems, WP3 on the developments on current observations from HFRs, WP1 and 4 on Science strategies towards 4D characterization of trans-boundary hydrography and transport, WP5 on the definition of Quality Control procedures for HF Radar data and WP6 on Virtual Access to the





data. Details of the individual presentations are available in the JERICO-Next webpage (<http://www.jerico-ri.eu/project-information/meeting-reports/>).

In Europe different European and international initiatives are also contributing to this effort: EuroGOOS Ocean Observing HFR Task Team and GEO GLOBAL HFR Task, and the projects INCREASE (CMEMs SE 2016 call) and SeaDataCloud. Other existing initiatives are gathering national experts or international expert teams working in common in some regions through the European coasts. The work in progress in Europe is aligned with initiatives at international level, where the Group on Earth Observations (GEO) is coordinating international efforts to build a Global HFR Network for data sharing and delivery and to promote the proliferation of HFRs.

THE ROLE OF HFR INTERNATIONAL NETWORKS AND INITIATIVES

Integrated HFR observatories providing real-time information with unified Quality Assessment and Quality Control standards are operating in the United States as part of the US-IOOS (<http://www.ioos.noaa.gov/hfradar>) (Harlan et al., 2010) and in Australia within the Australian Coastal Ocean Radar Network (ACORN) (Heron et al., 2008) (<http://www.ees.jcu.edu.au/acorn>). These networks support agencies for SAR applications and pollution mitigation (Harlan et al., 2011). The HFR networks operating in Asia and Oceania countries were recently censused by the 1st Ocean Radar Conference for Asia (ORCA) (Fujii et al., 2013).

The Group on Earth Observations (GEO) is coordinating international efforts to build a Global HFR Network for data sharing and delivery and to promote the proliferation of HFRs. NOAA (USA), with a small international co-chair group, has taken the lead in building this network and in promoting activities related to this task.

The Global HFR Network is collaborating to increase the numbers of coastal radars; ensure that HFR data is available in a single, standardized format; make/use a set of easy-to-use, standardized products; assimilate the data into ocean and ecosystem modelling; develop emerging uses of HFR. The 5th Meeting of the GEO Global HFR Task held in San Francisco, USA, on the 12th December 2016. The agenda of the meeting and presentations can be found at: <http://global-hfradar.org/meetings.html>

THE EUROGOOS OCEAN OBSERVING HFR TASK TEAM

Since 1994, EuroGOOS is coordinating the development and operation of (European) regional operational systems. Five systems are at present part of EuroGOOS: the Arctic (Arctic ROOS), the Baltic (BOOS), the North West Shelf (NOOS), the Ireland-Biscay-Iberian area (IBI-ROOS) and the Mediterranean (MONGOOS). EuroGOOS also contribute the Global Ocean System as one GRA of GOOS and in partnership with JCOMM. These regional assemblies are the key structures in which it is possible to discuss to promote active cooperation at different levels in order to maximize the





efficiency of national resources and investments in operational oceanography. This is done via specific and thematic working groups that collect and express the best expertise on specific fields. Recent EU marine data infrastructures and EU Programs are widely based on EuroGOOS and ROOSes achievements.

In 2014, the EuroGOOS Ocean Observing Task Teams were launched to organize and develop different ocean observation communities and foster cooperation to meet the needs of the European Ocean Observing System. In particular, the HFR Task Team was set up to promote coordinated activities in Europe around the development and use of this coastal technology. The purpose of the HFR Task Team is to coordinate and join the technological, scientific and operational HFR communities at European level. The goal of the group is to reach the harmonization of systems requirements, systems design, data quality, improvement and proof of the readiness and standardization of HFR data access and tools.

In 2015, a pilot action coordinated by EMODnet Physics, with the support of the HFR Task Team, begun 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. Further steps towards a HFR data network are oriented towards contributing to unlocking access to data and to supporting and organizing data sharing under open data policies, following EuroGOOS Data Management, Exchange and Quality (DATAMEQ) Working Group recommendations.

THE COPERNICUS MARINE ENVIRONMENT MONITORING SERVICE

The Copernicus Marine Environment Monitoring Service (CMEMS) has been designed to respond to issues emerging in the environmental, business and scientific sectors. Using information from both satellite and in situ observations, it provides state-of-the-art analyses and forecasts daily, which offer an unprecedented capability to observe, understand and anticipate marine environment events. The CMEMS In-Situ Thematic Assembly Centre (INSTAC) was designed and developed on JCOMM and the EuroGOOS ROOSs experience and expertise, which was further developed during the MyOcean projects. MyOcean enabled to run a demonstration pre-operational service for 6 years that is now fully integrated and constituting the CMEMS INSTAC.

Recently the Copernicus Marine Environment Monitoring Service (CMEMS) Service Evolution Call has supported the Innovation and Networking for the Integration of Coastal Radars into European mArine Services (INCREASE) project. Based on the progress of ongoing initiatives, INCREASE aims to begin the developments necessary for the integration of existing European HFR operational systems into the CMEMS and promote the use of HFR data for improving CMEMS numerical modelling systems.





During the first year of INCREASE (2016), the main results obtained included (1) a review of the current methodology, products definition and bases for elaborating guidelines on the use of HFRs, (2) an updated and extended description of the European HFR network (3) a roadmap for HFR products evolutions in compliance with CMEMS needs.

A very significant element towards the definition of this roadmap was the organization of the HFR expert workshop, which took place in Italy (La Spezia) on 13th-15th September 2016. This meeting gathered EuroGOOS HFR Task Team members, CMEMS representatives, main HFR technological providers, US and Australian communities representatives or other active HFR actors to work on: (i) making a diagnostic of the present development of European HFR systems (existing systems, operators, existing products); (ii) reviewing and setting methodologies for basic and HFR derived products; (iii) reviewing CMEMS needs and objectives and how HFRs can fit into them; (iv) designing a roadmap for the establishment of a European HFR network.

47 international experts from 29 different institutions and 14 countries participated to the meeting. In addition to sessions where individual presentations addressed the previous points, three parallel discussion groups were organized about the following topics: (i) definition of basic data products: data formats and QA/QC; (ii) definition of advanced products and applications; and (iii) technical implementation and strategic development. The elements gathered during this meeting have been very valuable to define the standard formats and procedures presented in this deliverable and most importantly to ensure that the recommendations that will be provided from JERICO-Next project are in agreement with the needs and expectations of the European HFR community and connected with other relevant international initiatives (GEO Global HFR). The minutes can be found online with all the presentations provided at:

<https://azti.box.com/v/EuroGOOSHFRRTTINCREASEexpWS>.

THE SEADATANET INFRASTRUCTURE

Another central European institution for ocean and marine data management is SeaDataNet (www.seadatanet.org). The SeaDataNet infrastructure network involves data centers of 35 countries, active in data collection. The networking of these professional data centers, in a unique virtual data management system, provides integrated data sets of standardized quality on-line historical data.

The SeaDataCloud project, launched in 2016, will contribute to the integration and long-term preservation of historical time series from HFR into the SeaDataNet infrastructure. The main steps in the HFR SeaDataCloud subtask for the integration of the HFR historical data into the SeaDataNet architecture are: (i) definition of standard interoperable data and Common Data Index (CDI) derived metadata formats





for historical radial and total velocity data; (ii) definition of QC standard procedures for historical radial and total velocity data, with particular focus on data versioning; (iii) design and implementation of an open tool (to be run on the cloud architecture) for the conversion of native HFR data (both radial and total velocity data) into the standard data and metadata formats and for the production of related CDIs; and (iv) implementation of prototype data access services for HFR in coordination with CMEMS.

THE EUROPEAN MARINE OBSERVATION AND DATA NETWORK: EMODNET

The European Marine Observation and Data network EMODnet was first coined in 2006 as a way to provide a sustainable focus for improving systematic observations (in situ and from space), interoperability and increasing access to data, based on robust, open and generic ICT solutions. The aim has always been to increase productivity in all tasks involving marine data gathering and management, to promote innovation and to reduce uncertainty about the behavior of the sea. EMODnet has been promoted as a key tool to lessen the risks associated with private and public investments in the blue economy, and facilitate more effective protection of the marine environment.

The development of EMODnet is a dynamic process so new data, products and functionality are added regularly while portals are continuously improved to make the service more fit for purpose and user friendly with the help of users and stakeholders. EMODnet Physics is one of the seven thematic lots, operating since 2010, and it is designed to be one access point to near real time and historical data on physical conditions of seas and oceans. EMODnet Physics is developed in cooperation and coordination with EuroGOOS and ROOSes and with other existing (major) European integrators infrastructures (CMEMS and SeaDataNet). In this context, the coordination, integration and cooperation between EMODnet Physics and CMEMS – INSTAC (former MyOcean) has resulted in a better and stronger involvement of the providers, a continuous improvement of the available in situ data products (more and better data), an involvement of a wider audience (diversification) of intermediate users (easier – different data and product access).

In collaboration and coordination with EuroGOOS and its HFR Task Team, EMODnet Physics proactively worked on HFR data stream management, harmonization and organization and it is now connected and presenting data and data products from 30 antennas (<http://www.emodnet-physics.eu/map/>).

OTHER REGIONAL INITIATIVES

Other initiatives are gathering national or international expert teams working in common in a number of regions along the European coasts. In Italy, the Italian 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 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 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.

In France the LEFE/GMMC working group ReNHFOR (Research and Networking for High Frequency Oceanographic Radar) is working to consolidate and advance the current state of knowledge of the technique, disseminate best practices for its implementation, and to structure the French contribution to a PanEuropean HFR network (Quentin et al., 2017 – submitted to the Mercator Newsletter).

4. Present status of JERICO-Next and European HFR metadata and data models

While all the radars share the same principles of operation, differences in signal transmission, reception and processing yield variations in metadata, quality control metrics and spatial registration. Even within the same type, HFRs may have different spatial ranges and resolutions, depending typically on the working frequency and bandwidth available. Although a general report on the status of HF-radar systems was produced for the WP2 (Harmonization of technologies and methodologies) D2.1 deliverable, a more detailed description on the present approaches in use for data formats, sharing protocols and quality control procedures in the JERICO-Next HFRs is presented here. The main aim is to show the diversity of approaches and the need to boost collaboration between institutions towards common formats and procedures. A secondary objective is to put the approaches used for the JERICO-Next HFRs in context of the whole HFR European community in order to show how the ensemble of HFRs represented by the JERICO-Next institutions is representative of the present situation in Europe. This point is important to ensure that JERICO-Next radars provide a good test case in the progress towards HFR common metadata and data model implementation in European marine data infrastructures.

The reference for the European HFRs used here is the outcome of the European HFR data Inventory launched in summer 2016 (Mader et al., 2016). The survey collected responses from European institutions active in HFR, and gathered aspects concerning





several technical aspects on their installations (location, working parameters, data formats, sharing protocols and policies, QA/QC, applications). A total of 51 HFR sites (20 networks) were listed as operational. The JERICO-Next organizations involved with HFR systems contributing to the present report are responsible for 23.5% of the HFRs being operated in Europe today. In Table 1 and Table 2 the different data formats, the operational availability of the data and level of QA/QC procedures being used by the JERICO-Next partners are listed.

Concerning JERICO-Next HFRs data formats in use, and as occurs for the rest of the European community (see Mader et al., 2016), most of the radial data are only available in the original Manufacturer’s format while total data of most of the operators are also available in netCDF (under different formats). NetCDF in use for radial data (only in Italian HFRs) are already those defined by EMODnet standards. In the case of netCDF for total data, there is more variability of formats, including netCDFs without compliances. The ensemble of data types in use by the JERICO-Next institutions is quite representative of the situation in Europe (Figure 1) and thus provides a good test case in the progress towards data formats harmonization.

Table 1 - HF-radar networks operated by JERICO-NEXT project partners and data formats and sharing protocols. The acronyms are defined as follows: N/type= Number of antennas, type of operation, PA = phased array, DF = direction-finding.

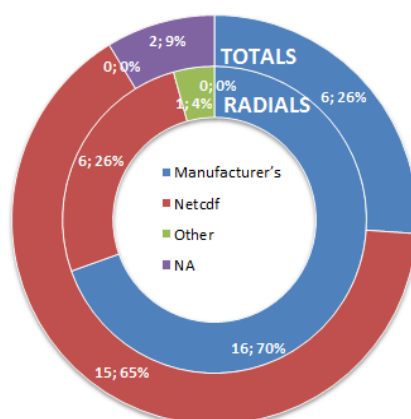
Operator	Network/ location	N/ Type	Existing Data formats		Online data availability ?	
			radials	totals	Real time	Historic al
Euskalmet – AZTI	Basque Country/ SE Bay of Biscay (Spain)	2/DF	Manufacturer’s	netCDF (Emodnet standards)	Yes, using a thredds data server	no
HZG	COSYNA / German Bight (Germany)	3/PA	Manufacturer’s netCDF	netCDF	Yes, web page	Yes, web page
ISMAR-CNR	TirLig/ Ligurian Sea (Italy)	2/DF	netCDF (Emodnet standards)	netCDF (Emodnet standards)	Yes, using a thredds data server	Yes, using a thredds data server
MIO-CNRS	MOOSE / Ligurian Sea (France)	3/DF	Other format (ascii, .xyuv)	netCDF without compliance	no	no



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SOCIB	Ibiza Channel/ Balearic Sea (Spain)	2/DF	Manufacturer's	netCDF version 3, CF-1.6	Yes, using a thredds data server	Yes, using a thredds data server
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Figure 1 - : Data format in use for radial and total data by the European HFR operators (N=23), from Mader et al. (2016).

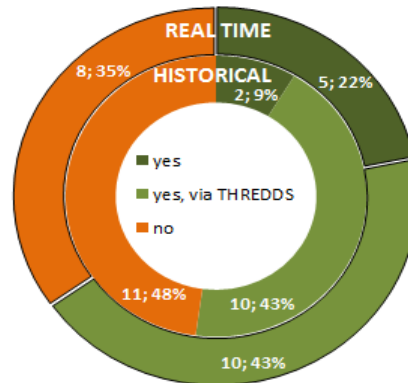


Concerning the online availability of the data from the JERICO-Next HFRs, 80% of the networks already offer online access to their real time data and 60% of the networks also to their historical data. This displays again a situation similar to that observed in the European community where 75% (51%) of the real time (historical) data are online (Figure 2). The most used protocol to put the data online is the THREDDs, although other possibilities coexist (e.g. through the institutions' data server or portals).





Figure 2 - Data availability and data sharing protocols in the European HFR community (extracted from Mader et al., 2016).



Finally, concerning QA/QC procedures there is high variability of approaches (Table 2). While some institutions follow basically the manufacturer’s recommendations, the approaches followed by SOCIB include different levels of quality-controlled data sets both for real-time and delayed mode data (Lana et al., 2015):

- [L0] Manufacturer QC procedures - Radial Components: Max Threshold - Total Vectors: Max Speed Threshold - 30° minimum required between radial vectors - First Order Limit settings – APM.
- [L1] SOCIB battery of tests - For individual total vector (spikes, gradients and out-of-range values) are flagged - System functioning diagnostic parameters at each radial station: signal-to noise, radial vector count, average radial bearing, difference between the average radial bearing from measured and ideal patterns. QA/QC based on the international standards used in MARACOOS by Roarty et al. (2012).

The data are then labelled using ARGO quality flags (0=no QC performed; 1=good; 2= probably good; 3= probably bad; 4= bad; 6=spike; 8= interpolated; 9=missing).

Table 2 - HF-radar networks operated by JERICO-NEXT project partners and QA/QC procedures.

Operator	Network/ location	QA/QC protocols		At what data level are the QA/QC applied?
		Real time	Historical/ Delayed time	
Euskalmet – AZTI	Basque Country/ SE Bay of Biscay (Spain)	Basic QA/QC based on manufacturer recommendations	Advanced QA/QC based on other parameters	Radial and totals



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HZG	COSYNA / German Bight (Germany)	Basic QA/QC based on manufacturer recommendations	Advanced QA/QC based on other parameters	Spectral, radial and totals
ISMAR-CNR	TirLig/ Ligurian Sea (Italy)	Advanced QA/QC based on other parameters	Advanced QA/QC based on other parameters	Radial and totals
MIO-CNRS	MOOSE / Ligurian Sea (France)	Advanced QA/QC based on other parameters	Advanced QA/QC based on other parameters	Spectral, radial and totals
SOCIB	Ibiza Channel/ Balearic Sea (Spain)	Advanced QA/QC based on other parameters	Advanced QA/QC based on other parameters	Radial and totals

From the results of the EU survey (Mader et al., 2016) 78% of institutions use Basic QA/QC parameters for their real time data and 65% of institutions use Basic QA/QC parameters also for their historical data.

The use of QA/QC advanced procedures is thus less frequent and highly diverse. Some of them include:

- At spectral level: use of SNR, 6dB peak width.
- System functioning diagnostic parameters at each radial station: radial vector count, average radial bearing, difference between the average radial bearing from measured and ideal patterns.
- For total data: velocity and GDOP Thresholds, spatial continuity, flags on spikes, gradients and out-of-range values.
- Spatial and temporal continuity, distributions of first and second order derivatives of radial and vector velocities, MAD filter, deviation from a reference signal.
- Validation exercises versus other in-situ or remote data as: current meters; different drifter designs (shapes and drogue); surface glider geostrophic velocities; SARAL/AltiKa altimetry velocity computation; Comparison with numerical operational models.

Following the survey responses, and again in agreement with what is observed for the JERICO-Next HFRs, 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%). There is also high heterogeneity on the flagging used once QA/QC procedures have been applied to the data.

The establishment of standards by consensus will help ensuring the expansion of the European HFR network in line with the free and open data principles, in agreement with other relevant international initiatives.

5. The European common data and metadata model for real-time HFR data

This section is going to provide the recommendations to constitute the European Common data and metadata model for real-time HFR data.

The purpose of the format specification is to ensure both efficient and automated HFR data discovery and interoperability, with tools and services across distributed and heterogeneous earth science data systems.

5.1. Data format

The European common data and metadata model for real-time HFR data uses NetCDF (Network Common Data Form), a set of software libraries and machine-independent data formats that is the international standard for common data and it is the one adopted by the US HFR network.

The recommended implementation of **NetCDF** is based on the community-supported Climate and Forecast Metadata Convention (CF), which provides a definitive description of the data in each variable, and the spatial and temporal properties of the data. The used version is **CF-1.6** and it must be identified in the 'Conventions' attribute.

Any relevant metadata should be included whether it is part of the standard or not.

The European common data and metadata model for real-time HFR data adds some requirements to the CF-1.6 standard, to make it easier to share in-situ data, to make it simpler for the Global Data Assembly Centers (GDACs) to aggregate data from multiple sites, and to ensure that the data can be created and understood by basic NetCDF utilities. In particular:

- Where time is specified as a string, the ISO8601 standard "**YYYY-MM-DDThh:mm:ssZ**" is used; this applies to attributes and to the base date in the 'units' attribute for time. There is no default time zone; **UTC** must be used, and specified.
- **Global attributes from Unidata's** NetCDF Attribute Convention for Data Discovery (ACDD) are implemented.





- **INSPIRE directive compliance** is recommended.
- **Variable names (short names) from SeaDataNet (SDN) P09** controlled vocabulary are recommended. Since the gridded HFR data are not yet spread within oceanographic standards, it happens that many of the HFR related variables have no coded names in the SDN P09 vocabulary. The needed variables with no SDN P09 coded name have been created as new 4-character-capitalized-letters names and they have been requested for addition to the SDN P09 vocabulary.

The definition of the European common data and metadata model for real-time HFR data follows the guidelines of the DATAMEQ working group.

The recommended **data and metadata model** applies to both **real-time radial** velocity data and **real-time total** velocity data.

The European common format for HFR real-time data is **netCDF-4 classic model** format.

NetCDF-4 is the state of the art version of the netCDF library and it has been launched in 2008 to support per-variable compression, multiple unlimited dimensions, more complex data types, and better performance, by layering an enhanced netCDF access interface on top of the HDF5 format.

At the same time, a format variant, netCDF-4 classic model format, was added for users who needed the performance benefits of the new format (such as compression) without the complexity of a new programming interface or enhanced data model.

It should be mentioned that both netCDF-3 and netCDF-4 libraries are part of a single software release and, as a consequence, if a netCDF-4 file conforms to the classic model then there are several easy ways to convert it to a netCDF-3 file (e. g. ncks -e infile.nc4 outfile.nc3) Consequently, in cases where netCDF-3 version is required by existing distribution services (e.g. CMEMS IN-SITU TAC), the conversion will be easily implemented.

The components (dimensions, variables and attributes) of NetCDF data set are described in Sections 5.3 to 5.7.

5.2. Quality Control tests

The European common data and metadata model for real-time HFR data requires real-time data to be mandatorily processed by the Quality Control (QC) tests listed in Table 3 (for radial velocity data) and in Table 4 (for total velocity data).

The mandatory QC tests have been defined according to the DATAMEQ working recommendations on real-time Quality Control (QC) and building on the QC tests





defined for surface currents in the Quality Assurance/Quality Control of Real-Time Oceanographic Data (QARTOD) manual produced by the US Integrated Ocean Observing System (IOOS).

The mandatory **QC tests** are manufacturer-independent, i.e. they do not rely on particular variables or information provided only by a specific device.

These standard sets of tests have been defined both **for radial and total velocity data** and they are the required ones for labelling the data as **Level 2B (for radial velocity)** and **Level 3B (for total velocity)** data. Please refer to Appendix A for the processing level definition.

Each QC test will result in a flag related to each data vector which will be inserted in the specific test variable. These variables can be matrices, in case the QC test evaluates each cell of the gridded data, or a scalar, in case the QC test assesses an overall property of the data.

An overall QC variable will report the quality flags related to the results of all the QC tests: it is a **“good data”** flag if and **only if all QC tests are passed** by the data. Please refer to Appendix B for the QC flagging scheme.

Table 3 – Mandatory QC tests for radial velocity data

QC test	Meaning	QC variable type
Syntax	Test ensuring the proper formatting and the existence of fields within the radial netCDF file.	scalar
Over-water	Test labeling vectors that lie on land.	gridded
Velocity Threshold	Test labeling velocity vectors beyond a maximum velocity threshold.	gridded
Variance Threshold	Test labeling velocity vectors beyond a maximum variance threshold.	gridded
Median Filter	For each source vector, the median of all velocities within a radius of <RCLim> and whose vector bearing (angle of arrival at site) is also within an angular distance of <AngLim> degrees from the source vector's bearing is evaluated. If the difference between the vector's velocity and the median velocity is greater than a threshold, then the median velocity is used	gridded
Average Radial Bearing	Test determining that the average radial bearing lies within a specified margin around the expected value of normal operation. The value of normal operation has to be defined within a time interval when the proper functioning of the device is assessed.	scalar



	The margin has to be set according site-specific properties.	
--	--------------------------------------------------------------	--

Table 4 – Mandatory QC tests for total velocity data.

QC test	Meaning	QC variable type
Data Density Threshold	Test checking if the minimum number of radial velocity is present for the combination into the total velocity vector.	gridded
Balance of contributing radials	Test checking if the number of radials coming from the different contributing sites are balanced for the combination into the total velocity vector.	gridded
Velocity Threshold	Test labeling velocity vectors beyond a maximum velocity threshold.	gridded
Variance Threshold	Test labeling velocity vectors beyond a maximum variance threshold.	gridded
GDOP Threshold	Test labeling velocity vectors beyond a maximum GDOP threshold.	gridded

5.3. Global attributes

The global attribute section of a netCDF file describes the contents of the file overall, and allows for data discovery. All fields should be human-readable and use units that are easy to understand. Global attribute names are case sensitive.

The European common data and metadata model for real-time HFR data divides global attributes to be adopted for HFR data in three categories: Mandatory Attributes, Recommended Attributes and Suggested Attributes.

The **Mandatory Attributes** include attributes necessary to comply with CF-1.6 and OceanSITES conventions. In Table 5, Mandatory Attributes are listed in **bold type**.

The **Recommended Attributes** include attributes necessary to comply with INSPIRE and Unidata Dataset Discovery conventions. In Table 5, Recommended Attributes are listed in *italic type*.

The Suggested Attributes include attributes that can be relevant in describing the data, whether it is part of the standard or not.

All of these attributes should be used and contain meaningful information, unless there are technical reasons rendering this impossible.





Attributes are organized by function: Discovery and Identification, Geo-spatial-temporal, Conventions used, Publication information, and Provenance.

Attributes that are part of the Attribute Convention for Data Discovery (ACDD) or Climate and Forecast (CF) standard, or that appear in the NetCDF Users Guide (NUG) are so indicated, as are those that are used by GDAC inventory software.

Table 5 – NetCDF global attributes.

Discovery and Identification		
Name	Example	Note
site_code	site_code=""	The site_code attribute is a code for each of the fixed measurement sites within the OceanSites project, as shown on the map at http://www.oceansites.org/ CMEMS requires this attribute, but the specific site codes for HFR sites and networks are in the process of being generated. In the meanwhile the attribute has to be left empty. Mandatory. (GDAC)
platform_code	platform_code="TirLig"	The platform_code is used for indexing the files, and for data synchronization between the distribution units (the regions of the insitu TAC). Therefore it has to be unique for each platform, and common among the InSitu TAC. For the HFR data, a platform_code for each antenna (for the radial current data files) and another one for the site (for the total current data files) are required. Mandatory. (GDAC)
data_mode	data_mode="R"	Indicates if the file contains real-time, provisional or delayed-mode data. The list of valid data modes is in Appendix C. Mandatory. (GDAC)
title	title="Near Real Time Surface Ocean Velocity"	Free format text describing the dataset, for use by human readers. Use the file name if in doubt. Mandatory. (NUG)





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summary	summary="The dataset consists of maps of total velocity of the surface current in the North-Western Tyrrhenian Sea and Ligurian Sea averaged over a time interval of 1 hour around the cardinal hour."	Longer free format text describing the dataset. This attribute should allow data discovery for a human reader. A paragraph of up to 100 words is appropriate. Mandatory. (ACDD)
<i>naming_authority</i>	naming_authority="it.cnr.ismar"	The organization that manages data set names. (ACDD)
<i>id</i>	id="TirLig_2016-10-17_00Z"	The "id" and "naming_authority" attributes are intended to provide a globally unique identification for each dataset. The id may be the file name without .nc suffix, which is designed to be unique. (ACDD) Both are <i>Recommended</i> .
source	source="coastal structure"	The term "coastal structure" from the SeaVoX Platform Categories (L06) list must be used for HFR data. Mandatory. (CF)
institution	institution="National Research Council of Italy – Institute of Marine Science. S.S. Lerici"	Specifies institution where the original data was produced. Mandatory. (CF)
<i>project</i>	project="RITMARE and Jerico-Next"	The scientific project that produced the data. <i>Recommended</i> .
network	network="ISMAR_HFR_TirLig"	A grouping of sites based on common shore-based logistics or infrastructure. Mandatory.
<i>keywords_vocabulary</i>	keywords_vocabulary="GCMD Science Keywords"	Please use one of 'GCMD Science Keywords', 'SeaDataNet Parameter Discovery Vocabulary' or 'AGU Index Terms'. <i>Recommended.</i> (ACDD)
keywords	keywords="OCEAN CURRENTS, SURFACE WATER, RADAR, SCR-HF"	Provide comma-separated list of terms that will aid in discovery of the dataset. Mandatory. (ACDD)
<i>comment</i>	comment="HF radar measurements of ocean"	Miscellaneous information about the data or methods used to produce it.



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	velocity are radial in direction relative to the radar location and representative of the upper 0.3-2.5 meters of the ocean.”	Any free format text is appropriate. <i>Recommended.</i> (ACDD)
data_language	data_language="eng"	The language in which the data elements are expressed.
data_character_set	data_character_set="utf8"	The character set used for expressing data.
metadata_language	metadata_language="eng"	The language in which the metadata elements are expressed.
metadata_character_set	metadata_character_set="utf8"	The character set used for expressing metadata.
topic_category	topic_category=oceans"	ISO 19115 topic category.
Geo-spatial-temporal		
area	area="Mediterranean Sea"	Geographical coverage. Try to specify the European sea where the HFR is working. <i>Recommended.</i>
geospatial_lat_min	geospatial_lat_min="43.5"	The southernmost latitude, a value between -90 and 90 degrees. It may be string or numeric, but string is strongly recommended. Mandatory. (ACDD, GDAC)
geospatial_lat_max	geospatial_lat_max="44.2"	The northernmost latitude, a value between -90 and 90 degrees. It may be string or numeric, but string is strongly recommended. Mandatory. (ACDD, GDAC)
geospatial_lat_units	geospatial_lat_units="degrees_north"	Must conform to udunits. If not specified, then "degrees_north" is assumed <i>Recommended.</i> (ACDD)
geospatial_lon_min	geospatial_lon_min="9.1"	The westernmost longitude, a value between -180 and 180 degrees. It may be string or numeric, but string is strongly recommended. Mandatory. (ACDD, GDAC)
geospatial_lon_max	geospatial_lon_max="10.5"	The easternmost longitude, a value between -180 and 180 degrees. It may be string or numeric, but string is strongly recommended. Mandatory. (ACDD, GDAC)



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<i>geospatial_lon_units</i>	geospatial_lon_units="degrees_east"	Must conform to udunits. If not specified, then "degrees_east" is assumed <i>Recommended</i> . (ACDD)
geospatial_vertical_min	geospatial_vertical_min="0"	The minimum depth of measurements. It may be string or numeric, but string is strongly recommended. Mandatory . (ACDD, GDAC)
geospatial_vertical_max	geospatial_vertical_max="1"	The maximum depth of measurements. It may be string or numeric, but string is strongly recommended. Mandatory . (ACDD, GDAC)
<i>geospatial_vertical_positive</i>	geospatial_vertical_positive="down"	Indicates which direction is positive; "up" means that z represents height, while a value of "down" means that z represents pressure or depth. If not specified then "down" is assumed. (ACDD)
<i>geospatial_vertical_units</i>	geospatial_vertical_units="m"	Units of depth. If not specified, then "m" is assumed <i>Recommended</i> . (ACDD)
time_coverage_start	time_coverage_start="2016-10-16T23:30:00Z"	Start date of the data in UTC. Time must be specified as a string according to the ISO8601 standard: "YYYY-MM-DDThh:mm:ssZ". Mandatory . (ACDD, GDAC)
time_coverage_end	time_coverage_end="2016-10-17T00:30:00Z"	Final date of the data in UTC. Time must be specified as a string according to the ISO8601 standard: "YYYY-MM-DDThh:mm:ssZ". Mandatory . (ACDD, GDAC)
<i>time_coverage_duration</i>	time_coverage_duration="PT1H"	Duration of the time coverage of the data. ISO8601 standard must be used: PnYnMnDTnHnMnS. <i>Recommended</i> . (ACDD)
<i>time_coverage_resolution</i>	time_coverage_resolution="PT1H"	Interval between records. ISO8601 standard must be used: PnYnMnDTnHnMnS. <i>Recommended</i> . (ACDD)
<i>cdm_data_type</i>	cdm_data_type="Grid"	The Unidata CDM (common data model) data type used by THREDDS. e.g. point, profile, section, station, station_profile,



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		trajectory, grid, radial, swath, image; use Grid for gridded HFR data. (ACDD)
reference_system	reference_system="EPSG:4806"	ESPG coordinate reference system.
Conventions used		
format_version	format_version="v1.0"	Version of the data model release. Mandatory. (GDAC)
Conventions	Conventions="CF-1.6, Unidata, OceanSITES, ACDD, INSPIRE"	Names of the conventions followed by the dataset. Mandatory. (NUG)
netcdf_version	netcdf_version="4.1.3"	NetCDF version used for the dataset. <i>Recommended.</i>
netcdf_format	netcdf_format="netcdf4_classic"	NetCDF format used for the dataset.
Publication information		
publisher_name	publisher_name="Lorenzo Corgnati"	Name of the person responsible for metadata and formatting of the data file. <i>Recommended.</i> (ACDD)
publisher_email	publisher_email="lorenzo.corgnati@sp.ismar.cnr.it"	Email address of the person responsible for metadata and formatting of the data file. <i>Recommended.</i> (ACDD)
publisher_url	publisher_url="http://radarhf.ismar.cnr.it"	Web address of the institution or of the data publisher. <i>Recommended.</i> (ACDD)
update_interval	update_interval="void"	Update interval for the file, in ISO8601 interval format: PnYnMnDTnHnM, where elements that are 0 may be omitted. Use "void" for data that are not updated on a schedule. Used by inventory software. Mandatory. (GDAC)
license	license="HF radar sea surface current velocity dataset by CNR-ISMAR is licensed under a Creative Commons Attribution 4.0 International License. You should have received a copy of the license along with this"	A statement describing the data distribution policy; it may be a project- or DAC-specific statement, but must allow free use of data. <i>Recommended.</i> (ACDD)



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	work. If not, see http://creativecommons.org/licenses/by/4.0/ ."	
citation	citation="Data collected and processed by CNR-ISMAR within RITMARE and Jerico-Next projects - Year 2016"	The citation to be used in publications using the dataset. Mandatory.
<i>acknowledgment</i>	acknowledgment="ISMAR HF Radar Network has been established within RITMARE and Jerico-Next projects. The network has been designed, implemented and managed through the efforts of ISMAR S.S. Lerici."	A place to acknowledge various types of support for the project that produced this data. <i>Recommended.</i> (ACDD)
Provenance		
date_created	date_created="2016-11-11T15:35:32Z"	The date on which the data file was created. Version date and time for the data contained in the file. (UTC). Time must be specified as a string according to the ISO8601 standard: "YYYY-MM-DDThh:mm:ssZ". Mandatory. (ACDD)
<i>date_modified</i>	date_modified="2016-11-11T15:35:32Z"	The date on which the data file was last modified. Time must be specified as a string according to the ISO8601 standard: "YYYY-MM-DDThh:mm:ssZ". <i>Recommended.</i> (ACDD)
history	history="2016-10-17T00:00:00Z data collected. 2016-11-11T15:35:32Z netCDF file created and sent to TAC"	Provides an audit trail for modifications to the original data. It should contain a separate line for each modification, with each line beginning with a timestamp, and including user name, modification name, and modification arguments. The time stamp must be specified as a string according to the ISO8601 standard: "YYYY-MM-DDThh:mm:ssZ". Mandatory. (NUG)
<i>processing_level</i>	processing_level="3B"	Level of processing and quality control applied to data. Valid values are listed in Appendix A. <i>Recommended.</i>





<i>contributor_name</i>	contributor_name="Vega Forneris; Cristina Tronconi"	A semi-colon-separated list of the names of any individuals or institutions that contributed to the creation of this data. <i>Recommended.</i> (ACDD)
<i>contributor_role</i>	contributor_role="THREDD S expert; metadata expert"	The roles of any individuals or institutions that contributed to the creation of this data, separated by semi-colons.(ACDD). <i>Recommended.</i> (ACDD)
<i>contributor_email</i>	contributor_email="expert1@threddsexpert.com; expert2@metadataexport.com"	The email addresses of any individuals or institutions that contributed to the creation of this data, separated by semi-colons. (ACDD)

Notes on global attributes:

- The file dates, `date_created` and `date_modified`, are our interpretation of the ACDD file dates. `date_created` is the time stamp on the file, `date_modified` may be used to represent the 'version date' of the geophysical data in the file. The `date_created` may change when e.g. metadata is added or the file format is updated, and the optional `date_modified` MAY be earlier.
- Geospatial extents (`geospatial_lat_min`, `max`, and `lon_min`, `max`) are preferred to be stored as strings for use in the GDAC software, however numeric fields are acceptable.

5.4. Dimensions

NetCDF dimensions provide information on the size of the data variables, and additionally tie coordinate variables to data. CF recommends that if any or all of the dimensions of a variable have the interpretations of "date or time" (T), "height or depth" (Z), "latitude" (Y), or "longitude" (X) then those dimensions should appear in the relative order T, Z, Y, X in the variable's definition.

Table 6 – NetCDF dimensions.

Name	Example	Comment
TIME	TIME = unlimited	Number of time steps.
DEPH	DEPH = 1	Number of depth levels.





LATITUDE	LATITUDE = 78	Dimension of the LATITUDE coordinate variable.
LONGITUDE	LONGITUDE = 106	Dimension of the LONGITUDE coordinate variable.
HEAD	HEAD = 73	Dimension of the HEAD coordinate variable (bearing away from instrument).
RANG	RANG = 46	Dimension of the RANG coordinate variable (range away from instrument).

Since HFR data have only one depth layer of measurement, i.e. the surface layer, the dimension DEPH must have size equal to 1 and value equal to 0 meters.

If non-physical variables are present in the data file, e.g. the processing parameters of the HFR device generating the data or the codes of the sites contributing to a total velocity data, related non-physical dimensions may be defined to expose the variables in the model.

5.5. Coordinate variables

NetCDF coordinates are a special subset of variables. Coordinate variables orient the data in time and space; they may be dimension variables or auxiliary coordinate variables (identified by the 'coordinates' attribute on a data variable).

Coordinate variables have an "axis" attribute defining that they represent the X, Y, Z, or T axis.

As with data variables, the European common data and metadata model for real-time HFR data recommends variable names and requires specific attributes for coordinate variables: units, axis, and, where available, standard_name are mandatory and are listed in **bold type** in Table 7.

Missing values are not allowed in coordinate variables.

All attributes in this section are highly recommended.

Table 7 – Required syntax for netCDF coordinate variables.

Type, name, dimension, attributes	Comment
Int TIME(TIME); TIME: standard_name = "time";	Date and time (UTC) of the measurement in seconds since midnight, 1970-01-01.



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<p>TIME:units = "seconds since 1970-01-01T00:00:00Z"; TIME:axis = "T"; TIME:long_name = "time of measurement UTC";</p>	<p>Example: Noon, Jan 1, 1970 is stored as 43200 (12x60x60).</p>
<p>Float LATITUDE(LATITUDE); LATITUDE:standard_name = "latitude"; LATITUDE:units = "degrees_north"; LATITUDE:axis="Y"; LATITUDE:long_name = "Latitude"; LATITUDE:reference="WGS84";</p>	<p>Latitude of the measurements. Units: degrees north; southern latitudes are negative. Example: 44.4991 for 44° 29' 56.76" N</p>
<p>Float LONGITUDE(LONGITUDE); LONGITUDE:standard_name = "longitude"; LONGITUDE:units = "degrees_east"; LONGITUDE:axis="X"; LONGITUDE:long_name = "Longitude"; LONGITUDE:reference="WGS84";</p>	<p>Longitude of the measurements. Units: degrees east; western latitudes are negative. Example: 16.7222 for 16° 43' 19.92" E</p>
<p>Float DEPH(DEPH); DEPH:standard_name = "depth"; DEPH:units = "m"; DEPH:positive =<Q> DEPH:axis="Z"; DEPH:reference=<R>; DEPH:long_name = "Depth of measurement";</p>	<p>Depth of measurements. Example: 0 for a measurement related to sea surface. <Q>: "Positive" attribute may be "up" (atmospheric, or oceanic relative to sea floor) or "down" (oceanic). <R>: The depth reference default value is "sea_level". Other possible values are : "mean_sea_level", "mean_lower_low_water", "wgs84_geoid"</p>
<p>Float HEAD(HEAD); HEAD:units = "degrees_true"; HEAD:axis="Y"; HEAD:long_name = "Bearing away from instrument";</p>	<p>Bearing of the measurement. Units: degrees true; valid values between 0 and 360 degrees.</p>





	Example: 44.4991 for 44° 29' 56.76" from instrument.
Float RANG(RANG); RANG:units = "km"; RANG:axis="X"; RANG:long_name = "Range away from instrument";	Range of the measurement. Units: kilometers.

Notes on coordinate variables:

- TIME: by default, the time word represents the center of the data sample or averaging period. The base date in the 'units' attribute for time is represented in ISO8601 standard "YYYY-MM-DDThh:mm:ssZ"; note that UTC (Z) must be explicitly specified. This requirement is an extension to ISO8601.
- DEPH: the depth variable may be positive in either upward or downward direction, which is defined in its "positive" attribute. Since HFR data have only one depth layer of measurement, i.e. the surface layer, the value of DEPH must be equal to 0 meters. aunq
- The default depth reference is "sea_level" (free sea surface).
- The latitude and longitude datum is WGS84. This is the default output of GPS systems.
- HEAD and RANG: bearing and range are the coordinate variables for radial velocity data. For radial data LATITUDE and LONGITUDE are data variables since they are evaluated starting from bearing and range. Thus LATITUDE and LONGITUDE must have the "coordinates" attribute with value "TIME DEPH HEAD RANG".

5.6. Data variables

Data variables contain the actual measurements and information about their quality, uncertainty, and mode by which they were obtained.

The European data and metadata model for real-time HFR data mandatorily requires some variables and recommends other variables. Mandatory and recommended variable names are listed in Table 8. Mandatory variables are marked in **bold type**.

When an appropriate **CF standard name** is available, it is required to be used; if no such name exists in the CF standard, the standard_name attribute should not be used. In those cases, we have recommended terms to be used in the long_name attribute. Please refer to the CF Standard Names table on line for authoritative information (definitions, canonical units) on standard names.





It is recommended that variable names be a 4-character-capitalized-letters name. They are not strictly standardized, however; one should use the CF standard_name attribute to query data files. Note that a single standard name may be used more than once in a file, but short names are unique.

Table 8 – Mandatory and recommended data variables for radial and total velocity data.

Radial velocity data		
Variable name	standard_name	long_name
TIME	time	Valid Time GMT
LATITUDE	latitude	Latitude
LONGITUDE	longitude	Longitude
RDVA	radial_sea_water_velocity_away_from_instrument	Radial Sea Water Velocity Away From Instrument
DRVA	direction_of_radial_vector_away_from_instrument	Direction Of Radial Vector Awat From Instrument
EWCT	surface_eastward_sea_water_velocity	Surface Eastward Sea Water Velocity
NSCT	surface_northward_sea_water_velocity	Surface Nortward Sea Water Velocity
ESPC		Radial Sea Water Velocity Spatial Quality
ETMP		Radial Sea Water Velocity Temporal Quality
ERSC		Radial Sea Water Velocity Spatial Quality Count
ERTC		Radial Sea Water Velocity Temporal Quality Count
XDST		Eastward Distance From Instrument
YDST		Northward Distance From Instrument
SPRC		Radial Sea Water Velocity Cross Spectra Range Cell
SLAT		Contributing Radar Site Latitudes



SLON		Contributing Radar Site Longitudes
SCOD		Contributing Radar Site Codes
Total velocity data		
EWCT	surface_eastward_sea_water_velocity	Surface Eastward Sea Water Velocity
NSCT	surface_northward_sea_water_velocity	Surface Northward Sea Water Velocity
EWCS		Standard Deviation Of Surface Eastward Sea Water Velocity
NSCS		Standard Deviation Of Surface Northward Sea Water Velocity
CCOV		Covariance Of Surface Sea Water Velocity
GDOP		Geometrical Dilution Of Precision
SLAT		Contributing Radar Site Latitudes
SLON		Contributing Radar Site Longitudes
SCOD		Contributing Radar Site Codes

The required syntax for data variables is reported in Table 9: replace <PARAM> with any of the variable names indicated in Table 8.

Required attributes are listed in **bold type**, however, the European data and metadata model for real-time HFR data recommends that all other attributes be used and contain meaningful information, unless technical reasons make this impossible.

<A>: standardized attributes.

: attributes whose values are set following the European data and metadata model for real-time HFR data rules.

<C>: attributes whose value is free text, set by the data provider.

Table 9 – Required syntax for netCDF data variables.

Type, name, dimension, attributes	Comment
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Float <PARAM>(TIME, DEPH, LATITUDE, LONGITUDE);	or Float <PARAM>(TIME, DEPH); or Float <PARAM>(TIME); or Float <PARAM>(TIME, DEPH, HEAD, RANG); or Float <PARAM>(HEAD,RANG);
<PARAM>:standard_name = <A>;	standard_name : required, if there is an appropriate, existing standard name in CF.
<PARAM>:units = <A>;	units : required.
<PARAM>:_FillValue = ;	_FillValue : required. Fill values must be chosen according to the variable data type (int, float, double).
<PARAM>:coordinates = ;	coordinates : required, if a data variable does not have 4 coordinates in its definition.
<PARAM>:long_name = ;	long_name : required. Text; should be a useful label for the variable.
<PARAM>:valid_range = ;	valid_range : required. A vector of two numbers specifying the minimum and maximum valid values for the variable. Range extremes must have the same data type (int, float, double, etc) of the data variable.
<PARAM>:comment = <C>;	comment : Text; useful free-format text.
<PARAM>:add_offset = ;	add_offset : offset value to be added to all the values of the variable. It must have the same data type (int, float, double, etc) of the data variable. If it is 0, the add_offset attribute must be omitted.
<PARAM>:scale_factor = ;	scale_factor : scaling value to be multiplied to all the values of the variable. It must have the same data type (int, float, double, etc) of the data variable. If it is 1, the add_offset attribute must be omitted.

Note on the “coordinates” attribute:

- There are two methods used to locate data in time and space. The preferred method is for the data variable to be declared with dimensions that are coordinate variables, e.g. EWCT(TIME, DEPH, LATITUDE, LONGITUDE). Alternatively, a variable may be declared with fewer dimensions, e.g. EWCT (TIME). In the latter case, the “coordinates” attribute of the variable provides





the spatiotemporal reference for the data. The value of the “coordinates” attribute is a blank separated list of the names of auxiliary coordinate variables; these must exist in the file, and their sizes must match a subset of the data variable’s dimensions; scalar coordinates do so by default. The use of coordinate variables as dimensions is preferred, because it conforms to COARDS and because it simplifies the use of the data by standard software.

5.7. Quality Control variables

Since in HFR data the quality control values vary along one or more axes of the data variables, they are provided as separate numeric flag variables, with at least one dimension that matches the ‘target’ variable.

When QC information is provided as a separate flag variable, CF-1.6 requires that these variables carry the “flag_values” and “flag_meanings” attributes. These provide a list of possible values and their meanings.

QC variables can also exist not linked to a target physical variable (e.g. GDOP threshold QC variable linked to GDOP variable), but also as standalone variables reporting the results of a specific QC test, e.g. Over-water test (see Section 5.2).

Table 10 describes how to provide QC information as a separate variable. Data variables are identified by the term <PARAM> which represents a name from the list of variable names (see Section 5.6). QC tests are identified by the term <TEST> which represents a test from the list of QC tests (see Section 5.2).

<A>: standardized attributes.

: attributes whose values are set following the European data and metadata model for real-time HFR data rules.

<C>: attributes whose value is free text, set by the data provider.

Table 10 – Required syntax for netCDF QC variables.

Type, name, dimension, attributes	Comment
Short <PARAM>_QC(TIME, DEPH, LATITUDE, LONGITUDE);	or Short <TEST>_QC(TIME, DEPH, LATITUDE, LONGITUDE); or Short <PARAM>_QC(TIME, DEPH, HEAD, RANG); or Short <TEST>_QC(TIME, DEPH, HEAD, RANG);
<PARAM>_QC:long_name = <A>;	long_name: required. Type char, fixed value.
<PARAM>_QC:units = <A>;	units: required.
<PARAM>_QC:_FillValue = ;	



<p><PARAM>_QC:valid_range = ;</p> <p><PARAM>_QC:flag_values = </p> <p><PARAM>_QC:flag_meanings = </p> <p><PARAM>_QC:comment = <C>;</p> <p><PARAM>_QC:add_offset = ;</p> <p><PARAM>_QC:scale_factor = ;</p>	<p>_FillValue: required. Fill values must be chosen according to the QC variable data type (int, float, double).</p> <p>valid_range: required. A vector of two numbers specifying the minimum and maximum valid values for the variable. Range extremes must have the same data type (int, float, double, etc) of the QC variable.</p> <p>flag_values: required. Fixed values listing the possible values of the QC variable.</p> <p>flag_meanings: required. Type char, fixed values providing the meanings of the possible values for the QC variable.</p> <p>comment: Text; useful free-format text.</p> <p>add_offset: offset value to be added to all the values of the variable. It must have the same data type (int, float, double, etc) of the QC variable. If it is 0, the add_offset attribute must be omitted.</p> <p>scale_factor: scaling value to be multiplied to all the values of the variable. It must have the same data type (int, float, double, etc) of the QC variable. If it is 1, the add_offset attribute must be omitted.</p>
---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------





6. Data management and distribution

HFR data is in situ gridded data in time (big data) that has to be managed according its peculiarity, and it is necessary to design and develop the hardware and software infrastructures, as well as the data formats, file conventions, file dimension, file naming and labelling for both real time (i.e. the continuous data flow for latest days) and historical (i.e. the complete series) HFR data management.

The identified core infrastructure for managing and providing data is based on Thematic Real-time Environmental Distributed Data Services (THREDDS) that consists of two main building blocks: the THREDDS Data Server (TDS) and the Common Data Model (CDM) / netCDF-Java library.

For a new HFR data provider, in order to set up an infrastructure to connect and be harmonized to other EU HFR, THREDDS may represent the easiest and more complete way. However, alternative approaches like using ncWMS and Opendap-Hyrax are totally compatible (Baschek et al. 2016).

The TDS is open source and runs inside the open source Tomcat Servlet container. The TDS provides catalog, metadata, and data access services for scientific data. Every TDS publishes THREDDS catalogs that advertise the datasets and services it makes available. THREDDS catalogs are XML documents that list datasets and the data access services available for the datasets. Catalogs may contain metadata to document details about the datasets. TDS configuration files provide the TDS with information about which datasets and data collections are available and what services are provided for the datasets.

The available remote data access protocols include OPeNDAP, OGC WCS, OGC WMS, and HTTP. It has to be noticed that the ncISO service allows THREDDS catalogs to be translated into ISO metadata records.

The CDM provides data access through the netCDF-Java API to a variety of data formats (e.g., netCDF, HDF, GRIB). Layered above the basic data access, the CDM uses the metadata contained in datasets to provide a higher-level interface to geoscience specific features of datasets, in particular, providing geolocation and data subsetting in coordinate space.

The TDS uses the CDM/netCDF-Java to read datasets in various formats. The CDM also provides the foundation for all the services made available through the TDS.

A pluggable framework allows other developers to add readers for their own specialized formats. The CDM also provides standard APIs for georeferencing coordinate systems, and specialized queries for scientific feature types like Grid, Point, and Radial datasets, and so it represents the best suitable available technology to manage HFR data products.





How to set up a TDS²

The THREDDS Data Server is implemented in 100% Java (requirement: Java version 7+), and is contained in a single file, which allows easy installation into the open-source Tomcat web server (requirement: Tomcat version 7+, more specifically **Tomcat >= 7.0.43**). Before installing the TDS the user has to:

- Install Java (download and install the SDK)
- Create a dedicated user and group for running Tomcat who does not have root privileges.
- As this user, download and install the latest version of Tomcat 7. **Tomcat >= 7.0.43**.

Now the user can proceed with the TDS installation, in particular he has to:

- Download the latest thredds.war file, and put it into **`\${tomcat_home}/webapps**.
- Start/restart Tomcat so that it has a chance to create initial files in **`\${tomcat_home}/content/thredds** (optional).
- Modify **`\${tomcat_home}/content/thredds/catalog.xml** for your site.
- Modify **`\${tomcat_home}/content/thredds/threddsConfig.xml** for your site in the following manner:
 - Add the needed information to the `serverInformation` element
 - Enable any other optional services like WMS or WCS.
- If needed, limit access to the TDS and create a `robots.txt` file in **`\${tomcat_home}/webapps/ROOT/** to restrict crawler activity.

How to configure a TDS Catalog

TDS is configured with *configuration catalogs* that live in the directory **`\${tomcat_home}/content/thredds/** and its subdirectories. These contain information needed only on the server, which is removed when the TDS sends the *client catalog* to the requester.

The *default root catalog* is **`\${content_root}/thredds/catalog.xml**. It may reference other configuration catalogs using the `catalogRef` element. These catalogs can also contain `catalogRef` elements, etc.

Catalog Caching

Static catalogs are read and cached in memory when the TDS *web application* starts up (e.g. when Tomcat starts up). The `expires` attribute can be used to decide whether to reread the catalog. If no `expires` attribute, the catalog is not automatically reread:

² Further details at <http://www.unidata.ucar.edu/software/thredds/current/tds/reference/ChecklistReference.html>





DatasetScan Dynamic Catalogs

Dynamic catalogs are generated by DatasetScan elements, at the time the user request is made. These catalogs are not cached. The request causes a single disk directory to be read. Files in the directory (that pass the filter) are made into *dataset* elements. Any subdirectories are made into *catalogRef* elements, and are not read until a request is made for them.

More info at the Unidata website:
<http://www.unidata.ucar.edu/software/thredds/current/tds/reference/DatasetScan.html>

Feature Collection Dynamic Catalogs

Dynamic catalogs are also generated by FeatureCollection elements, at the time the user request is made. Typically the top collection catalog is cached, but not any subcollections. Each request typically causes a single collection index file to be read.

More info at the Unidata website:
<http://www.unidata.ucar.edu/software/thredds/current/tds/reference/collections/FeatureCollections.html>





Thredds Configuration³

The TDS configuration file (`${content_root}/thredds/threddsConfig.xml`) allows the TDS administrator to set a number of parameters that control the behavior of the TDS. Most of these parameters will be set with reasonable default values. However, a number of them allow the user to describe the server, provide contact information, and change the "theme" of server-generated HTML pages.

Server Information

Information describing the TDS installation and providing contact information is configured in the `serverInformation` element of the TDS configuration file. This includes:

- basic information about the server (e.g., name, abstract, keywords, host institution)
- contact information so that users will know where to go with problems or questions.

Configure TDS to Allow WCS, WMS, and ncISO Access

Out of the box, the TDS distribution will have WCS, WMS, and ncISO disabled. They must be explicitly allowed in the `threddsConfig.xml` file. The default `threddsConfig.xml` file (which should now be in your `${tomcat_home}/content/thredds` directory) contains commented out sections for each of these services.

WCS Configuration

To enable the WCS service for locally served datasets, the user will need the following in your `threddsConfig.xml` file:

```
<WCS>
  <allow>true</allow>
</WCS>
```

Additional WCS configuration options can be set in the `threddsConfig.xml` file.

WMS Configuration

To enable the WMS service for locally served datasets, the user will need the following in the `threddsConfig.xml` file:

³ For further information visit <http://www.unidata.ucar.edu/software/thredds/current/tds/reference/CatalogConfiguration.html>





```
<WMS>
  <allow>true</allow>
</WMS>
```

Additional WMS configuration options can be set in the `threddsConfig.xml` file. There are several styling and displaying capabilities available in TDS:

- The WMS tries to identify vector components that it can combine and display as a single vector layer. It looks for CF `standard_name` attributes with values of the form "eastward_*" and "northward_*" and combines those that match into a vector layer.
- The WMS provides several vector styles: `barb`, `stumpvec`, `trivec`, `linevec`, `fancyvec`.
- Some styling properties can be specified through the non-standard optional parameters supported by ncWMS
- Some non-standard requests are supported:
 - `GetTransect`
 - `GetVerticalProfile`
 - `GetVerticalSection`

ncISO Configuration

To enable the ncISO services for locally served datasets, the user will need the following in the `threddsConfig.xml` file:

```
<NCISO>
  <ncmlAllow>true</ncmlAllow>
  <uddcAllow>true</uddcAllow>
  <isoAllow>true</isoAllow>
</NCISO>
```

Each "*Allow" element allows one of the three ncISO services.





Adding WCS and WMS Services

Once the WCS and WMS services are enabled, all that is required for the TDS to provide WCS and WMS access to datasets is for those datasets to reference WCS and WMS service elements. Adding them to an existing compound service would look something like this:

```
<service name="grid" serviceType="Compound" base="" >
  <service name="odap" serviceType="OpenDAP" base="/thredds/dodsC/" />
  <service name="wcs" serviceType="WCS" base="/thredds/wcs/" />
  <service name="wms" serviceType="WMS" base="/thredds/wms/" />
  <service name="ncss" serviceType="NetcdfSubset" base="/thredds/ncss/" />
  <service name="http" serviceType="HTTPServer" base="/thredds/fileServer/" />
</service>
```

HFR DATA MANAGEMENT INTO THE JERICONEXT

The JERICONEXT project is developing the HFR data management in cooperation with the INCREASE CMEMS SE project and EMODnet Physics. The INCREASE TDS was identified to be the European node for the HFR data stream and all of the HFR data are processed and harmonized, and disseminated on the common TDS.

Two time aggregation are available:

- Last 60 days: it is a sliding window file for last 60 days. Data are collected, aggregated and presented as a single NetCDF file; updated every day.
- Monthly: starting the first day of the month data are added incrementally in a single NetCDF files; for the current month NetCDF file is partial and makes available the data from the first day of the month to today; the file is closed last day of the month. Each month is a single NetCDF file.

All data are accessible with the following services:

- OPENDAP (reference <http://opendap.org/>)
- WMS (reference <http://www.opengeospatial.org/standards/wms>)





- NetcdfSubset (reference <http://www.unidata.ucar.edu/software/thredds/current/tds/reference/NetcdfSubsetServiceReference.html>)

Monthly files are also accessible for direct download of the NetCDF file via HTTPServer service link:

<http://thredds.emodnet-physics.eu/threddsINCREASE/catalog.html>

The main catalog contains links to 60 days aggregations and monthly files for each provider.

In case the provider catalog is not compliant with the JERICONEXT – INCREASE recommendation, a specific adapter processes the provider catalog and data and makes them compatible and harmonized with recommendations.

The Catalogs are set up by a FeatureCollection, a DatasetScan and four service type: OpenDAP, HTTPServer, WMS and NetcdfSubset.

The FeatureCollection element is configured with a metadata section containing information about the dataset (like creator, documentation link, summary data). This dataset create a 60 days logical aggregation of single daily files. This element is accessible via OpenDAP, WMS and NetcdfSubset services. There is no access to single daily files.

The DatasetScan element give access to single monthly data files, but do not aggregate them. Each monthly file is accessible via OpenDAP, HTTPServer, WMS and NetcdfSubset services.

An example of a HFR catalog compliant with the recommendations is the RITMARE Catalog:

```
<service name="all" base="" serviceType="compound">
  <service name="odap" serviceType="OpenDAP" base="/thredds/dodsC/" />
  <service name="http" serviceType="HTTPServer" base="/thredds/fileServer/" />
  <service name="wms" serviceType="WMS" base="/thredds/wms/" />
  <service name="ncss" serviceType="NetcdfSubset" base="/thredds/ncss/" />
</service>
.....
<dataset name="RITMARE Catalog">
  <featureCollection featureType="FMRC" name="Ritmare Last 60 Days" harvest="true"
    path="fmrc/RITMARElast60days">
    <metadata inherited="true">
      <serviceName>all</serviceName>
      <dataFormat>FMRC</dataFormat>
      <authority>ISMAR - CNR</authority>
      <documentation xlink:href="http://www.ritmare.it/" xlink:title="Progetto RITMARE"/>
    </metadata>
  </featureCollection>
</dataset>
```



```
<documentation xlink:href="http://www.jerico-ri.eu/" xlink:title="Jerico-Next EU project"/>
<documentation type="rights">
The dataset is licensed under a Creative Commons Attribution 4.0
</documentation>
<documentation type="citation">
Data collected and processed by CNR-ISMAR within Jerico-Next and RITMARE
projects.
</documentation>
<documentation type="product version">
v1.0 - netCDF 4.1.3, CF-1.6, ACDD, Unidata Data Discovery, INSPIRE compliant.
</documentation>
<documentation type="summary">
The data set consists of maps of total velocity of the surface current in the North-
Western Tyrrhenian
Sea and Ligurian Sea averaged over a time interval of 1 hour around the cardinal hour.
Surface ocean velocities estimated by HF Radar are representative of the upper 0.3-2.5
meters of the ocean.
</documentation>
<creator>
  <name vocabulary="ISMAR - CNR">
    Institute of Marine Sciences of the Italian National Research Council
  </name>
  <contact url="http://www.ismar.cnr.it/" email="lorenzo.cognati@sp.ismar.cnr.it"/>
</creator>
</metadata>
<collection
spec="/opt/lvdata00/Data/HFRadar/RITMARE/Daily/Ritmارة_#yyyyMMdd#.nc$"/>
  <fmrcConfig regularize="false" datasetTypes="" >
    <dataset name="Ritmارة_HFRadar" offsetsGreaterEqual="0"/>
  </fmrcConfig>
  <update startup="test" rescan="0 10 0/1 1/1 * ? *" trigger="allow"/>
</featureCollection>

<datasetScan name="Ritmارة Monthly Files" path="RITMARE/monthlyfiles"
location="/opt/lvdata00/Data/HFRadar/RITMARE/Monthly">
  <serviceName>all</serviceName>
  <filter>
    <include wildcard="*.nc"/>
  </filter>
</datasetScan>
```







7. Conclusions and next steps

This manual sets the basis of the European common data and metadata model for real-time HFR data. By following the recommendations described in the manual, any HFR operator will be able to produce data in a standard format and to be immediately integrated in the European HFR operational system.

The manual allows HFR operators to produce HFR quality-controlled real-time surface currents data and key derived products and sets the basis for the management of historical data and methodologies for advanced delayed mode quality-control techniques.

Anyway, discussions are still ongoing within the European HFR community in order to improve and extend the core of recommendations for the implementation of the common data and metadata model.

In particular:

- sensor and instrument metadata will be defined for providing complete information about sensors;
- a common way to include native HFR file header in the metadata model will be defined and implemented;
- a naming convention for HFR NetCDF data files is in the process of being defined on the basis of OceanSITES and EMODnet regulations. Since these conventions require to insert the site codes in the file names and the specific site codes for HFR sites are in the process of being defined, the final naming convention will be released at the end of the site code definition process.





8. References

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9. Useful links

In the following the useful links to the reference conventions applied by the European common data and metadata model for real-time HFR data are listed.

- NetCDF Best Practices:
unidata.ucar.edu/software/netcdf/docs/BestPractices.html
- NetCDF Climate and Forecast Metadata Convention 1.6, including the CF standard names: cfconventions.org
- Uduits package as implemented by CF:
unidata.ucar.edu/software/udunits/
- ISO8601 description:
http://en.wikipedia.org/wiki/ISO_8601
- Unidata NetCDF Attribute Convention for Dataset Discovery (ACDD):
http://wiki.esipfed.org/index.php/Category:Attribute_Conventions_Dataset_Discovery
https://podaac.jpl.nasa.gov/PO.DAAC_DataManagementPractices
- INSPIRE convention:
<http://inspire.ec.europa.eu/index.cfm/pageid/101>
http://inspire.ec.europa.eu/documents/Metadata/MD_IR_and_ISO_20131029.pdf
- NODC NetCDF Templates:
<http://www.nodc.noaa.gov/data/formats/netcdf/>
- Online CF-1.6 compliance checker:
<http://puma.nerc.ac.uk/cgi-bin/cf-checker.pl?cfversion=1.6>
- The SeaDataNet P09 controlled vocabulary:
<http://vocab.nerc.ac.uk/collection/P09/current/>
- THREDDS:
unidata.ucar.edu/projects/THREDDS/CDM/CDM-TDS.htm
- EPSG, used for the coordinate reference frames:
<http://www.epsg.org/>
- QARTOD manual:
https://ioos.noaa.gov/wp-content/uploads/2016/06/HFR_QARTOD_Manual_05_26_16.pdf
- OceanSITES convention manual:
http://www.oceansites.org/docs/oceansites_data_format_reference_manual.pdf





A. Processing Levels

This table describes the processing levels for the identification of the different data produced during the processing workflow of a HFR. The definition of these processing levels is manufacturer-independent, i.e. the level schema is suitable to all the most common HFR.

The string values are used as an overall indicator (i.e. one summarizing all measurements) of each data file in the processing_level attribute.

Table 11 – Processing levels for HFR data.

Processing Level	Definition	Products
LEVEL 0	Reconstructed, unprocessed instrument/payload data at full resolution; any and all communications artifacts, e.g. synchronization frames, communications headers, duplicate data removed.	Signal received by the antenna before the processing stage. (No access to these data in Codar systems)
LEVEL 1A	Reconstructed, unprocessed instrument data at full resolution, time-referenced and annotated with ancillary information, including radiometric and geometric calibration coefficients and georeferencing.	Spectra by antenna channel
LEVEL 1B	Level 1A data that have been processed to sensor units for next processing steps. Not all instruments will have data equivalent to Level 1B.	Spectra by beam direction
LEVEL 2A	Derived geophysical variables at the same resolution and locations as the Level 1 source data.	Radial velocity data
LEVEL 2B	Level 2A data that have been processed with a minimum set of QC.	Radial velocity data
LEVEL 3A	Variables mapped on uniform space-time grid scales, usually with some completeness and consistency	HFR total velocity data
LEVEL 3B	Level 3A data that have been processed with a minimum set of QC.	HFR total velocity data
LEVEL 4	Model output or results from analyses of lower level data, e.g. variables derived from multiple measurements	Energy density maps, residence times, etc.





B. Quality Control indicators

The quality control flags indicate the data quality of the data values in a file, following the ARGO QC flag scale. The byte codes in column 1 are used only in the QC variables to describe the quality of each measurement, the strings in column 2 ('meaning') are used in the attribute flag_meanings of each QC variable to describe the overall quality of the parameter.

When the numeric codes are used, the flag_values and flag_meanings attributes are required and should contain lists of the codes (comma-separated) and their meanings (space separated, replacing spaces within each meaning by ' ').

Table 12 – Argo quality control flag scale

Code	Meaning	Comment
0	unknown	No QC was performed
1	good data	All QC tests passed
2	probably good data	
3	potentially correctable bad data	These data are not to be used without scientific correction or re-calibration
4	bad data	Data have failed one or more QC tests
5	-	Not used
6	-	Not used
7	nominal value	Data were not observed but reported (e.g. instrument target depth)
8	interpolated value	
9	missing value	





C. Data mode

The values for the global attribute “data_mode” are defined as follows:

Table 13 – Valid data modes.

Value	Meaning
R	Real-time data. Data coming from the (typically remote) platform through a communication channel without physical access to the instruments, disassembly or recovery of the platform.
P	Provisional data. Data obtained after instruments have been recovered or serviced; some calibrations or editing may have been done, but the data is not thought to be fully processed. Refer to the history attribute for more detailed information.
D	Delayed-mode data. Data published after all calibrations and quality control procedures have been applied on the internally recorded or best available original data. This is the best possible version of processed data.
M	Mixed. It indicates that the file contains data in more than one of the above states.





D. Radial velocity data file header example

```
netcdf RDL_m_TINO_2016_10_17_0000 {
dimensions:
  TIME = UNLIMITED ; // (1 currently)
  HEAD = 73 ;
  RANG = 46 ;
  DEPH = 1 ;
  NSIT = 1 ;
  SMXL = 9 ;
  QMXL = 1 ;
variables:
  int TIME(TIME) ;
    TIME:long_name = "Time of Measurement UTC" ;
    TIME:standard_name = "time" ;
    TIME:units = "seconds since 1970-01-01T00:00:00Z" ;
    TIME:calendar = "Gregorian" ;
    TIME:axis = "T" ;
  float HEAD(HEAD) ;
    HEAD:axis = "Y" ;
    HEAD:long_name = "Bearing Away From Instrument" ;
    HEAD:units = "degrees_true" ;
  float RANG(RANG) ;
    RANG:axis = "X" ;
    RANG:long_name = "Range Away From Instrument" ;
    RANG:units = "km" ;
  float DEPH(DEPH) ;
    DEPH:long_name = "Depth of Measurement UTC" ;
    DEPH:standard_name = "depth" ;
    DEPH:units = "m" ;
    DEPH:axis = "Z" ;
    DEPH:positive = "down" ;
    DEPH:reference = "sea_level" ;
  float LATITUDE(HEAD, RANG) ;
    LATITUDE:standard_name = "latitude" ;
    LATITUDE:long_name = "Latitude" ;
    LATITUDE:units = "degrees_north" ;
    LATITUDE:valid_range = -90.f, 90.f ;
    LATITUDE:coordinates = "TIME DEPH HEAD RANG" ;
    LATITUDE:FillValue = 9.96921e+36f ;
  float LONGITUDE(HEAD, RANG) ;
    LONGITUDE:standard_name = "longitude" ;
    LONGITUDE:long_name = "Longitude" ;
    LONGITUDE:units = "degrees_east" ;
    LONGITUDE:valid_range = -180.f, 180.f ;
    LONGITUDE:coordinates = "TIME DEPH HEAD RANG" ;
```



JERICO-NEXT

```
LONGITUDE:FillValue = 9.96921e+36f ;
float RDVA(TIME, DEPH, HEAD, RANG) ;
RDVA:valid_range = -1000.f, 1000.f ;
RDVA:standard_name = "radial_sea_water_velocity_away_from_instrument" ;
RDVA:units = "m s-1" ;
RDVA:long_name = "Radial Sea Water Velocity Away From Instrument" ;
RDVA:FillValue = 9.96921e+36f ;
RDVA:scale_factor = 1.f ;
RDVA:add_offset = 0.f ;
RDVA:coordinates = "LONGITUDE LATITUDE" ;
short DRVA(TIME, DEPH, HEAD, RANG) ;
DRVA:valid_range = 0s, 3600s ;
DRVA:standard_name = "direction_of_radial_vector_away_from_instrument" ;
DRVA:long_name = "Direction Of Radial Vector Away From Instrument" ;
DRVA:FillValue = -32767s ;
DRVA:add_offset = 0.f ;
DRVA:units = "degrees_true" ;
DRVA:coordinates = "LONGITUDE LATITUDE" ;
DRVA:scale_factor = 0.1f ;
float EWCT(TIME, DEPH, HEAD, RANG) ;
EWCT:valid_range = -1000.f, 1000.f ;
EWCT:standard_name = "surface_eastward_sea_water_velocity" ;
EWCT:long_name = "Surface Eastward Sea Water Velocity" ;
EWCT:FillValue = 9.96921e+36f ;
EWCT:scale_factor = 1.f ;
EWCT:add_offset = 0.f ;
EWCT:units = "m s-1" ;
EWCT:coordinates = "LONGITUDE LATITUDE" ;
float NSCT(TIME, DEPH, HEAD, RANG) ;
NSCT:valid_range = -1000.f, 1000.f ;
NSCT:standard_name = "surface_northward_sea_water_velocity" ;
NSCT:long_name = "Surface Northward Sea Water Velocity" ;
NSCT:FillValue = 9.96921e+36f ;
NSCT:scale_factor = 1.f ;
NSCT:add_offset = 0.f ;
NSCT:units = "m s-1" ;
NSCT:coordinates = "LONGITUDE LATITUDE" ;
short QCflag(TIME, DEPH, HEAD, RANG) ;
QCflag:long_name = "Overall Quality Flags" ;
QCflag:valid_range = 0s, 9s ;
QCflag:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
QCflag:flag_meanings = "unknown good_data probably_good_data
potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value"
;
QCflag:comment = "OceanSITES quality flagging for all QC tests." ;
QCflag:FillValue = -32767s ;
```





JERICO-NEXT

```
QCflag:scale_factor = 1.f ;
QCflag:add_offset = 0.f ;
QCflag:units = "1" ;
short OWTR_QC(TIME, DEPH, HEAD, RANG) ;
  OWTR_QC:long_name = "Over-water Quality Flags" ;
  OWTR_QC:valid_range = 0s, 9s ;
  OWTR_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
  OWTR_QC:flag_meanings = "unknown good_data probably_good_data
potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value"
;
  OWTR_QC:comment = "OceanSITES quality flagging for Over-water QC test." ;
  OWTR_QC:FillValue = -32767s ;
  OWTR_QC:scale_factor = 1.f ;
  OWTR_QC:add_offset = 0.f ;
  OWTR_QC:units = "1" ;
  OWTR_QC:coordinates = "LONGITUDE LATITUDE" ;
short MDFL_QC(TIME, DEPH, HEAD, RANG) ;
  MDFL_QC:long_name = "Median Filter Quality Flags" ;
  MDFL_QC:valid_range = 0s, 9s ;
  MDFL_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
  MDFL_QC:flag_meanings = "unknown good_data probably_good_data
potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value"
;
  MDFL_QC:comment = "OceanSITES quality flagging for Median Filter QC test.
Threshold set to m/s." ;
  MDFL_QC:FillValue = -32767s ;
  MDFL_QC:scale_factor = 1.f ;
  MDFL_QC:add_offset = 0.f ;
  MDFL_QC:units = "1" ;
  MDFL_QC:coordinates = "LONGITUDE LATITUDE" ;
short VART_QC(TIME, DEPH, HEAD, RANG) ;
  VART_QC:long_name = "Variance Threshold Quality Flags" ;
  VART_QC:valid_range = 0s, 9s ;
  VART_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
  VART_QC:flag_meanings = "unknown good_data probably_good_data
potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value"
;
  VART_QC:comment = "OceanSITES quality flagging for Variance Threshold QC
test. Threshold set to m2/s2." ;
  VART_QC:FillValue = -32767s ;
  VART_QC:scale_factor = 1.f ;
  VART_QC:add_offset = 0.f ;
  VART_QC:units = "1" ;
  VART_QC:coordinates = "LONGITUDE LATITUDE" ;
short VELT_QC(TIME, DEPH, HEAD, RANG) ;
  VELT_QC:long_name = "Velocity Threshold Quality Flags" ;
```



JERICO-NEXT

```
VELT_QC:valid_range = 0s, 9s ;
VELT_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
VELT_QC:flag_meanings = "unknown good_data probably_good_data
potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value"
;
VELT_QC:comment = "OceanSITES quality flagging for Velocity Threshold QC test.
Threshold set to m/s." ;
VELT_QC:FillValue = -32767s ;
VELT_QC:scale_factor = 1.f ;
VELT_QC:add_offset = 0.f ;
VELT_QC:units = "1" ;
VELT_QC:coordinates = "LONGITUDE LATITUDE" ;
short AVRQB_QC(QMXML) ;
AVRB_QC:long_name = "Average Radial Bearing Quality Flags" ;
AVRB_QC:valid_range = 0s, 9s ;
AVRB_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
AVRB_QC:flag_meanings = "unknown good_data probably_good_data
potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value"
;
AVRB_QC:comment = "OceanSITES quality flagging for Average Radial Bearing
QC test. Threshold set to deg." ;
AVRB_QC:FillValue = -32767s ;
AVRB_QC:scale_factor = 1.f ;
AVRB_QC:add_offset = 0.f ;
AVRB_QC:units = "1" ;
float ESPC(TIME, DEPH, HEAD, RANG) ;
ESPC:valid_range = -1000.f, 1000.f ;
ESPC:long_name = "Radial Sea Water Velocity Spatial Quality" ;
ESPC:units = "m s-1" ;
ESPC:coordinates = "LONGITUDE LATITUDE" ;
ESPC:FillValue = 9.96921e+36f ;
ESPC:scale_factor = 1.f ;
ESPC:add_offset = 0.f ;
float ETMP(TIME, DEPH, HEAD, RANG) ;
ETMP:valid_range = -1000.f, 1000.f ;
ETMP:long_name = "Radial Sea Water Velocity Temporal Quality" ;
ETMP:units = "m s-1" ;
ETMP:coordinates = "LONGITUDE LATITUDE" ;
ETMP:FillValue = 9.96921e+36f ;
ETMP:scale_factor = 1.f ;
ETMP:add_offset = 0.f ;
float MAXV(TIME, DEPH, HEAD, RANG) ;
MAXV:long_name = "Radial Sea Water Velocity Away From Instrument Maximum"
;
MAXV:valid_range = -1000.f, 1000.f ;
MAXV:FillValue = 9.96921e+36f ;
```



JERICO-NEXT

```
MAXV:scale_factor = 1.f ;
MAXV:add_offset = 0.f ;
MAXV:units = "m s-1" ;
MAXV:coordinates = "LONGITUDE LATITUDE" ;
float MINV(TIME, DEPH, HEAD, RANG) ;
MINV:long_name = "Radial Sea Water Velocity Away From Instrument Minimum" ;
MINV:valid_range = -1000.f, 1000.f ;
MINV:FillValue = 9.96921e+36f ;
MINV:scale_factor = 1.f ;
MINV:add_offset = 0.f ;
MINV:units = "m s-1" ;
MINV:coordinates = "LONGITUDE LATITUDE" ;
byte ERSC(TIME, DEPH, HEAD, RANG) ;
ERSC:long_name = "Radial Sea Water Velocity Spatial Quality Count" ;
ERSC:valid_range = 0.f, 1000000.f ;
ERSC:FillValue = -127b ;
ERSC:scale_factor = 1.f ;
ERSC:add_offset = 0.f ;
ERSC:units = "1" ;
ERSC:coordinates = "LONGITUDE LATITUDE" ;
byte ERTC(TIME, DEPH, HEAD, RANG) ;
ERTC:long_name = "Radial Sea Water Velocity Temporal Quality Count" ;
ERTC:valid_range = 0.f, 1000000.f ;
ERTC:FillValue = -127b ;
ERTC:scale_factor = 1.f ;
ERTC:add_offset = 0.f ;
ERTC:units = "1" ;
ERTC:coordinates = "LONGITUDE LATITUDE" ;
float XDST(HEAD, RANG) ;
XDST:long_name = "Eastward Distance From Instrument" ;
XDST:valid_range = 0.f, 1000.f ;
XDST:FillValue = 9.96921e+36f ;
XDST:scale_factor = 1.f ;
XDST:add_offset = 0.f ;
XDST:units = "km" ;
XDST:coordinates = "LONGITUDE LATITUDE" ;
float YDST(HEAD, RANG) ;
YDST:long_name = "Northward Distance From Instrument" ;
YDST:valid_range = 0.f, 1000.f ;
YDST:FillValue = 9.96921e+36f ;
YDST:scale_factor = 1.f ;
YDST:add_offset = 0.f ;
YDST:units = "km" ;
YDST:coordinates = "LONGITUDE LATITUDE" ;
byte SPRC(TIME, DEPH, HEAD, RANG) ;
SPRC:long_name = "Radial Sea Water Velocity Cross Spectral Range Cell" ;
```





```
SPRC:valid_range = -1000.f, 1000.f ;
SPRC:FillValue = -127b ;
SPRC:scale_factor = 1.f ;
SPRC:add_offset = 0.f ;
SPRC:units = "1" ;
SPRC:coordinates = "LONGITUDE LATITUDE" ;
float SLAT(NSIT) ;
  SLAT:long_name = "Contributing radar site latitudes" ;
  SLAT:valid_range = -180.f, 180.f ;
  SLAT:FillValue = 9.96921e+36f ;
  SLAT:scale_factor = 1.f ;
  SLAT:add_offset = 0.f ;
  SLAT:units = "degrees_north" ;
float SLON(NSIT) ;
  SLON:long_name = "Contributing radar site longitudes" ;
  SLON:valid_range = -90.f, 90.f ;
  SLON:FillValue = 9.96921e+36f ;
  SLON:scale_factor = 1.f ;
  SLON:add_offset = 0.f ;
  SLON:units = "degrees_east" ;
char SCOD(NSIT, SMXL) ;
  SCOD:long_name = "Contributing radar site codes" ;
  SCOD:comment = "RDLM: Ideal Antenna Pattern is applied to the radial data. RDLM:
Measured Antenna Pattern is applied to the radial data." ;

// global attributes:
  :site_code = "MED" ;
  :platform_code = "" ;
  :data_mode = "R" ;
  :title = "Near Real Time Surface Ocean Radial Velocity" ;
  :summary = "The dataset consists of maps of radial velocity of the surface current
in the North-Western Tyrrhenian Sea and Ligurian Sea averaged over a time interval of 1 hour
around the cardinal hour. HF-RADAR measurements of ocean velocity are radial in direction
relative to the radar location and representative of the upper 0.3 - 2.5 meters of the ocean. " ;
  :naming_authority = "it.cnr.ismar" ;
  :id = "TINO_RDLM_2016-10-17_00Z" ;
  :source = "coastal structure" ;
  :institution = "CNR-ISMAR: National Research Council - Institute of Marine
Sciences, U.O.S. La Spezia" ;
  :project = "RITMARE and Jerico-Next" ;
  :network = "HF-Radar Ocean Surface Observation" ;
  :keywords_vocabulary = "GCMD Science Keywords" ;
  :keywords = "OCEAN CURRENTS, SURFACE WATER, RADAR, SCR-HF" ;
  :comment = "HF-RADAR measurements of ocean velocity are radial in direction
relative to the radar location and representative of the upper 0.3 - 2.5 meters of the ocean." ;
  :area = "Mediterranean Sea" ;
```




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```
:geospatial_lat_min = "43.6239" ;
:geospatial_lat_max = "44.4288" ;
:geospatial_lat_units = "degrees_north" ;
:geospatial_lon_min = "9.2895" ;
:geospatial_lon_max = "10.409" ;
:geospatial_lon_units = "degrees_east" ;
:geospatial_vertical_max = "0" ;
:geospatial_vertical_min = "1" ;
:geospatial_vertical_positive = "down" ;
:geospatial_vertical_units = "m" ;
:geospatial_vertical_resolution = "1" ;
:time_coverage_start = "2016-10-16T23:30:00Z" ;
:time_coverage_end = "2016-10-17T00:30:00Z" ;
:time_coverage_duration = "PT1H" ;
:time_coverage_resolution = "PT1H" ;
:cdm_data_type = "Grid" ;
:format_version = "v1.0" ;
:Conventions = "CF-1.6, Unidata, OceanSITES, ACDD, INSPIRE" ;
:netcdf_version = "4.1.3" ;
:netcdf_format = "netcdf4_classic" ;
:metadata_convention = "Unidata Dataset Discovery v1.0 compliant. NOAA
GNOME format compliant." ;
:publisher_name = "Lorenzo Corgnati" ;
:publisher_url = "http://radarhf.ismar.cnr.it" ;
:publisher_email = "lorenzo.corgnati@sp.ismar.cnr.it" ;
:update_interval = "void" ;
:license = "HF radar sea surface current velocity dataset by CNR-ISMAR is licensed
under a Creative Commons Attribution 4.0 International License. You should have received a
copy of the license along with this work. If not, see http://creativecommons.org/licenses/by/4.0/."
;
:citation = "Data collected and processed by CNR-ISMAR within RITMARE and
Jerico-Next projects - Year 2016" ;
:acknowledgment = "ISMAR HF Radar Network has been established within
RITMARE and Jerico-Next projects. The network has been designed, implemented and
managed through the efforts of ISMAR UOS La Spezia." ;
:date_created = "2016-11-11T15:37:02Z" ;
:date_modified = "2016-11-11T15:37:02Z" ;
:history = "2016-10-17T00:00:00Z data collected. 2016-11-11T15:37:02Z netCDF
file created and sent to TAC" ;
:processing_level = "2A" ;
:contributor_name = "Vega Forneris, Cristina Tronconi" ;
:contributor_role = "THREDDS expert, metadata expert" ;
:data_language = "eng" ;
:data_character_set = "utf8" ;
:topic_category = "oceans" ;
:reference_system = "EPSG:4806" ;
```



JERICO-NEXT

```
:metadata_language = "eng" ;
:metadata_character_set = "utf8" ;
:metadata_contact = "lorenzo.corgnati@sp.ismar.cnr.it" ;
:metadata_date_stamp = "2016-11-11T15:37:02Z" ;
:abstract = "The dataset consists of maps of radial velocity of the surface current in
the North-Western Tyrrhenian Sea and Ligurian Sea averaged over a time interval of 1 hour
around the cardinal hour. " ;
:standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata
Convention Standard Name Table Version 1.6" ;
:creator_name = "Lorenzo Corgnati" ;
:creator_email = "lorenzo.corgnati@sp.ismar.cnr.it" ;
:creator_url = "http://www.ismar.cnr.it/" ;
:platform = "CNR-ISMAR HF Radar Network" ;
:sensor = "CODAR SeaSonde" ;
:operational_manager = "Carlo Mantovani" ;
:operational_manager_email = "carlo.mantovani@cnr.it" ;
:date_issued = "2016-11-11T15:37:02Z" ;
:quality_control = "Level-A: manufacturer QC" ;
:geospatial_lat_resolution = "" ;
:geospatial_lon_resolution = "" ;
:references = "HFR_Progs Matlab Documentation - Copyright (C) 2006-7 David M.
Kaplan; Otero,M. (2013). ENCODING NETCDF RADIAL DATA IN THE HF-RADAR
NETWORK. http://cordc.ucsd.edu/projects/mapping/documents/HFRNet\_Radial\_NetCDF.pdf
";
:CTF = "1.00" ;
:FileType = "LLUV rdls RadialMap" ;
:LLUVSpec = "1.18 2012 05 07" ;
:UUID = "F2623688-A3F6-441A-B79D-74A9361A3274" ;
:manufacturer = "CODAR Ocean Sensors. SeaSonde" ;
:Site = "TINO " ;
:TimeZone = "UTC +0.000 0 GMT" ;
:TimeCoverage = "75.000 Minutes" ;
:Origin = " 44.0263667  9.8492167" ;
:GreatCircle = "WGS84 6378137.000 298.257223562997" ;
:GeodVersion = "CGEO 1.57 2009 03 10" ;
:LLUVTrustData = "all " ;
:RangeStart = "2" ;
:RangeEnd = "35" ;
:RangeResolutionKMeters = "0.994500" ;
:AntennaBearing = "282.0 True" ;
:ReferenceBearing = "0 True" ;
:AngularResolution = "5 Deg" ;
:SpatialResolution = "5 Deg" ;
:PatternType = "Measured" ;
:PatternDate = "2016 09 07 12 11 11" ;
:PatternResolution = "1.0 deg" ;
```



JERICO-NEXT

```
:TransmitCenterFreqMHz = "26.275000" ;
:DopplerResolutionHzPerBin = "0.001953125" ;
:FirstOrderMethod = "0" ;
:BraggSmoothingPoints = "2" ;
:CurrentVelocityLimit = "180.0" ;
:BraggHasSecondOrder = "1" ;
:RadialBraggPeakDropOff = "100.000" ;
:RadialBraggPeakNull = "63.100" ;
:RadialBraggNoiseThreshold = "4.000" ;
:PatternAmplitudeCorrections = "3.5051 5.8781" ;
:PatternPhaseCorrections = "38.40 37.50" ;
:PatternAmplitudeCalculations = "4.4170 2.2084" ;
:PatternPhaseCalculations = "127.10 61.30" ;
:RadialMusicParameters = "40.000 20.000 2.000" ;
:MergedCount = "7" ;
:RadialMinimumMergePoints = "2" ;
:FirstOrderCalc = "1" ;
:MergeMethod = "1 MedianVectors" ;
:PatternMethod = "1 PatternVectors" ;
:TransmitSweepRateHz = "2.000000" ;
:TransmitBandwidthKHz = "-150.727203" ;
:SpectraRangeCells = "63" ;
:SpectraDopplerCells = "1024" ;
:TableType = "LLUV RDL9" ;
:TableColumns = "18" ;
:TableColumnTypes = "LOND LATD VELU VELV VFLG ESPC ETMP MAXV MINV
ERSC ERTC XDST YDST RNGE BEAR VELO HEAD SPRC " ;
:TableRows = "1657" ;
```





E. Total velocity data file header example

```
netcdf TOTL_2016_10_17_0000 {
dimensions:
  TIME = UNLIMITED ; // (1 currently)
  LATITUDE = 78 ;
  LONGITUDE = 106 ;
  DEPH = 1 ;
  NSIT = 2 ;
  SMXL = 9 ;
  NLMK = 1 ;
  NPRP = 11 ;
variables:
  int TIME(TIME) ;
      TIME:long_name = "Time of Measurement UTC" ;
      TIME:standard_name = "time" ;
      TIME:units = "seconds since 1970-01-01T00:00:00Z" ;
      TIME:calendar = "Gregorian" ;
      TIME:axis = "T" ;
  float LATITUDE(LATITUDE) ;
      LATITUDE:long_name = "Latitude" ;
      LATITUDE:standard_name = "latitude" ;
      LATITUDE:units = "degrees_north" ;
      LATITUDE:axis = "Y" ;
  float LONGITUDE(LONGITUDE) ;
      LONGITUDE:long_name = "Longitude" ;
      LONGITUDE:standard_name = "longitude" ;
      LONGITUDE:units = "degrees_east" ;
      LONGITUDE:axis = "X" ;
  float DEPH(DEPH) ;
      DEPH:long_name = "Depth of measurement" ;
      DEPH:standard_name = "depth" ;
      DEPH:units = "m" ;
      DEPH:axis = "Z" ;
      DEPH:positive = "down" ;
      DEPH:reference = "sea_level" ;
  double EWCT(TIME, DEPH, LATITUDE, LONGITUDE) ;
      EWCT:_FillValue = 9.96920996838687e+36 ;
      EWCT:long_name = "Surface Eastward Sea Water Velocity" ;
      EWCT:standard_name = "surface_eastward_sea_water_velocity" ;
      EWCT:units = "m s-1" ;
      EWCT:scale_factor = 1. ;
      EWCT:add_offset = 0. ;
      EWCT:ioos_category = "Currents" ;
      EWCT:coordsys = "geographic" ;
      EWCT:valid_range = -3000., 3000. ;
```



JERICO-NEXT

```
double NSCT(TIME, DEPH, LATITUDE, LONGITUDE) ;
    NSCT:_FillValue = 9.96920996838687e+36 ;
    NSCT:long_name = "Surface Northward Sea Water Velocity" ;
    NSCT:standard_name = "surface_northward_sea_water_velocity" ;
    NSCT:units = "m s-1" ;
    NSCT:scale_factor = 1. ;
    NSCT:add_offset = 0. ;
    NSCT:ioos_category = "Currents" ;
    NSCT:coordsys = "geographic" ;
    NSCT:valid_range = -3000., 3000. ;
double EWCS(TIME, DEPH, LATITUDE, LONGITUDE) ;
    EWCS:_FillValue = 9.96920996838687e+36 ;
    EWCS:long_name = "Standard Deviation of Surface Eastward Sea Water Velocity"
;
    EWCS:units = "m s-1" ;
    EWCS:valid_range = -3000., 3000. ;
    EWCS:scale_factor = 1. ;
    EWCS:add_offset = 0. ;
double NSCS(TIME, DEPH, LATITUDE, LONGITUDE) ;
    NSCS:_FillValue = 9.96920996838687e+36 ;
    NSCS:long_name = "Standard Deviation of Surface Northward Sea Water Velocity"
;
    NSCS:units = "m s-1" ;
    NSCS:valid_range = -3000., 3000. ;
    NSCS:scale_factor = 1. ;
    NSCS:add_offset = 0. ;
double CCOV(TIME, DEPH, LATITUDE, LONGITUDE) ;
    CCOV:_FillValue = 9.96920996838687e+36 ;
    CCOV:long_name = "Covariance of Surface Sea Water Velocity" ;
    CCOV:units = "m2 s-2" ;
    CCOV:valid_range = -3000., 3000. ;
    CCOV:scale_factor = 1. ;
    CCOV:add_offset = 0. ;
double GDOP(TIME, DEPH, LATITUDE, LONGITUDE) ;
    GDOP:_FillValue = 9.96920996838687e+36 ;
    GDOP:long_name = "Geometrical Dilution of precision" ;
    GDOP:units = "1" ;
    GDOP:valid_range = -100., 100. ;
    GDOP:scale_factor = 1. ;
    GDOP:add_offset = 0. ;
    GDOP:comment = "The Geometric Dilution of Precision (GDOP) is the coefficient of
the uncertainty, which relates the uncertainties in radial and velocity vectors. The GDOP is a
unit-less coefficient, which characterizes the effect that radar station geometry has on the
measurement and position determination errors. A low GDOP corresponds to an optimal
geometric configuration of radar stations, and results in accurate surface current data.
Essentially, GDOP is a quantitative way to relate the radial and velocity vector uncertainties.
```





JERICO-NEXT

Setting a threshold on GDOP for total combination avoids the combination of radials with an intersection angle below a certain value. GDOP is a useful metric for filtering errant velocities due to poor geometry." ;

```
short QCflag(TIME, DEPH, LATITUDE, LONGITUDE) ;
    QCflag:_FillValue = -32767s ;
    QCflag:long_name = "Overall Quality Flags" ;
    QCflag:units = "1" ;
    QCflag:valid_range = 0s, 9s ;
    QCflag:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
    QCflag:flag_meanings = "unknown good_data probably_good_data
potentially_correctable_bad_data bad_data nominal_value interpolated_value
missing_value" ;
    QCflag:comment = "OceanSITES quality flagging for all QC tests" ;
    QCflag:scale_factor = 1s ;
    QCflag:add_offset = 0s ;
short VAR_QC(TIME, DEPH, LATITUDE, LONGITUDE) ;
    VAR_QC:_FillValue = -32767s ;
    VAR_QC:long_name = "Variance Threshold Quality flags" ;
    VAR_QC:units = "1" ;
    VAR_QC:valid_range = 0s, 9s ;
    VAR_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
    VAR_QC:flag_meanings = "unknown good_data probably_good_data
potentially_correctable_bad_data bad_data nominal_value interpolated_value
missing_value" ;
    VAR_QC:comment = "OceanSITES quality flagging for variance threshold QC test.
Threshold set to m2/s2" ;
    VAR_QC:scale_factor = 1s ;
    VAR_QC:add_offset = 0s ;
short GDOP_QC(TIME, DEPH, LATITUDE, LONGITUDE) ;
    GDOP_QC:_FillValue = -32767s ;
    GDOP_QC:long_name = "GDOP Threshold Quality flags" ;
    GDOP_QC:units = "1" ;
    GDOP_QC:valid_range = 0s, 9s ;
    GDOP_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
    GDOP_QC:flag_meanings = "unknown good_data probably_good_data
potentially_correctable_bad_data bad_data nominal_value interpolated_value
missing_value" ;
    GDOP_QC:comment = "OceanSITES quality flagging for GDOP threshold QC test.
Threshold set to \002." ;
    GDOP_QC:scale_factor = 1s ;
    GDOP_QC:add_offset = 0s ;
short Density_QC(TIME, DEPH, LATITUDE, LONGITUDE) ;
    Density_QC:_FillValue = -32767s ;
    Density_QC:long_name = "Data density Threshold Quality flags" ;
    Density_QC:units = "1" ;
    Density_QC:valid_range = 0s, 9s ;
```



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```
Density_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
Density_QC:flag_meanings = "unknown good_data probably_good_data
potentially_correctable_bad_data bad_data nominal_value interpolated_value
missing_value" ;
Density_QC:comment = "OceanSITES quality flagging for Data density threshold
QC test. Threshold set to contributing radials." ;
Density_QC:scale_factor = 1s ;
Density_QC:add_offset = 0s ;
short Balance_QC(TIME, DEPH, LATITUDE, LONGITUDE) ;
Balance_QC:_FillValue = -32767s ;
Balance_QC:long_name = "Balance of number of radials from each contributing site
Quality flags" ;
Balance_QC:units = "1" ;
Balance_QC:valid_range = 0s, 9s ;
Balance_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
Balance_QC:flag_meanings = "unknown good_data probably_good_data
potentially_correctable_bad_data bad_data nominal_value interpolated_value
missing_value" ;
Balance_QC:comment = "OceanSITES quality flagging for Balance of number of
radials from each contributing site QC test. Balance threshold set to ." ;
Balance_QC:scale_factor = 1s ;
Balance_QC:add_offset = 0s ;
short CSPD_QC(TIME, DEPH, LATITUDE, LONGITUDE) ;
CSPD_QC:_FillValue = -32767s ;
CSPD_QC:long_name = "Velocity threshold Quality flags" ;
CSPD_QC:units = "1" ;
CSPD_QC:valid_range = 0s, 9s ;
CSPD_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
CSPD_QC:flag_meanings = "unknown good_data probably_good_data
potentially_correctable_bad_data bad_data nominal_value interpolated_value
missing_value" ;
CSPD_QC:comment = "OceanSITES quality flagging for Velocity threshold QC test.
Threshold set to m/s." ;
CSPD_QC:scale_factor = 1s ;
CSPD_QC:add_offset = 0s ;
float SLAT(NSIT) ;
SLAT:long_name = "Contributing radar site latitudes" ;
SLAT:standard_name = "latitude" ;
SLAT:units = "degrees_north" ;
float SLON(NSIT) ;
SLON:long_name = "Contributing radar site longitudes" ;
SLON:standard_name = "longitude" ;
SLON:units = "degrees_east" ;
char SCOD(NSIT, SMXL) ;
SCOD:long_name = "Contributing radar site codes" ;
```



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SCOD:comment = "RDLI: Ideal Antenna Pattern is applied to the radial data. RDLM:
Measured Antenna Pattern is applied to the radial data." ;
byte LMSK(NLMK) ;
    LMSK:long_name = "Flag for masking dry grid points" ;
    LMSK:units = "1" ;
    LMSK:comment = "Flag = 0: masking inactive Flag = 1: masking active" ;
double PRPC(NPRP) ;
    PRPC:long_name = "Near Real Time data processing parameters" ;
    PRPC:units = "1" ;
    PRPC:comment = "01) Maximum GDOP threshold 02) Maximum velocity threshold
[m/s] 03) Minimum number of sites required 04) Minimum number of radials required 05)
Maximum angular gap to interpolate radials [degrees_true] (0 = no interpolation) 06) Spatial
search radius for radial solutions [km] 07) Minimum latitude for total combination
[degrees_north] 08) Maximum latitude for total combination [degrees_north] 09) Minimum
longitude for total combination [degrees_east] 10) Maximum longitude for total combination
[degrees_east] 11) Spatial Resolution [km]" ;

// global attributes:
    :site_code = "MED" ;
    :platform_code = "" ;
    :data_mode = "R" ;
    :title = "Near Real Time Surface Ocean Velocity" ;
    :summary = "The data set consists of maps of total velocity of the surface current in
the North-Western Tyrrhenian Sea and Ligurian Sea averaged over a time interval of 1 hour
around the cardinal hour. Surface ocean velocities estimated by HF Radar are representative
of the upper 0.3-2.5 meters of the ocean. The main objective of near real time processing is
to produce the best product from available data at the time of processing. Total velocities are
derived using least square fit that maps radial velocities measured from individual sites onto
a cartesian grid. The final product is a map of the horizontal components of the ocean currents
on a regular grid in the area of overlap of two or more radar stations." ;
    :naming_authority = "it.cnr.ismar" ;
    :id = "GoM_2016-10-17_00Z" ;
    :source = "coastal structure" ;
    :institution = "National Research Council - Institute of Marine Science, U.O.S. La
Spezia" ;
    :project = "RITMARE and Jerico-Next" ;
    :network = "HF Radar Surface Observation" ;
    :keywords_vocabulary = "GCMD Science Keywords" ;
    :keywords = "OCEAN CURRENTS, SURFACE WATER, RADAR, SCR-HF" ;
    :comment = "Total velocities are derived using least square fit that maps radial
velocities measured from individual sites onto a cartesian grid. The final product is a map of
the horizontal components of the ocean currents on a regular grid in the area of overlap of
two or more radar stations." ;
    :area = "Mediterranean Sea" ;
    :geospatial_lat_min = "43.5" ;
    :geospatial_lat_max = "44.2" ;
```




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:geospatial_lat_units = "degrees_north" ;
:geospatial_lon_min = "9" ;
:geospatial_lon_max = "10.5" ;
:geospatial_lon_units = "degrees_east" ;
:geospatial_vertical_max = "0" ;
:geospatial_vertical_min = "1" ;
:geospatial_vertical_positive = "down" ;
:geospatial_vertical_units = "m" ;
:geospatial_vertical_resolution = "1" ;
:time_coverage_start = "2016-10-16T23:30:00Z" ;
:time_coverage_end = "2016-10-17T00:30:00Z" ;
:time_coverage_duration = "PT1H" ;
:time_coverage_resolution = "PT1H" ;
:cdm_data_type = "Grid" ;
:format_version = "v1.0" ;
:Conventions = "CF-1.6, Unidata, OceanSITES, ACDD, INSPIRE" ;
:netcdf_version = "4.1.3" ;
:netcdf_format = "netcdf4_classic" ;
:metadata_convention = "Unidata Dataset Discovery v1.0 compliant. NOAA
GNOME format compliant." ;
:publisher_name = "Lorenzo Corgnati" ;
:publisher_url = "http://radarhf.ismar.cnr.it" ;
:publisher_email = "lorenzo.corgnati@sp.ismar.cnr.it" ;
:update_interval = "void" ;
:license = "HF radar sea surface current velocity dataset by CNR-ISMAR is licensed
under a Creative Commons Attribution 4.0 International License. You should have received a
copy of the license along with this work. If not, see
http://creativecommons.org/licenses/by/4.0/." ;
:citation = "Data collected and processed by CNR-ISMAR within RITMARE and
Jerico-Next projects - Year 2016" ;
:acknowledgment = "ISMAR HF Radar Network has been established within
RITMARE and Jerico-Next projects. The network has been designed, implemented and
managed through the efforts of ISMAR UOS La Spezia." ;
:date_created = "2016-11-11T15:35:32Z" ;
:date_modified = "2016-11-11T15:35:32Z" ;
:history = "2016-10-17T00:00:00Z data collected. 2016-11-11T15:35:32Z netCDF
file created and sent to TAC" ;
:processing_level = "3B" ;
:contributor_name = "Vega Forneris, Cristina Tronconi" ;
:contributor_role = "THREDDS expert, metadata expert" ;
:data_language = "eng" ;
:data_character_set = "utf8" ;
:topic_category = "oceans" ;
:reference_system = "EPSG:4806" ;
:metadata_language = "eng" ;
:metadata_character_set = "utf8" ;
```



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```
:metadata_contact = "lorenzo.corgnati@sp.ismar.cnr.it" ;
:metadata_date_stamp = "2016-11-11T15:35:32Z" ;
:abstract = "The data set consists of maps of total velocity of the surface current in the North-Western Tyrrhenian Sea and Ligurian Sea averaged over a time interval of 1 hour around the cardinal hour. Surface ocean velocities estimated by HF Radar are representative of the upper 0.3-2.5 meters of the ocean. Total velocities are derived using least square fit that maps radial velocities measured from individual sites onto a cartesian grid. The final product is a map of the horizontal components of the ocean currents on a regular grid in the area of overlap of two or more radar stations." ;
:standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table Version 1.6" ;
:creator_name = "Lorenzo Corgnati" ;
:creator_url = "http://radarhf.ismar.cnr.it" ;
:creator_email = "lorenzo.corgnati@sp.ismar.cnr.it" ;
:platform = "CNR-ISMAR HF Radar Network" ;
:sensor = "CODAR SeaSonde" ;
:grid_resolution = "1.5 Km" ;
:grid_mapping = "Transverse Mercator" ;
:institution_reference = "http://www.ismar.cnr.it" ;
:operational_manager = "Carlo Mantovani" ;
:operational_manager_email = "carlo.mantovani@cnr.it" ;
:regional_description = "North-Western Tyrrhenian Sea and Ligurian Sea, Italy" ;
:date_issued = "2016-11-11T15:35:32Z" ;
:software_name = "HFR_Combiner_TirLig" ;
:software_version = "v2.1" ;
:quality_control = "Level-B: Velocity Threshold + GDOP Threshold" ;
:file_quality_index = 0 ;
:interpolation = "" ;
:geospatial_lat_resolution = 0.00909090909090793 ;
:geospatial_lon_resolution = 0.0126050420168067 ;
:references = "HFR_Progs Matlab Documentation - Copyright (C) 2006-7 David M. Kaplan; Otero,M. (2008).NETCDF DESCRIPTION FOR NEAR REAL-TIME SURFACE CURRENTS PRODUCED BY THE HF-RADAR NETWORK. https://cordc.ucsd.edu/projects/mapping/documents/HFRNet_RTV-NetCDF.pdf" ;
```

