Joint European Research Infrastructure network for Coastal Observatory - Novel European eXpertise for coastal observaTories - **JERICO-NEXT**

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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.

HFR technology is rapidly expanding in Europe, as it is increasingly used to support decision-making by coastal ocean users and managers, and its current and wave data will be operationally distributed by the main data distribution services, i.e. Copernicus Marine Environment Monitoring Service In Situ Thematic Assembly Center (CMEMS-INSTAC) and SeaDataCloud (SDC). Moreover, in the next years it is expected that HFR surface current data will be systematically ingested in data assimilation processes necessary for predictive model adjustment. Thus, the unified implementation and coordination are needed for producing interoperable and high quality HFR data for scientific and societal applications.

Task 5.6 of JERICO-Next project deals specifically with defining common formats and Quality Control (QC) procedures for HFR data. A common data and metadata model and QC test battery for Near Real Time (NRT) current data from HFR were defined and implemented to ensure efficient and automated data discovery and interoperability across distributed and heterogeneous earth science data systems.

A first recommendation at European level to achieve the harmonization of HFR data management was published within JERICO-Next deliverable D5.13 and in the INCREASE deliverable D3.1 (http://www.cmems-increase.eu/static/INCREASE_Report_D3.1.pdf), defining data format, metadata structure, QC flagging scheme and QC tests.

The data model and the basic set of QC tests defined in JERICO-Next D5.13 and recovered in CMEMS Service Evolution INCREASE project (deliverable D3.1) have been further analyzed and improved, also in synergy with the work performed in Task 3.2. The work has been performed within an extended group including scientists from the HF radar European community as well as from the US IOOS and the Australian ACORN networks. Additional QC tests with respect to the basic set have been defined and the data model has been refined accordingly, also aiming at the full integration of CMEMS-INSTAC and SDC requirements.

This deliverable presents these improved 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 DATAMEQ, 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 that allows the 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 Wahsburn, 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 for HFR data implementation in European marine data infrastructures; (ii) a standard QC procedure established for the evaluation of delayed-mode and near real time HFR data.

The work in Task 5.6 was performed 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 (SE[1] 2016 call) project, which aims to the integration of existing European HFR operational systems into the CMEMS-INSTAC service and to the promotion of the use of HFR data for improving CMEMS numerical modelling systems.

First recommendations on common HFR data model and QC procedures have been previously summarized in the JERICO-Next deliverable D5.13, which defines the European Common data and metadata model, detailing data format and mandatory QC tests. Also, in the framework of the INCREASE project, deliverable D3.1 reports a sensitivity study on the impact of threshold values for the mandatory QC tests defined within JERICO- Next, with the aim of setting a methodology for the correct application of the tests in different regions.

[1] CMEMS- Service Evolution 21-SE-CALL1

In order to further refine and improve the standard schemes taking into account new specific issues and the precious experience of the HF radar operators, the HF radar community has kept alive the discussions about these topics in the framework of the JERICO-Next project and of the different ongoing initiatives and projects at European level aiming at being effective in the implementation of the coordinated development of coastal High Frequency Radar technology and its products, with the final goal of establishing the operational HFR European network.

All the discussions and activities have been carried on in strict collaboration with the US colleagues managing the US Integrated Ocean Observing System (IOOS) through the Radiowave Operators Working Group (US ROWG). Also, other important external contributions have been given by other networks, such as the Australian ACORN network. The deliverables D5.13 and INCREASE D3.1 have been shared with this wide international community and a fruitful review about the comparison and analysis of HF radar data and metadata schemes has taken place. Based on the results of this discussion, a set of modifications and improvements have been implemented on the mandatory QC procedures and on the common data model, and they are presented in this document. The core points of the discussions that led to the current improvements are detailed in the JERICO-Next deliverable D3.3.

The first part of this document (Section 3) 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. The QC procedures to be applied to HFR data for the delivery of high quality data are detailed in Section 4, while recommendations on the European Common data and metadata model for real-time HFR data are provided in Section 5. Section 6 is focused on the aggregation strategy defined for the distribution of interoperable historical datasets. Finally, conclusions and next steps to implement the HFR data management are presented in the last sections.

3. JERICO-Next networking and international framework

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, in strict collaboration with the different European and international initiatives that are also contributing to this effort: EuroGOOS Ocean Observing HFR Task Team and GEO GLOBAL HFR Task, the INCREASE (CMEMS SE 2016 call) and SeaDataCloud projects and the CMEMS-INSTAC distribution service, that will operationally distribute HFR current NRT data starting from April 2019.

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 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 contributes the Global Ocean System as one GOOS Regional Alliance (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.

In order to enforce and support the operational ingestion of HFR data into CMEMS-INSTAC and SDC distribution services, the HFR Task Team is in the process of setting up the central European HFR node. The node is intended (i) to set up a Global Data Assembly Centre (GDAC) dedicated to link all the available data providers and collect and process HFR data; (ii) to develop and upgrade the software tools for the harmonization of data and metadata of HFR data coming from different sources; (iii) to apply data processing, both in real time and delayed mode, and create catalogues of HFR data compliant with the requirements of CMEMS-INSTAC and SDC.

Its implementation will be based on a hierarchical infrastructure to facilitate management and integration of any potential data provider according to a simple and very effective rule: if the data provider can set up the data flow according the defined standards, the HFR central node only has to link and include the new catalogue and data stream. If the data provider cannot setup the data flow (because of lack of experience, technical capacity, etc.), the HFR node will work on harvesting the data from the provider, harmonize and format these data and make them available.

All the software tools needed for the collection, QC and processing of HFR data according to the European QC model and the European data and metadata model presented in this document are freely available (and continuously maintained and updated) at https://github.com/LorenzoCorgnati/HFR_Node_tools

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 begun the developments necessary for the integration of existing European HFR operational systems into the CMEMS and promoted the use of HFR data for improving CMEMS numerical modelling systems.

The INCREASE project provided (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. In particular, the main project outcomes are: (i) the definition of basic data products, data formats and QA/QC; (ii) the definition of advanced products and applications and (iii) the technical implementation and strategic development toward the operational ingestion of HFR data into CMEMS-INSTAC services.

The activities performed during the project 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).

Based on the results of the INCREASE project, CMEMS-INSTAC will operationally ingest and distribute HFR NRT current data starting from April 2019.

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.

Specific focus is also given to the definition of a data model for gridded data within the SDC transport formats. In this framework, tasks have been carried on to define a data model that fully integrates SDC CF extension requirements and CMEMS-INSTAC requirements, in order to have a unique standard for both HFR NRT and historical data.

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 more than 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. The European common QC model for real-time HFR data

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 1 (for radial velocity data) and in Table 2 (for total velocity data).

These 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 with the same dimensions of the data variable, containing, for each cell, the flag related to the vector lying in that cell, 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.

For some of these tests, HFR operators will need to select the best thresholds. Since a successful QC effort is highly dependent upon selection of the proper thresholds, this choice is not straightforward, and may require trial and error before final selections are made. These thresholds should not be determined arbitrarily, but based on historical knowledge or statistics derived from historical data.

Table 1 – Mandatory QC tests for radial velocity data

QC test	**Meaning**	**QC variable type**
Syntax	This test will ensure the proper formatting and the existence of all the necessary fields within the radial netCDF file. This test is performed on the netCDF files and it assesses the presence and correctness of all data and attribute fields and the correct syntax throughout the file.	N/A, it is a test on the netCDF file structure, not on data content.
Over-water	This test labels radial vectors that lie on land with a "bad data" flag and radial vectors that lie on water with a "good data" flag.	gridded
Velocity Threshold	This test labels radial velocity vectors whose module is bigger than a maximum velocity threshold with a "bad data" flag and radial vectors whose module is smaller than the threshold with a "good data" flag.	gridded
Variance Threshold	This test labels radial vectors whose temporal variance is bigger than a maximum threshold with a "bad data" flag and radial vectors whose temporal variance is	gridded

	smaller than the threshold with a “good data” flag. This test is applicable only to Beam Forming (BF) systems. Data files from Direction Finding (DF) systems will apply instead the “Temporal Derivative” test reporting the explanation “Test not applicable to Direction Finding systems. The Temporal Derivative test is applied.” in the comment attribute.	
Temporal Derivative	For each radial bin, the current hour velocity vector is compared with the previous and next ones. If the differences are bigger than a threshold (specific for each radial bin and evaluated on the basis of the analysis of one-year-long time series), the present vector is flagged as bad_data, otherwise it is labelled with a good_data flag. Since this method implies a one-hour delay in the data provision, the current hour file should have the related QC flag set to 0 (no QC performed) until it is updated to the proper values when the next hour file is generated.	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 vector is labelled with a “bad_data” flag, otherwise it is labelled with a “good_data” flag.	gridded
Average Radial Bearing	This test labels the entire datafile with a ‘good_data” flag if the average radial bearing of all the vectors contained in the data file lies within a specified margin around the expected value of normal operation. Otherwise, the data file is labelled with a “bad_data” flag. The value of normal operation has to be defined within a time interval when the proper functioning of the device is assessed. The margin has to be set according site-specific properties. This test is applicable only to DF systems. Data files from BF systems will have this variable filled with “good_data” flags (1) and the explanation “Test not applicable to Beam Forming systems” in the comment attribute.	scalar
Radial Count	Test labelling radial data having a number of velocity vectors bigger than the threshold with a “good data” flag and radial data having a number of velocity vectors smaller than the threshold with a “bad data” flag.	scalar

Table 2 – Mandatory QC tests for total velocity data.

QC test	**Meaning**	**QC variable type**
Syntax	This test will ensure the proper formatting and the existence of all the necessary fields within the total netCDF file. This test is performed on the netCDF files and it assesses the presence and correctness of all data and attribute fields and the correct syntax throughout the file.	N/A, it is a test on the netCDF file structure, not on data content.
Data Density Threshold	This test labels total velocity vectors with a number of contributing radials bigger than the threshold with a "good data" flag and total velocity vectors with a number of contributing radials smaller than the threshold with a "bad data" flag.	gridded
Velocity Threshold	This test labels total velocity vectors whose module is bigger than a maximum velocity threshold with a "bad data" flag and total vectors whose module is smaller than the threshold with a "good data" flag.	gridded
Variance Threshold	This test labels total vectors whose temporal variance is bigger than a maximum threshold with a "bad data" flag and total vectors whose temporal variance is smaller than the threshold with a "good data" flag. This test is applicable only to Beam Forming (BF) systems. Data files from Direction Finding (DF) systems will apply instead the "Temporal Derivative" test reporting the explanation "Test not applicable to Direction Finding systems. The Temporal Derivative test is applied." in the comment attribute.	gridded
Temporal Derivative	For each grid cell, the current hour velocity vector is compared with the previous and next ones. If the differences are bigger than a threshold (specific for each grid cell and evaluated on the basis of the analysis of one-year-long time series), the present vector is flagged as bad_data, otherwise it is labelled with a good_data flag. Since this method implies a one-hour delay in the data provision, the current hour file should have the related QC flag set to 0 (no QC performed) until it is updated to the proper values when the next hour file is generated.	gridded
GDOP Threshold	This test labels total velocity vectors whose GDOP is bigger than a maximum threshold with a "bad data" flag and the vectors whose GDOP is smaller than the threshold with a "good data" flag.	gridded

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.

The European Common data and metadata model for real-time HFR data is intended to be **the unique model for HFR data distribution in Europe**, thus it integrates CMEMS and SeaDataCloud (SDC) requirements. Thus, it complies with **CF-1.6, OceanSITES, CMEMS IN-SITU TAC conventions** (Copernicus-InSituTAC-SRD-1.4, CopernicusInSituTAC-ParametersList-3.1.0) and to the **SDC CF extension** requirements.

The data model integrates the SDC requirements about the **SeaDataNet metadata services** (https://www.seadatanet.org/Metadata) for enforcing discovery and access of HFR data and in order to gain visibility and valorization for the projects and the institutions producing HFR data.

The HFR related metadata directories constituting the SeaDataNet metadata services are:

- European Directory of Marine Organisations (**EDMO**): it contains up-to-date addresses and activity profiles of research institutes, data holding centres, monitoring agencies, governmental and private organisations, that are in one way or another engaged in oceanographic and marine research activities, data and information management and/or data acquisition activities (https://www.seadatanet.org/Metadata/EDMO-Organisations).
- European Directory of the Initial Ocean-Observing Systems (**EDIOS**): it gives an overview of the ocean measuring and monitoring systems operated by European countries. This directory includes discovery information on location, measured parameters, data availability, responsible institutes and links to data-holding agencies plus some more technical information on instruments (https://www.seadatanet.org/Metadata/EDIOS-Observing-systems).
- Common Data Index (**CDI**): it gives users a highly detailed insight in the availability and geographical spreading of marine data sets and it provides a unique interface for requesting access, and if granted, for downloading data sets from the distributed data centres across Europe (https://www.seadatanet.org/Metadata/CDI-Common-Data-Index).

EDMO, EDIOS and CDI entries are xml files to be prepared using Mikado software (https://www.seadatanet.org/Software/MIKADO). Entries have to be mailed to sdn-userdesk@seadatanet.org for ingestion.

Each HFR data provider is asked to have EDMO, EDIOS and CDI entries (mandatory entries).

SDC is also managing the following catalogs:

- European Directory of Marine Environmental Research Projects (**EDMERP**): it covers marine research projects for a wide range of disciplines. Research projects are described as metadata factsheets with their most relevant aspects. The primary objective is to support users in identifying interesting research activities and in connecting them to involved research managers and organizations across Europe (https://www.seadatanet.org/Metadata/EDMERP-Projects).
- European Directory of Marine Environmental Datasets (**EDMED**): it is a comprehensive reference to the marine data sets and collections held within European research laboratories, so as to provide marine scientists, engineers and policy makers with a simple mechanism for their identification. It covers a wide range of disciplines (https://www.seadatanet.org/Metadata/EDMED-Datasets).

EDMERP and EDMED entries are xml files to be prepared using Mikado software (https://www.seadatanet.org/Software/MIKADO). entries have to be mailed to sdn-userdesk@seadatanet.org for ingestion.

HFR data providers are invited to provide EDMERP and EDMED entries.

It has to be noted that comprehensive metadata description is a prerequisite for the full implementation of EuroGOOS providing an inventory of the continuously available data for operational models. It is also necessary for creating and giving an overview of marine monitoring programmes relevant for the Marine Strategy Framework Directive (MSFD) implementation.

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 fulfil the requirements of CMEMS-INSTAC and SDC CF extension.

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 used. 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 5.2 to 5.7.

5.2. 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, OceanSITES** and **CMEMS IN-SITU TAC conventions** (Copernicus-InSituTAC-SRD-1.4, CopernicusInSituTAC-ParametersList-3.1.0). The global attributes required for the **SDC Common Data Index (CDI)** scheme and the **SDC CF extension** have been added as mandatory as well. In Table 3, Mandatory Attributes are listed in **bold type**.

The **Recommended Attributes** include attributes necessary **to comply with INSPIRE and Unidata Dataset Discovery conventions**. In Table 3, 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.

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 the GDAC/European HFR Node inventory software.

Table 3 – NetCDF global attributes.

Discovery and Identification		
Name	Example	Note
site_code	site_code="HFR_TirLig"	The site code identifies a defined area where observations are performed. Site codes have to be defined in a homogeneous way. The policy for HFR data is to define a site_code for the network, one code for each radar site as platform_code for the radial current data files and one platform_code for the total current data files.

		The site_code has to be set equal to the EDIOS Series id of the HFR network. The EDIOS codes are managed by the SeaDataNet project; they are available at http://seadatanet.maris2.nl/v_edios_v2/search.asp **It is mandatory to have the trigram 'HFR' in the EDIOS Series id** (if the EDIOS Series entry already exists, modifications of the id are possible writing to sdn-userdesk@seadatanet.org). If your observing system has no EDIOS codes, please write to sdn-userdesk@seadatanet.org to obtain them. **Mandatory**. (GDAC)
platform_code	platform_code="HFR_TirLig_Total" (for totals produced by the TirLig network) platform_code="HFR_TirLig_MONT" (for radials from MONT radar site: MONT radar site belongs to the TirLig network)	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 INSTAC. Platform codes have to be defined in a homogeneous way. The policy for HFR data is to define a site_code for the network, one code for each radar site as platform_code for the radial current data files and one platform_code for the total current data files. **The naming convention shall be:** ***platform_code=EDIOS-Series-id_Total*** **for total current data files and:** ***platform_code= EDIOS-Series-id_EDIOS-Platform-id*** **for radial current data files.** **The second part of platform_code has to be set equal to the EDIOS Program id of the HFR site.**

		The EDIOS codes are managed by the SeaDataNet project; they are available at http://seadatanet.maris2.nl/v_edios_v2/search.asp If your observing system has no EDIOS codes, please write to sdn-userdesk@seadatanet.org to obtain them. **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 Table 14. **Mandatory**. (GDAC)
DoA_estimation_method	DoA_estimation_method ="Direction Finding"	Specifies if the system is Direction Finding or Beam Forming. Possible values are "Direction Finding" and "Beam Forming". **Mandatory**. (GDAC)
calibration_type	calibration_type ="APM"	Specifies if calibration has been performed. Possible values are: "None", "Ideal", "APM", "full", "internal", "physical", "AEA". **Mandatory**. (GDAC)
last_calibration_date	last_calibration_date ="2016-02-04T11:25:37Z"	Reports the date of the last calibration. It must be specified as a string in the ISO8601 standard "YYYY-MM-DD-Thh:mm:ssZ". UTC must be used, and specified. **Mandatory**. (GDAC)
calibration_link	calibration_link ="carlo.mantovani@cnr.it"	Indicates the link to a contact person able to provide data about the calibration. **Mandatory**. (GDAC)
title	title="Near Real Time Surface Ocean Velocity by TirLig"	Free format text describing the dataset, for use by human readers. Use the file name if in doubt. **Mandatory**. (NUG)
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)
source	source="coastal structure"	The method of production of the original data. If it was model-generated, source should name the

		model and its version, as specifically as could be useful. If it is observational, source should characterize it (e.g., "surface observation" or "radiosonde"). The term "coastal structure" from the SeaVoX Platform Categories (L06) list must be used for HFR data. **Mandatory**. (CF)
source_platform_category_code	source_platform_category_code="17"	SeaDataNet vocabulary L06 (SeaVoX) reports platform categories, as a code and a label. For HFR data the code "17" must be used. **Mandatory**
institution	institution="National Research Council of Italy – Institute of Marine Science. S.S. Lerici"	Specifies institution where the original data was produced. **Mandatory**. (CF)
institution_edmo_code	institution_edmo_code="134"	The EDMO codes are managed by the SeaDataNet project; they are available at http://seadatanet.maris2.nl/edmo/ If your institution has no EDMO code, please write to sdn-userdesk@seadatanet.org to obtain one. **Mandatory.**
data_assembly_center	data_assembly_center="European HFR Node"	Institution in charge of the aggregation and distribution of data. **Mandatory**.
id	id="HFR_TirLig_Total_2017-01-01T00:00:00Z" (for totals produced by the TirLig network) id="HFR_TirLig_MONT_2017-01-01T00:00:00Z" (for radials from MONT radar site: MONT radar site belongs to the TirLig network)	The "id" attribute is intended to provide a globally unique identification for each dataset. **The id must contain the platform_code and the data time stamp specified as a string in the ISO8601 standard "YYYY-MM-DD-Thh:mm:ssZ".** **The naming convention must be:** **id=platform_code_ YYYY-MM-DD-Thh:mm:ssZ** **Mandatory (ACDD, GDAC)**
project	project="RITMARE and Jerico-Next" project="12058, 12227" (EDMERP codes for RITMARE and Jerico-Next projects)	The scientific project that produced the data. Each project must have its own EDMERP entry. The EDMERP codes are managed by the SeaDataNet project; they are

		available at http://seadatanet.maris2.nl/v_edmerp/search.asp If your projects have no EDMERP codes, please write to sdn-userdesk@seadatanet.org to obtain them. *Recommended* for compliance with SDC CDI scheme. (ACDD, GDAC).
naming_authority	naming_authority="it.cnr.ismar"	The organization that manages data set names. The **reverse-DNS naming is recommended** for the naming authority attribute. *Recommended* (ACDD)
keywords	keywords="OCEAN CURRENTS, SURFACE WATER, RADAR, SCR-HF"	Provide comma-separated list of terms that will aid in discovery of the dataset. *Recommended*. (ACDD)
keywords_vocabulary	keywords_vocabulary="GCMD Science Keywords"	Please use one of 'GCMD Science Keywords', 'SeaDataNet Parameter Discovery Vocabulary' or 'AGU Index Terms'. *Recommended*. (ACDD)
comment	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."	Miscellaneous information about the data or methods used to produce it. Any free format text is appropriate. *Recommended*. (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.
network	network="ISMAR_HFR_TirLig"	A grouping of sites based on common shore-based logistics or infrastructure.
Geo-spatial-temporal		
data_type	data_type="HF radar total data" (for total current data files) data_type="HF radar radial data" (for radial current data files)	Copernicus In Situ NetCDF files family of data. **Mandatory**. (ACDD, GDAC)

feature_type	feature_type="surface"	Description of the spatio-temporal shape of the data held in the netCDF using a vocabulary specified in CF 1.6. The value to be used for HFR data is "surface". **Mandatory** (for compliance with SDC CF extension).
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_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)
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)
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)

area	area="Mediterranean Sea"	Geographical coverage. Try to specify the European sea where the HFR is working. *Recommended*.
geospatial_lat_units	geospatial_lat_units="degrees_north"	Must conform to udunits. If not specified, then "degrees_north" is assumed **Mandatory**. (ACDD)
geospatial_lon_units	geospatial_lon_units="degrees_east"	Must conform to udunits. If not specified, then "degrees_east" is assumed **Mandatory**. (ACDD)
geospatial_vertical_resolution	geospatial_vertical_resolution="0.48"	Vertical resolution of the measurement. For HFR data it has to be set as the maximum integration depth of the radar system, according to operating frequency. *Recommended* for compliance with SDC CDI scheme. (ACDD, GDAC)
geospatial_vertical_units	geospatial_vertical_units="m"	Units of depth. If not specified, then "m" is assumed. *Recommended* for compliance with SDC CDI scheme. (ACDD, GDAC)
geospatial_vertical_positive	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. *Recommended* (ACDD)
time_coverage_resolution	time_coverage_resolution="PT1H"	Interval between records. ISO8601 standard must be used: PnYnMnDTnHnMnS. *Recommended* for compliance with SDC CDI scheme (GDAC)
time_coverage_duration	time_coverage_duration="PT1H"	Duration of the time coverage of the data. ISO8601 standard must be used: PnYnMnDTnHnMnS. *Recommended*. (ACDD)
reference_system	reference_system="EPSG:4806" (in case of WGS84)	ESPG coordinate reference system. *Recommended* for compliance with SDC CDI scheme (GDAC)
grid_resolution	grid_resolution="1.5 km"	Resolution of the grid for total velocity data. *Recommended* **only for totals**, for compliance with SDC CDI scheme (GDAC)
cdm_data_type	cdm_data_type="Grid"	The Unidata CDM (common data model) data type used by THREDDS. e.g. point, profile,

		section, station, station_profile, trajectory, grid, radial, swath, image; use Grid for gridded HFR data. *Recommended* (ACDD)
Conventions used		
format_version	format_version="v2.1"	Version of the data model release. **Mandatory**. (GDAC)
Conventions	Conventions="CF-1.6, OceanSITES-Manual-1.2, Copernicus-InSituTAC-SRD-1.4, CopernicusInSituTAC-ParametersList-3.1.0, Unidata, ACDD, INSPIRE"	Names of the conventions followed by the dataset. The attribute Conventions should be reported as follow: "CF-1.6, OceanSITES-Manual-1.2, Copernicus-InSituTAC-SRD-1.4, CopernicusInSituTAC-ParametersList-3.1.0, ". Additional conventions can be appended at the list. **Mandatory**. (NUG)
netcdf_version	netcdf_version="4.1.3"	NetCDF version used for the dataset. *Recommended*.
netcdf_format	netcdf_format="netcdf4_classic"	NetCDF format used for the dataset.
Publication information		
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)
citation	citation=" These data were collected and made freely available by the Copernicus project and the programs that contribute to it. 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. The citation statement has to be reported as follows: "These data were collected and made freely available by the Copernicus project and the programs that contribute to it." An additional citation statement can be appended to the "citation" attribute. **Mandatory**.
distribution_statement	distribution_statement=" These data follow Copernicus standards; they are public and free of charge. User assumes all risk for use of data. User must display citation in any publication o product	The distribution statement has to be reported as follows: "These data follow Copernicus standards; they are public and free of charge. User assumes all risk for use of data. User

	using data. User must contact PI prior to any commercial use of data.”	must display citation in any publication o product using data. User must contact PI prior to any commercial use of data.” **Mandatory**
publisher_name	publisher_name=”Lorenzo Corgnati”	Name of the person responsible for metadata and formatting of the data file. **Mandatory**. (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. **Mandatory**. (ACDD)
publisher_url	publisher_url=”http://radarhf.ismar.cnr.it”	Web address of the institution or of the data publisher. **Mandatory**. (ACDD)
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 work. If not, see http://creativecommons.org/licenses/by/4.0/.”	A statement describing the data distribution policy; it may be a project- or DAC-specific statement, but must allow free use of data. **Mandatory**. (ACDD)
acknowledgment	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. **Mandatory** (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)
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)
date_modified	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" **Mandatory**. (ACDD)
date_update	date_update="2016-11-11T15:35:32Z"	Timestamp specifying when the contents (i.e. its attributes and/or values) of the file were last changed Time must be specified as a string according to the ISO8601 standard: "YYYY-MM-DDThh:mm:ssZ" The value has to be set equal to the "date_modified" one. **Mandatory** (for compliance with SDC CF extension).
processing_level	processing_level="3B"	Level of processing and quality control applied to data. Valid values are listed in Table 12**Erreur ! Source du renvoi introuvable.**. **Mandatory**.
contributor_name	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. **Mandatory**. (ACDD)
contributor_role	contributor_role="THREDDS expert; metadata expert"	The roles of any individuals or institutions that contributed to the creation of this data, separated by semi-colons. **Mandatory**. (ACDD)
contributor_email	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. **Mandatory** (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.

5.3. 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.

In the specific case of HFR radial data files, if the radial measurements are taken by the instruments based on a polar geometry (e.g. Codar .ruv files), the X and Y axis dimension shall be "bearing" (Y) and "range" (X). In this case, anyway, latitude and longitude shall be present in the netCDF file as data variable.

Table 4 – NetCDF dimensions.

Name	Example	Comment
TIME	TIME = unlimited	Number of time steps.
DEPH	DEPH = 1	Number of depth levels. Use 1 for HFR data.
LATITUDE	LATITUDE = 78	Dimension of the LATITUDE coordinate variable.
LONGITUDE	LONGITUDE = 106	Dimension of the LONGITUDE coordinate variable.
BEAR	BEAR = 73	Dimension of the BEAR coordinate variable (bearing away from instrument).
RNGE	RNGE = 46	Dimension of the RNGE coordinate variable (range away from instrument).
STRING15	STRING15 = 15	Length in characters of the strings used in the data file. It is mandatory that the string length dimension STRINGx has the value of x.
MAXSITE	SCALAR = 50	Maximum number of antennas. Set it as an upper bound.
REFMAX	SCALAR = 3	Maximum number of external resource linkages. Set it as an upper bound.

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.

If needed, more than one STRINGx dimension can be defined, provided that that the string length dimension STRINGx has the value of x.

5.4. 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 5. If standard_name is not available, long_name is mandatory.

Coordinate variables and variable attributes required in the **SDC CF extension** have been added as mandatory as well. In particular, the SDN extensions to CF were concerned with providing storage for standardized semantics and metadata included in the SDN profiles format. The standardized semantics are included as four **mandatory** parameter attributes for each data or co-ordinate variable, which are:

- sdn_parameter_urn – this is the URN for the parameter description taken from the P01 vocabulary.
- sdn_parameter_name – this is the plain language label (Entryterm) for the parameter taken from the P01 vocabulary at the time of data file creation.
- sdn_uom_urn – this is the URN for the parameter units of measure taken from the P06 vocabulary.
- sdn_uom_name - this is the plain language label (Entryterm) for the parameters' units of measure, taken from the P06 vocabulary at the time of data file creation.

According to **SDC CF extension**, the ancillary_variables attribute is mandatory and has to be set as the list of QC variables related to the specific variable.

Missing values are not allowed in coordinate variables.

All attributes in this section are highly recommended.

Table 5 – Required syntax for netCDF coordinate variables.

Type, name, dimension, attributes	Comment
Double TIME(TIME); TIME:**standard_name** = "time"; TIME:**units** = "days since 1950-01-01T00:00:00Z"; ' TIME:**axis** = "T"; TIME:**calendar** = "Julian"; TIME:**long_name** = "time of measurement UTC"; TIME:**ancillary_variables** = "TIME_SEADATANET_QC";	Date and time (UTC) of the measurement in days since midnight, 1950-01-01. Example: Noon, Jan 1, 1950 is stored as 0.5.

TIME:**sdn_parameter_name** = “Elapsed time (since 1950-01-01T00:00:00Z)”; TIME:**sdn_parameter_urn** = “SDN:P01::ELTJLD01”; TIME:**sdn_uom_name** = “Days”; TIME:**sdn_uom_urn** = “SDN:P06::UTAA”;	
Float LATITUDE(LATITUDE); LATITUDE:**standard_name** = “latitude”; LATITUDE:**units** = “degrees_north”; LATITUDE:**axis**=”Y”; LATITUDE:**long_name** = “Latitude”; LATITUDE:reference="WGS84"; LATITUDE:**grid_mapping** = crs; LATITUDE:**ancillary_variables** = “POSITION_ SEADATANET _QC”; LATITUDE:**sdn_parameter_name** = “Latitude north”; LATITUDE:**sdn_parameter_urn** = “SDN:P01::ALATZZ01”; LATITUDE:**sdn_uom_name** = “Degrees north”; LATITUDE:**sdn_uom_urn** = “SDN:P06::DEGN”;	Latitude of the measurements. Units: degrees north; southern latitudes are negative. Example: 44.4991 for 44° 29’ 56.76’’ N
Float LONGITUDE(LONGITUDE); LONGITUDE:**standard_name** = “longitude”; LONGITUDE:**units** = “degrees_east”; LONGITUDE:**axis**=”X”; LONGITUDE:**long_name** = “Longitude”; LONGITUDE:reference="WGS84"; LONGITUDE:**grid_mapping** = crs; LONGITUDE:**sdn_parameter_name** = “Longitude east”; LONGITUDE:**sdn_parameter_urn** = ”SDN:P01::ALONZZ01”; LONGITUDE:**sdn_uom_name** = “Degrees east”; LONGITUDE:**sdn_uom_urn** = “SDN:P06::DEGE”; LONGITUDE:**ancillary_variables** = “POSITION_SEADATANET_QC”;	Longitude of the measurements. Units: degrees east; western latitudes are negative. Example: 16.7222 for 16° 43’ 19.92’’ E
Int crs(crs); crs:**grid_mapping_name** = "latitude_longitude" ; crs:**epsg_code** = "EPSG:4326" ; crs:**semi_major_axis** = 6378137. ; crs:**inverse_flattening** = 298.257223563 ;	Coordinate reference system. These values have to be set for WGS84.

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”; DEPH:**sdn_parameter_name** = “Depth below surface of the water body”; DEPH:**sdn_parameter_urn** = “SDN:P01::ADEPZZ01”; DEPH:**sdn_uom_name** = “Metres”; DEPH:**sdn_uom_urn** = “SDN:P06::ULAA”; DEPH:**ancillary_variables** = “DEPTH_SEADATANET_QC”;	Depth of measurements. <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” Example: 0 for a measurement related to sea surface.
Float BEAR(BEAR); BEAR:**units** = “degrees_true”; BEAR:**axis**=”Y”; BEAR:**long_name** = “Bearing away from instrument”; BEAR:**sdn_parameter_name** = “Bearing BEAR:**sdn_parameter_urn** = “SDN:P01::BEARRFTR”; BEAR:**sdn_uom_name** = “Degrees true”; BEAR:**sdn_uom_urn** = “SDN:P06::UABB”; BEAR:**ancillary_variables** = “POSITION_SEADATANET_QC”;	Bearing of the measurement. Units: degrees true; valid values between 0 and 360 degrees. Example: 44.4991 for 44° 29’ 56.76’’ from instrument.
Float RNGE (RNGE); RNGE:**units** = “km”; RNGE:**axis**=”X”; RNGE:**long_name** = “Range away from instrument”; RNGE:**sdn_parameter_name** = “Range (from fixed reference point) by unspecified GPS system”; RNGE:**sdn_parameter_urn** = “SDN:P01::RIFNAX01”; RNGE:**sdn_uom_name** = “Kilometers”; RNGE:**sdn_uom_urn** = “SDN:P06::ULKM”; RNGE:**ancillary_variables** = “POSITION_SEADATANET_QC”;	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.
- BEAR and RNGE: bearing and range are the coordinate variables for radial velocity data. For radial data measured on a polar geometry (e.g. Codar .ruv files), LATITUDE and LONGITUDE are data variables since they are evaluated starting from bearing and range. In order to distribute radial netCDF files as gridded data via THREDDS catalogs, **every variable in the netCDF file of radial data must have the “coordinates” attribute with value “TIME DEPH LATITUDE LONGITUDE”.**

5.5. SDN namespace variables

The SDN extensions to CF were concerned with providing storage for standardized semantics and metadata included in the SDN profiles format. In addition to extending coordinate variables and attributes within variables (see Section 5.4, Section 5.6 and Section 5.7), there are a number of SDN namespace variables that form part of the SeaDataCloud extension. These variables are listed and explained in Table 6.

All variables in this section are **mandatory**.

Table 6 – Required syntax for netCDF SDN namespace variables.

Type, name, dimension, attributes	Comment
char SDN_CRUISE(TIME, STRING50); **SDN_CRUISE:long_name = “Grid grouping label”;**	Array (which can have a dimension of 1 for single object storage) containing text strings identifying a grouping label for the data object to which the array element belongs. **It has to be set equal to the ‘site_code’ global attribute (see Table 3).** Example: SDN_CRUISE = "HFR_TirLig"

char SDN_STATION(TIME, STRING50); **SDN_STATION:long_name = "Grid label";**	Array of text strings identifying the data object to which the array element belongs. **It has to be set equal to the 'platform_code' global attribute (see Table 3).** Example: SDN_STATION = "HFR_TirLig_Total" (for totals produced by the TirLig network) SDN_STATION = "HFR_TirLig_MONT" (for radials from MONT radar site: MONT radar site belongs to the TirLig network)
char SDN_LOCAL_CDI_ID(TIME, STRING50); **SDN_LOCAL_CDI_ID:long_name = "Grid label";** SDN_LOCAL_CDI_ID:cf_role = "grid_id" ;	Array of text strings containing the local identifier of the Common Data Index (CDI) record associated with the data object to which the array element belongs. **It has to be set equal to the 'id' global attribute (see Table 3).** Example: SDN_LOCAL_CDI_ID = "HFR_TirLig_Total_2018-05-18_11Z" (for totals produced by the TirLig network) SDN_LOCAL_CDI_ID = "HFR_TirLig_MONT_2018-05-18_11Z" (for radials from MONT radar site: MONT radar site belongs to the TirLig network)
int SDN_EDMO_CODE(TIME); **SDN_EDMO_CODE:long_name = "European Directory of Marine Organisations code for the CDI partner";**	Integer array containing keys identifying the organisation hosting the Download Manager (CDI_partner) given in the European Directory of Marine Organisations (EDMO). **It has to be set equal to the 'institution_edmo_code' global attribute (see Table 3).** The EDMO codes are managed by the SeaDataNet project; they are available at http://seadatanet.maris2.nl/edmo/ If your institution has no EDMO code, please write to sdn-userdesk@seadatanet.org to obtain one. Example: SDN_EDMO_CODE = 134
char SDN_REFERENCES(TIME, STRING200); **SDN_ REFERENCES:long_name = "Usage metadata reference";**	Link to a single landing page - an XHTML document providing additional information. Example: SDN_REFERENCES = "http://150.145.136.27:8080/thredds/HF_RADAR/TirLig/TirLig_catalog.html" ;
char SDN_XLINK(TIME, REFMAX, STRING200); **SDN_ XLINK:long_name = "External resource linkages";**	Array of text strings containing a URI (URN or URL) pointing to a web resource such as a usage metadata document for the

	data object to which the array element belongs. If URNs such as DOIs are used then the namespace (e.g. 'doi:' for DOI) must be included. Each string is formatted according to the following model: **<sdn_reference xlink:type="URN" xlink:role="text" xlink:href="URI"/>** The xlink:href is **mandatory**, whilst xlink:type and xlink:role are optional. It is either a URL or a URN including namespace. The xlink:type attribute specifies the XML document type using the URN of that document type in the L23 vocabulary. For example, SDN:L23::CDI specifies a Common Data Index document. If xlink:type is omitted then the document type is assumed to be XHTML. The xlink:role indicates the purpose of the document. The following roles are allowed: • isDescribedBy CDI document or controlled vocabulary concept document • isObservedBy CSR document or EDIOS series document Example: SDN_ XLINK = "<sdn_reference xlink:href=\"http://150.145.136.27:8080/thredds/HF_RADAR/TirLig/TirLig_catalog.html\" xlink:role=\"\" xlink:type=\"URL\"/>" ;

Notes on SDN namespace variables variables:

- The SDN approach was to keep duplication of information to a minimum through the provision of external linkages to additional information. Initially, the intention was to follow the DOI model and provide a mechanism to link the SDN data file to a single 'landing page' - an XHTML document providing additional information. The intention was that this page could include additional links to other XML documents, such as the CDI. The SDN_REFERENCES variable was introduced for this purpose. This is a character array for each INSTANCE (i.e. normally one per file for SDN) in which a URI is stored. This is either the landing page URL or a URN including namespace such as a DOI.
- However, this was considered insufficient as there was no information in the data files to inform software agents what to expect at the end of the URI and insufficient control over landing page content to guarantee that it would be provided elsewhere. Consequently, the SDN_XLINK character array was introduced. This allows any number (the REFMAX dimension) of strings to be associated with each INSTANCE.

5.6. Data variables

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

Mandatory and recommended variable names are listed in Table 7. 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, the **long_name** attribute has to be used. 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.

Data variables required in the **SDC CF extension** have been added as mandatory as well.

Table 7 – Mandatory and recommended data variables for radial and total velocity data.

Radial velocity data		
Variable name	standard_name	long_name
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
HCSS		Radial Variance of Current Velocity Over Coverage Period
EACC		Radial Accuracy of Current Velocity Over Coverage Period
XDST		Eastward Distance From Instrument
YDST		Northward Distance From Instrument
SPRC		Radial Sea Water Velocity Cross Spectra Range Cell
NARX		Number of Receive Antennas
NATX		Number of Transmit Antennas

SLTR		Receive Antenna Latitudes
SLNR		Receive Antenna Longitudes
SLTT		Transmit Antenna Latitudes
SLNT		Transmit Antenna Longitudes
SCDR		Receive Antenna Codes
SCDT		Transmit Antenna Codes
Total velocity data		
EWCT	surface_eastward_sea_water_velocity	Surface Eastward Sea Water Velocity
NSCT	surface_northward_sea_water_velocity	Surface Nortward Sea Water Velocity
EWCS		Standard Deviation Of Surface Eastward Sea Water Velocity
NSCS		Standard Deviation Of Surface Northward Sea Water Velocity
GDOP		Geometrical Dilution Of Precision
CCOV		Covariance Of Surface Sea Water Velocity
UACC		Accuracy Of Surface Eastward Sea Water Velocity
VACC		Accuracy Of Surface Northward Sea Water Velocity
NARX		Number of Receive Antennas
NATX		Number of Transmit Antennas
SLTR		Receive Antenna Latitudes
SLNR		Receive Antenna Longitudes
SLTT		Transmit Antenna Latitudes
SLNT		Transmit Antenna Longitudes
SCDR		Receive Antenna Codes
SCDT		Transmit Antenna Codes

The required syntax for data variables is reported in Table 8: replace <PARAM> with any of the variable names indicated in Table 7.

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. Variable attributes required in the **SDC CF extension** have been added as mandatory as well. Please refer to Table 9 for the SDN namespace variable attributes required for SDC CF extension.

<A>: standardized attributes.

<B>: 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 8 – Required syntax for netCDF data variables.

Type, name, dimension, attributes	Comment
Float <PARAM>(TIME, DEPH, LATITUDE, LONGITUDE);	or Float <PARAM>(TIME, DEPH); or Float <PARAM>(TIME); or Float <PARAM>(TIME, DEPH, BEAR, RNGE); or Float <PARAM>(BEAR,RNGE);
<PARAM>:standard_name = <A>;	standard_name: required, if there is an appropriate, existing standard name in CF.
<PARAM>:**units** = <A>;	units: required.
<PARAM>:**_FillValue** = <B>;	_FillValue: required. Fill values must be chosen according to the variable data type (int, float, double).
<PARAM>:**coordinates** = <B>;	coordinates: lists the coordinate variables for the measurement value as a space-delimited list: **"TIME DEPH LATITUDE LONGITUDE"**.
<PARAM>:**long_name** = <B>;	long_name: required. Text; should be a useful label for the variable.
<PARAM>:**valid_range** = <B>;	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 = <B>;	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 = <B>;	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.
<PARAM>:**sdn_parameter_name** = <A>;	sdn_parameter_name is the plain language label (Entryterm) for the parameter taken from the P01 vocabulary at the time of data file creation.
<PARAM>:**sdn_parameter_urn** = <A>;	sdn_parameter_urn is the URN for the parameter description taken from the P01 vocabulary
<PARAM>:**sdn_uom_name** = <A>;	sdn_uom_name is the plain language label (Entryterm) for the parameters' units of measure, taken from the P06 vocabulary at the time of data file creation.

<PARAM>:**sdn_uom_urn** = <A>;	sdn_uom_urn is the URN for the parameter units of measure taken from the P06 vocabulary.
<PARAM>:**ancillary_variables** = <B>;	ancillary_variables: name of the flag channel for the variable. The list of all related QC variables must be indicated.

Table 9 - Mandatory and recommended SDN namespace data variable attributes for radial and total velocity data

Radial velocity data				
Variable name	sdn_parameter_name	sdn_parameter_urn	sdn_uom_name	sdn_uom_urn
TIME	“Elapsed time (since 1950-01-01T00:00:00Z)”	“SDN:P01::ELTJLD01”	“Days”	“SDN:P06::UTAA”
BEAR	“Bearing”	“SDN:P01::BEARRFTR”	“Degrees true”	“SDN:P06::UABB”
RNGE	“Range (from fixed reference point) by unspecified GPS system”	“SDN:P01::RIFNAX01”	“Kilometres”	“SDN:P06::ULKM”
DEPH	“Depth below surface of the water body”	“SDN:P01::ADEPZZ01”	“Metres”	“SDN:P06::ULAA”
LATITUDE	“Latitude north”	“SDN:P01::ALATZZ01”	“Degrees north”	“SDN:P06::DEGN”
LONGITUDE	“Longitude east”	”SDN:P01::ALONZZ01”	“Degrees east”	“SDN:P06::DEGE”
RDVA	“Current speed (Eulerian) in the water body by directional range-gated radar”	“SDN:P01::LCSAWVRD”	“Metres per second”	“SDN:P06::UVAA”
DRVA	“Current direction (Eulerian) in the water body by directional range-gated radar”	“SDN:P01::LCDAWVRD”	“Degrees true”	“SDN:P06::UABB”
EWCT	Eastward current velocity in the water body”	“SDN:P01::LCEWZZ01”	“Metres per second”	“SDN:P06::UVAA”
NSCT	Northward current velocity in the water body”	“SDN:P01:: LCNSZZ01”	“Metres per second”	“SDN:P06::UVAA”
ESPC	“”	“”	“Metres per second”	“SDN:P06::UVAA”
ETMP	“”	“”	“Metres per second”	“SDN:P06::UVAA”
ERSC	“”	“”	“Dimensionless”	“SDN:P06::UUUU”
ERTC	“”	“”	“Dimensionless”	“SDN:P06::UUUU”
HCSS	“Current speed standard deviation in the water body”	“SDN:P01::SDSAZZ01”	“Metres per second”	“SDN:P06::UVAA”
EACC	“”	“”	“Metres per second”	“SDN:P06::UVAA”

XDST	“”	“”	“Kilometres”	“SDN:P06::ULKM”
YDST	“”	“”	“Kilometres”	“SDN:P06::ULKM”
SPRC	“”	“”	“Dimensionless”	“SDN:P06::UUUU”
NARX	“”	“”	“Dimensionless”	“SDN:P06::UUUU”
NATX	“”	“”	“Dimensionless”	“SDN:P06::UUUU”
SLTR	“Latitude north”	“SDN:P01::ALATZZ01”	“Degrees north”	“SDN:P06::DEGN”
SLNR	“Longitude east”	”SDN:P01::ALONZZ01”	“Degrees east”	“SDN:P06::DEGE”
SLTT	“Latitude north”	“SDN:P01::ALATZZ01”	“Degrees north”	“SDN:P06::DEGN”
SLNT	“Longitude east”	”SDN:P01::ALONZZ01”	“Degrees east”	“SDN:P06::DEGE”
SCDR	“”	“”	“Dimensionless”	“SDN:P06::UUUU”
SCDT	“”	“”	“Dimensionless”	“SDN:P06::UUUU”
Total velocity data				
TIME	“Elapsed time (since 1950-01-01T00:00:00Z)”	“SDN:P01::ELTJLD01”	“Days”	“SDN:P06::UTAA”
LATITUDE	“Latitude north”	“SDN:P01::ALATZZ01”	“Degrees north”	“SDN:P06::DEGN”
LONGITUDE	“Longitude east”	”SDN:P01::ALONZZ01”	“Degrees east”	“SDN:P06::DEGE”
DEPH	“Depth below surface of the water body”	“SDN:P01::ADEPZZ01”	“Metres”	“SDN:P06::ULAA”
EWCT	Eastward current velocity in the water body”	“SDN:P01::LCEWZZ01”	“Metres per second”	“SDN:P06::UVAA”
NSCT	Northward current velocity in the water body”	“SDN:P01:: LCNSZZ01”	“Metres per second”	“SDN:P06::UVAA”
EWCS	“Eastward current velocity standard deviation in the water body”	“SDN:P01::SDEWZZZZ”	“Metres per second”	“SDN:P06::UVAA”
NSCS	“Northward current velocity standard deviation in the water body”	“SDN:P01::SDNSZZZZ”	“Metres per second”	“SDN:P06::UVAA”
CCOV	“”	“”	“Square metres per second squared”	“SDN:P06::SQM2”
GDOP	“”	“”	“Dimensionless”	“SDN:P06::UUUU”
UACC	“”	“”	“Metres per second”	“SDN:P06::UVAA”
VACC	“”	“”	“Metres per second”	“SDN:P06::UVAA”
NARX	“”	“”	“Dimensionless”	“SDN:P06::UUUU”
NATX	“”	“”	“Dimensionless”	“SDN:P06::UUUU”
SLTR	“Latitude north”	“SDN:P01::ALATZZ01”	“Degrees north”	“SDN:P06::DEGN”

SLNR	“Longitude east”	”SDN:P01::ALONZZ01”	“Degrees east”	“SDN:P06::DEGE”
SLTT	“Latitude north”	“SDN:P01::ALATZZ01”	“Degrees north”	“SDN:P06::DEGN”
SLNT	“Longitude east”	”SDN:P01::ALONZZ01”	“Degrees east”	“SDN:P06::DEGE”
SCDR	“”	“”	“Dimensionless”	“SDN:P06::UUUU”
SCDT	“”	“”	“Dimensionless”	“SDN:P06::UUUU”

Notes 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.

Even if CF conventions prefer the use of coordinate variables as dimensions, because it conforms to COARDS (Cooperative Ocean-Atmosphere Research Data Service) convention and because it simplifies the use of the data by standard software, in order to comply with SDC CF extension data model, the European common data and metadata model for NRT HFR data mandates to declare the variables with all their dimensions and also to have the “coordinates” attribute filled with the list of dimensions.

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 4).

QC variables (TIME_SEADATANET_QC, POSITION_SEADATANET_QC and DEPTH_SEADATANET_QC) for coordinate variables have been added as mandated by the **CMEMS-INSTAC profile**. Since no constraints are present for the naming of these variables, these variables have been named according to the **SDC CF**

Extension. Anyway, in order to have these variables fully compliant with SDC CF Extension requirements, some attributes have to be added.

No CF-1.6 standard names exist for QC variables, thus long names have to be used. QC variables must be of type short.

Table 10 list the mandatory QC variables to include in the data file.

Table 10 – Mandatory QC variables for radial and total velocity data.

Radial velocity data		
Variable name	long_name	Variable dimensionality
TIME_SEADATANET_QC	Time SeaDataNet quality flag	scalar
POSITION_SEADATANET_QC	Position SeaDataNet quality flag	gridded
DEPTH_SEADATANET_QC	Depth SeaDataNet quality flag	scalar
QCflag	Overall Quality Flags	gridded
OWTR_QC	Over-water Quality Flags	gridded
MDFL_QC	Median Filter Quality Flags	gridded
VART_QC	Variance Threshold Quality Flags	gridded
CSPD_QC	Velocity Threshold Quality Flags	gridded
AVRB_QC	Average Radial Bearing Quality Flags	scalar
RDCT_QC	Radial Count Quality Flags	scalar
Total velocity data		
TIME_SEADATANET_QC	Time SeaDataNet quality flag	scalar
POSITION_SEADATANET_QC	Position SeaDataNet quality flag	gridded
DEPTH_SEADATANET_QC	Depth SeaDataNet quality flag	scalar
QCflag	Overall Quality Flags	gridded
VART_QC	Variance Threshold Quality Flags	gridded
GDOP_QC	GDOP Threshold Quality Flags	gridded
DDNS_QC	Data Density Threshold Quality Flags	gridded
CSPD_QC	Velocity Threshold Quality Flags	gridded

Table 11 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 4).

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.

<B>: 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 11 – 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, BEAR, RNGE);
	or Short <TEST>_QC(TIME, DEPH, BEAR, RNGE);

<PARAM>_QC:**long_name** = <A>;	long_name: required. Type char, fixed value.
<PARAM>_QC:**units** = <A>;	units: required.
<PARAM>_QC:**_FillValue** = <B>;	_FillValue: required. Fill values must be chosen according to the QC variable data type (int, float, double).
<PARAM>_QC:**valid_range** = <B>;	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.
<PARAM>_QC:**flag_values** = <B>	flag_values: required. Fixed values listing the possible values of the QC variable.
<PARAM>_QC:**flag_meanings** = <B>	flag_meanings: required. Type char, fixed values providing the meanings of the possible values for the QC variable.
<PARAM>_QC:**coordinates** = <B>	coordinates: lists the coordinate variables for the measurement value as a space-delimited list: **"TIME DEPH LATITUDE LONGITUDE"**.
<PARAM>_QC:comment = <C>;	comment: Text; useful free-format text.
<PARAM>_QC:add_offset = <B>;	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.
<PARAM>_QC:scale_factor = <B>;	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.

5.8. Data types and naming convention

The data type is a bigram used in file names for a quick identification of the file content. According to CMEMS-INSTAC requirements, each data type is part of 5 groups of data. The data type bigram for HFR data is HF and it belongs to the group Etc.
These 5 groups are subdirectories in the monthly and history directories. HFR data will be stored in the subdirectory Etc in the monthly and history directories.
The naming convention for CMEMS-INSTAC data files requires to have the two bigrams '_XX_YY_' as part of the filename, where:

- The bigram 'XX' indicates the type of measurement (e.g. PR=profiles, TS=timeseries);
- The bigram 'YY' indicates the data type.

For HFR data the two bigrams 'XX' and 'YY' are defined as:

- XX=**TV** (Total Velocity) for total current data files;
- XX=**RV** (Radial Velocity) for radial current data files;
- YY=HF

Thus, the two bigrams 'XX_YY' inside the filenames are:

- '**TV_HF'** for total current velocity data files;
- '**RV_HF**' for radial current velocity data files.

Please refer to CMEMS-INSTAC System Requirement Document (http://archimer.ifremer.fr/doc/00297/40846/50211.pdf) and to INCREASE project deliverable D4.1 (http://www.cmems-increase.eu/static/INCREASE_Report_D4.1_vf.pdf) for the comprehensive description of the naming convention to be used for data distribution on CMEMS-INSTAC.

6. Time aggregation strategy for data distribution on SDC services

The European common data and metadata model for real time HFR data presented in this document is intended to be the unique model for HFR data distribution in Europe, thus it is expected to integrate CMEMS and SeaDataCloud (SDC) requirements. Nevertheless, the model does not achieve the full compliance with the SDC CF extension due to some incompatibilities between the SDC CF extension and the CMEMS-INSTAC requirements. In particular, these incompatibilities are the following:

- SDC CF extension requires different QC variable type and flagging scheme with respect to the ones mandated by the CMEMS-INSTAC requirements:
  - QC variable type is 'byte'.
  - :flag_values = 48b, 49b, 50b, 51b, 52b, 53b, 54b, 55b, 56b, 57b, 65b ;
  - :flag_meanings = "no_quality_control good_value probably_good_probably_bad_value bad_value changed_value value_below_detection value_in_excess interpolated_value missing_value value_phenomenon_uncertain" ;
- SDC CF extension requires the depth variable to be named DEPTH, while CMEMS-INSTAC requires it to be named DEPH;
- According to INSPIRE directive, the SDC CF extension requires the Lambert Azimuthal Equal Area (ETRS89-LAEA) coordinate reference system instead of WGS84, as mandated by CMEMS-INSTAC.

Since SDC services give access to reprocessed historical datasets and their related metadata objects, near real time HFR data have to be time aggregated and reprocessed in order to be ingested by the SDC distribution system. The recommended strategy for these aggregation and reprocessing step is then to complement the workflow for data processing and aggregation with a tool that will solve the incompatibilities.In particular:

- The DEPH variable has be renamed to DEPTH when the temporal aggregation for the SDC datasets is performed: this will avoid to have two coordinate variables related to depth but with different names in the netCDF files;
- the flag values and meanings have to be converted via a mapping table when the temporal aggregation is performed. In that phase the :Conventions and :sdn_conventions_urn attributes have to be added to the QC variables. This will avoid to have replicated QC variables related to the same QC tests but with different names and schemes in the netCDF files.

Concerning the incompatibility on the coordinate reference system, the SDC coordination sent a Very Urgent Change Requests for the EU JRC with respect to the INSPIRE compliance, specifically for the acceptance of the WGS84 coordinate reference system. In case of acceptance of the request, that is considered very likely, the issue will be solved. Otherwise, all variables would have to be remapped on the ETRS89-LAEA reference system and the following variables have to be added:

- INSPIRE_LONGITUDE --> conversion from WGS84

- INSPIRE_LATITUDE --> conversion from WGS84
- INSPIRE_crs --> verbatim for ETRS89-LAEA

This remapping and variable addition can be performed in automated way while aggregating and reprocessing the real time data to build the historical datasets.

7. Conclusions and next steps

This manual describes the European common HFR data and metadata model and a common real-time QC model. The way to achieve this consensus has been led by the JERICO-RI HFR community receiving inputs from a wider group of operators worldwide and from the main components of the European marine data infrastructures. 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 and to be distributed by CMEMS-INSTAC, SDC and EMODnet distribution services.

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.

This achievement will be populated in particular through the EuroGOOS DATAMEQ working group and the EuroGOOS HFR Task Team. Moreover these organizations will keep open discussions and reviews in order to maintain and refine the data model and the QC model.

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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
- Udunits 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
- CMEMS-INSTAC System Requirement Document: http://archimer.ifremer.fr/doc/00297/40846/50211.pdf
- INCREASE project deliverable D4.1: http://www.cmems-increase.eu/static/INCREASE_Report_D4.1_vf.pdf

- Repository containing the software tools needed for the collection, QC and processing of HFR data according to the European QC model and the European data and metadata model: https://github.com/LorenzoCorgnati/HFR_Node_tools

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 12 – 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.	HFR radial velocity data
LEVEL 2B	Level 2A data that have been processed with a minimum set of QC.	HFR radial velocity data
LEVEL 2C	Level 2A data that have been reprocessed for advanced QC.	Reprocessed HFR 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 3C	Level 3A data that have been reprocessed for advanced QC.	Reprocessed 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 13 – *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	These data should be used with caution
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	value changed	Data may be recovered after transmission error
6	-	Not used
7	nominal value	The provided value is not measured but comes from a priori knowledge (instrument design or deployment), e.g. instrument target depth
8	interpolated value	Missing data may be interpolated from neighbouring data in space or time
9	missing value	

C. Data mode

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

Table 14 – 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 HFR_TirLig_RDL_m_MONT_2017_01_01_0000 {
dimensions:
 TIME = 1 ;
 BEAR = 73 ;
 RNGE = 51 ;
 DEPH = 1 ;
 MAXSITE = 50 ;
 REFMAX = 1 ;
 STRING4 = 4 ;
 STRING10 = 10 ;
 STRING15 = 15 ;
 STRING36 = 36 ;
 STRING70 = 70 ;
 STRING131 = 131 ;
variables:
 float TIME(TIME) ;
        TIME:long_name = "Time of Measurement UTC" ;
        TIME:standard_name = "time" ;
        TIME:units = "days since 1950-01-01T00:00:00Z" ;
        TIME:calendar = "Julian" ;
        TIME:axis = "T" ;
        TIME:sdn_parameter_name = "Elapsed time (since 1950-01-01T00:00:00Z)"
;
        TIME:sdn_parameter_urn = "SDN:P01::ELTJLD01" ;
        TIME:sdn_uom_name = "Days" ;
        TIME:sdn_uom_urn = "SDN:P06::UTAA" ;
        TIME:ancillary_variables = "TIME_SEADATANET_QC" ;
 float BEAR(BEAR) ;
        BEAR:axis = "Y" ;
        BEAR:long_name = "Bearing Away From Instrument" ;
        BEAR:units = "degrees_true" ;
        BEAR:sdn_parameter_name = "Bearing" ;
        BEAR:sdn_parameter_urn = " SDN:P01::BEARRFTR" ;
        BEAR:sdn_uom_name = "Degrees true" ;
        BEAR:sdn_uom_urn = "SDN:P06::UABB" ;
        BEAR:ancillary_variables = "POSITION_SEADATANET_QC" ;
 float RNGE(RNGE) ;
        RNGE:axis = "X" ;
        RNGE:long_name = "Range Away From Instrument" ;
        RNGE:units = "km" ;
```

```
		RNGE:sdn_parameter_name = "Range (from fixed reference point) by unspecified GPS system" ;
		RNGE:sdn_parameter_urn = "SDN:P01::RIFNAX01" ;
		RNGE:sdn_uom_name = "Kilometres" ;
		RNGE:sdn_uom_urn = "SDN:P06::ULKM" ;
		RNGE:ancillary_variables = "POSITION_SEADATANET_QC" ;
	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" ;
		DEPH:sdn_parameter_name = "Depth below surface of the water body" ;
		DEPH:sdn_parameter_urn = "SDN:P01::ADEPZZ01" ;
		DEPH:sdn_uom_name = "Metres" ;
		DEPH:sdn_uom_urn = "SDN:P06::ULAA" ;
		DEPH:ancillary_variables = "DEPTH_SEADATANET_QC" ;
	float LATITUDE(BEAR, RNGE) ;
		LATITUDE:standard_name = "latitude" ;
		LATITUDE:long_name = "Latitude" ;
		LATITUDE:units = "degrees_north" ;
		LATITUDE:valid_range = -90.f, 90.f ;
		LATITUDE:FillValue = 9.96921e+36f ;
		LATITUDE:sdn_parameter_name = "Latitude north" ;
		LATITUDE:sdn_parameter_urn = "SDN:P01::ALATZZ01" ;
		LATITUDE:sdn_uom_name = "Degrees north" ;
		LATITUDE:sdn_uom_urn = "SDN:P06::DEGN" ;
		LATITUDE:ancillary_variables = "POSITION_SEADATANET_QC" ;
	float LONGITUDE(BEAR, RNGE) ;
		LONGITUDE:standard_name = "longitude" ;
		LONGITUDE:long_name = "Longitude" ;
		LONGITUDE:units = "degrees_east" ;
		LONGITUDE:valid_range = -180.f, 180.f ;
		LONGITUDE:FillValue = 9.96921e+36f ;
		LONGITUDE:sdn_parameter_name = "Longitude east" ;
		LONGITUDE:sdn_parameter_urn = "SDN:P01::ALONZZ01" ;
		LONGITUDE:sdn_uom_name = "Degrees east" ;
		LONGITUDE:sdn_uom_urn = "SDN:P06::DEGE" ;
		LONGITUDE:ancillary_variables = "POSITION_SEADATANET_QC" ;
	short crs(TIME) ;
		crs:grid_mapping_name = "latitude_longitude" ;
		crs:epsg_code = "EPSG:4326" ;
```

```
        crs:semi_major_axis = 6378137.f ;
        crs:inverse_flattening = 298.2572f ;
char SDN_CRUISE(TIME, STRING10) ;
        SDN_CRUISE:long_name = "Grid grouping label" ;
char SDN_STATION(TIME, STRING15) ;
        SDN_STATION:long_name = "Grid label" ;
char SDN_LOCAL_CDI_ID(TIME, STRING36) ;
        SDN_LOCAL_CDI_ID:long_name = "SeaDataCloud CDI identifier" ;
        SDN_LOCAL_CDI_ID:cf_role = "grid_id" ;
short SDN_EDMO_CODE(TIME) ;
        SDN_EDMO_CODE:long_name = "European Directory of Marine
Organisations code for the CDI partner" ;
char SDN_REFERENCES(TIME, STRING70) ;
        SDN_REFERENCES:long_name = "Usage metadata reference" ;
char SDN_XLINK(TIME, REFMAX, STRING131) ;
        SDN_XLINK:long_name = "External resource linkages" ;
float RDVA(TIME, DEPH, BEAR, RNGE) ;
        RDVA:valid_range = -10.f, 10.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:sdn_parameter_name = "Current speed (Eulerian) in the water body
by directional range-gated radar" ;
        RDVA:sdn_parameter_urn = "SDN:P01::LCSAWVRD" ;
        RDVA:sdn_uom_name = "Metres per second" ;
        RDVA:sdn_uom_urn = "SDN:P06::UVAA" ;
        RDVA:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
        RDVA:ancillary_variables = "QCflag, OWTR_QC, MDFL_QC, CSPD_QC,
RDCT_QC" ;
short DRVA(TIME, DEPH, BEAR, RNGE) ;
        DRVA:valid_range = 0s, 360s ;
        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:scale_factor = 0.1f ;
```

```
            DRVA:sdn_parameter_name = "Current direction (Eulerian) in the water body
by directional range-gated radar" ;
            DRVA:sdn_parameter_urn = "SDN:P01::LCDAWVRD" ;
            DRVA:sdn_uom_name = "Degrees True" ;
            DRVA:sdn_uom_urn = "SDN:P06::UABB" ;
            DRVA:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
            DRVA:ancillary_variables = "QCflag, OWTR_QC, MDFL_QC, AVRB_QC,
RDCT_QC" ;
float EWCT(TIME, DEPH, BEAR, RNGE) ;
            EWCT:valid_range = -10.f, 10.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:sdn_parameter_name = "Eastward current velocity in the water body"
;
            EWCT:sdn_parameter_urn = "SDN:P01::LCEWZZ01" ;
            EWCT:sdn_uom_name = "Metres per second" ;
            EWCT:sdn_uom_urn = "SDN:P06::UVAA" ;
            EWCT:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
            EWCT:ancillary_variables = "QCflag, OWTR_QC, MDFL_QC, CSPD_QC,
VART_QC, AVRB_QC, RDCT_QC" ;
float NSCT(TIME, DEPH, BEAR, RNGE) ;
            NSCT:valid_range = -10.f, 10.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:sdn_parameter_name = "Northward current velocity in the water body"
;
            NSCT:sdn_parameter_urn = "SDN:P01::LCNSZZ01" ;
            NSCT:sdn_uom_name = "Metres per second" ;
            NSCT:sdn_uom_urn = "SDN:P06::UVAA" ;
            NSCT:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
            NSCT:ancillary_variables = "QCflag, OWTR_QC, MDFL_QC, CSPD_QC,
VART_QC, AVRB_QC, RDCT_QC" ;
float ESPC(TIME, DEPH, BEAR, RNGE) ;
            ESPC:valid_range = -1000.f, 1000.f ;
```

```
        ESPC:long_name = "Radial Standard Deviation of Current Velocity over the Scatter Patch" ;
        ESPC:units = "m s-1" ;
        ESPC:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
        ESPC:FillValue = 9.96921e+36f ;
        ESPC:scale_factor = 1.f ;
        ESPC:add_offset = 0.f ;
        ESPC:sdn_parameter_name = "" ;
        ESPC:sdn_parameter_urn = "" ;
        ESPC:sdn_uom_name = "Metres per second" ;
        ESPC:sdn_uom_urn = "SDN:P06::UVAA" ;
        ESPC:ancillary_variables = "QCflag, VART_QC" ;
float ETMP(TIME, DEPH, BEAR, RNGE) ;
        ETMP:valid_range = -1000.f, 1000.f ;
        ETMP:long_name = "Radial Standard Deviation of Current Velocity over Coverage Period" ;
        ETMP:units = "m s-1" ;
        ETMP:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
        ETMP:FillValue = 9.96921e+36f ;
        ETMP:scale_factor = 1.f ;
        ETMP:add_offset = 0.f ;
        ETMP:sdn_parameter_name = "" ;
        ETMP:sdn_parameter_urn = "" ;
        ETMP:sdn_uom_name = "Metres per second" ;
        ETMP:sdn_uom_urn = "SDN:P06::UVAA" ;
        ETMP:ancillary_variables = "QCflag, VART_QC" ;
float MAXV(TIME, DEPH, BEAR, RNGE) ;
        MAXV:long_name = "Radial Sea Water Velocity Away From Instrument Maximum" ;
        MAXV:valid_range = -10.f, 10.f ;
        MAXV:FillValue = 9.96921e+36f ;
        MAXV:scale_factor = 1.f ;
        MAXV:add_offset = 0.f ;
        MAXV:units = "m s-1" ;
        MAXV:sdn_parameter_name = "Current speed (Eulerian) in the water body by directional range-gated radar" ;
        MAXV:sdn_parameter_urn = "SDN:P01::LCSAWVRD" ;
        MAXV:sdn_uom_name = "Metres per second" ;
        MAXV:sdn_uom_urn = "SDN:P06::UVAA" ;
        MAXV:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
        MAXV:ancillary_variables = "QCflag, MDFL_QC, CSPD_QC, VART_QC" ;
float MINV(TIME, DEPH, BEAR, RNGE) ;
```

```
        MINV:long_name = "Radial Sea Water Velocity Away From Instrument Minimum" ;
        MINV:valid_range = -10.f, 10.f ;
        MINV:FillValue = 9.96921e+36f ;
        MINV:scale_factor = 1.f ;
        MINV:add_offset = 0.f ;
        MINV:units = "m s-1" ;
        MINV:sdn_parameter_name = "Current speed (Eulerian) in the water body by directional range-gated radar" ;
        MINV:sdn_parameter_urn = "SDN:P01::LCSAWVRD" ;
        MINV:sdn_uom_name = "Metres per second" ;
        MINV:sdn_uom_urn = "SDN:P06::UVAA" ;
        MINV:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
        MINV:ancillary_variables = "QCflag, MDFL_QC, CSPD_QC, VART_QC" ;
short ERSC(TIME, DEPH, BEAR, RNGE) ;
        ERSC:long_name = "Radial Sea Water Velocity Spatial Quality Count" ;
        ERSC:valid_range = 0s, 127s ;
        ERSC:FillValue = -32767s ;
        ERSC:scale_factor = 1s ;
        ERSC:add_offset = 0s ;
        ERSC:units = "1" ;
        ERSC:sdn_parameter_name = "" ;
        ERSC:sdn_parameter_urn = "" ;
        ERSC:sdn_uom_name = "Dimensionless" ;
        ERSC:sdn_uom_urn = "SDN:P06::UUUU" ;
        ERSC:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
        ERSC:ancillary_variables = "QCflag" ;
short ERTC(TIME, DEPH, BEAR, RNGE) ;
        ERTC:long_name = "Radial Sea Water Velocity Temporal Quality Count" ;
        ERTC:valid_range = 0s, 127s ;
        ERTC:FillValue = -32767s ;
        ERTC:scale_factor = 1s ;
        ERTC:add_offset = 0s ;
        ERTC:units = "1" ;
        ERTC:sdn_parameter_name = "" ;
        ERTC:sdn_parameter_urn = "" ;
        ERTC:sdn_uom_name = "Dimensionless" ;
        ERTC:sdn_uom_urn = "SDN:P06::UUUU" ;
        ERTC:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
        ERTC:ancillary_variables = "QCflag" ;
float XDST(BEAR, RNGE) ;
        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:sdn_parameter_name = "" ;
        XDST:sdn_parameter_urn = "" ;
        XDST:sdn_uom_name = "Kilometres" ;
        XDST:sdn_uom_urn = "SDN:P06::ULKM" ;
        XDST:coordinates = "BEAR RNGE" ;
        XDST:ancillary_variables = "QCflag, OWTR_QC, MDFL_QC, CSPD_QC,
VART_QC" ;
float YDST(BEAR, RNGE) ;
        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:sdn_parameter_name = "" ;
        YDST:sdn_parameter_urn = "" ;
        YDST:sdn_uom_name = "Kilometres" ;
        YDST:sdn_uom_urn = "SDN:P06::ULKM" ;
        YDST:coordinates = "BEAR RNGE" ;
        YDST:ancillary_variables = "QCflag, OWTR_QC, MDFL_QC, CSPD_QC,
VART_QC" ;
short SPRC(TIME, DEPH, BEAR, RNGE) ;
        SPRC:long_name = "Radial Sea Water Velocity Cross Spectral Range Cell"
;
        SPRC:valid_range = 0s, 127s ;
        SPRC:FillValue = -32767s ;
        SPRC:scale_factor = 1s ;
        SPRC:add_offset = 0s ;
        SPRC:units = "1" ;
        SPRC:sdn_parameter_name = "" ;
        SPRC:sdn_parameter_urn = "" ;
        SPRC:sdn_uom_name = "Dimensionless" ;
        SPRC:sdn_uom_urn = "SDN:P06::UUUU" ;
        SPRC:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
        SPRC:ancillary_variables = "QCflag, OWTR_QC, MDFL_QC, CSPD_QC,
VART_QC" ;
short NARX(TIME) ;
        NARX:long_name = "Number of Receive Antennas" ;
        NARX:valid_range = 0s, 50s ;
```

```
        NARX:FillValue = -32767s ;
        NARX:scale_factor = 1s ;
        NARX:add_offset = 0s ;
        NARX:units = "1" ;
        NARX:sdn_parameter_name = "" ;
        NARX:sdn_parameter_urn = "" ;
        NARX:sdn_uom_name = "Dimensionless" ;
        NARX:sdn_uom_urn = "SDN:P06::UUUU" ;
short NATX(TIME) ;
        NATX:long_name = "Number of Transmit Antennas" ;
        NATX:valid_range = 0s, 50s ;
        NATX:FillValue = -32767s ;
        NATX:scale_factor = 1s ;
        NATX:add_offset = 0s ;
        NATX:units = "1" ;
        NATX:sdn_parameter_name = "" ;
        NATX:sdn_parameter_urn = "" ;
        NATX:sdn_uom_name = "Dimensionless" ;
        NATX:sdn_uom_urn = "SDN:P06::UUUU" ;
float SLTR(TIME, MAXSITE) ;
        SLTR:long_name = "Receive Antenna Latitudes" ;
        SLTR:standard_name = "latitude" ;
        SLTR:valid_range = -180.f, 180.f ;
        SLTR:FillValue = 9.96921e+36f ;
        SLTR:scale_factor = 1.f ;
        SLTR:add_offset = 0.f ;
        SLTR:units = "degrees_north" ;
        SLTR:sdn_parameter_name = "Latitude north" ;
        SLTR:sdn_parameter_urn = "SDN:P01::ALATZZ01" ;
        SLTR:sdn_uom_name = "Degrees north" ;
        SLTR:sdn_uom_urn = "SDN:P06::DEGN" ;
        SLTR:coordinates = "TIME MAXSITE" ;
float SLNR(TIME, MAXSITE) ;
        SLNR:long_name = "Receive Antenna Longitudes" ;
        SLNR:standard_name = "longitude" ;
        SLNR:valid_range = -90.f, 90.f ;
        SLNR:FillValue = 9.96921e+36f ;
        SLNR:scale_factor = 1.f ;
        SLNR:add_offset = 0.f ;
        SLNR:units = "degrees_east" ;
        SLNR:sdn_parameter_name = "Longitude east" ;
        SLNR:sdn_parameter_urn = "SDN:P01::ALONZZ01" ;
        SLNR:sdn_uom_name = "Degrees east" ;
```

```
		SLNR:sdn_uom_urn = "SDN:P06::DEGE" ;
		SLNR:coordinates = "TIME MAXSITE" ;
	float SLTT(TIME, MAXSITE) ;
		SLTT:long_name = "Transmit Antenna Latitudes" ;
		SLTT:standard_name = "latitude" ;
		SLTT:valid_range = -180.f, 180.f ;
		SLTT:FillValue = 9.96921e+36f ;
		SLTT:scale_factor = 1.f ;
		SLTT:add_offset = 0.f ;
		SLTT:units = "degrees_north" ;
		SLTT:sdn_parameter_name = "Latitude north" ;
		SLTT:sdn_parameter_urn = "SDN:P01::ALATZZ01" ;
		SLTT:sdn_uom_name = "Degrees north" ;
		SLTT:sdn_uom_urn = "SDN:P06::DEGN" ;
		SLTT:coordinates = "TIME MAXSITE" ;
	float SLNT(TIME, MAXSITE) ;
		SLNT:long_name = "Transmit Antenna Longitudes" ;
		SLNT:standard_name = "longitude" ;
		SLNT:valid_range = -90.f, 90.f ;
		SLNT:FillValue = 9.96921e+36f ;
		SLNT:scale_factor = 1.f ;
		SLNT:add_offset = 0.f ;
		SLNT:units = "degrees_east" ;
		SLNT:sdn_parameter_name = "Longitude east" ;
		SLNT:sdn_parameter_urn = "SDN:P01::ALONZZ01" ;
		SLNT:sdn_uom_name = "Degrees east" ;
		SLNT:sdn_uom_urn = "SDN:P06::DEGE" ;
		SLNT:coordinates = "TIME MAXSITE" ;
	char SCDR(TIME, MAXSITE, STRING4) ;
		SCDR:long_name = "Receive Antenna Codes" ;
		SCDR:sdn_parameter_name = "" ;
		SCDR:sdn_parameter_urn = "" ;
		SCDR:sdn_uom_name = "Dimensionless" ;
		SCDR:sdn_uom_urn = "SDN:P06::UUUU" ;
	char SCDT(TIME, MAXSITE, STRING4) ;
		SCDT:long_name = "Transmit Antenna Codes" ;
		SCDT:sdn_parameter_name = "" ;
		SCDT:sdn_parameter_urn = "" ;
		SCDT:sdn_uom_name = "Dimensionless" ;
		SCDT:sdn_uom_urn = "SDN:P06::UUUU" ;
	short TIME_SEADATANET_QC(TIME) ;
		TIME_SEADATANET_QC:long_name = "Time SeaDataNet quality flag" ;
		TIME_SEADATANET_QC:valid_range = 0s, 9s ;
```

TIME_SEADATANET_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
TIME_SEADATANET_QC:flag_meanings = "unknown good_data probably_good_data potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value" ;
TIME_SEADATANET_QC:comment = "OceanSITES quality flagging for temporal coordinate." ;
TIME_SEADATANET_QC:FillValue = -32767s ;
TIME_SEADATANET_QC:scale_factor = 1s ;
TIME_SEADATANET_QC:add_offset = 0s ;
TIME_SEADATANET_QC:units = "1" ;
short POSITION_SEADATANET_QC(TIME, DEPH, BEAR, RNGE) ;
POSITION_SEADATANET_QC:long_name = "Position SeaDataNet quality flag" ;
POSITION_SEADATANET_QC:valid_range = 0s, 9s ;
POSITION_SEADATANET_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
POSITION_SEADATANET_QC:flag_meanings = "unknown good_data probably_good_data potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value" ;
POSITION_SEADATANET_QC:comment = "OceanSITES quality flagging for position coordinates" ;
POSITION_SEADATANET_QC:FillValue = -32767s ;
POSITION_SEADATANET_QC:scale_factor = 1s ;
POSITION_SEADATANET_QC:add_offset = 0s ;
POSITION_SEADATANET_QC:units = "1" ;
POSITION_SEADATANET_QC:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
short DEPTH_SEADATANET_QC(TIME) ;
DEPTH_SEADATANET_QC:long_name = "Depth SeaDataNet quality flag" ;
DEPTH_SEADATANET_QC:valid_range = 0s, 9s ;
DEPTH_SEADATANET_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
DEPTH_SEADATANET_QC:flag_meanings = "unknown good_data probably_good_data potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value" ;
DEPTH_SEADATANET_QC:comment = "OceanSITES quality flagging for depth coordinate." ;
DEPTH_SEADATANET_QC:FillValue = -32767s ;
DEPTH_SEADATANET_QC:scale_factor = 1s ;
DEPTH_SEADATANET_QC:add_offset = 0s ;
DEPTH_SEADATANET_QC:units = "1" ;
short QCflag(TIME, DEPH, BEAR, RNGE) ;
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 ;
QCflag:scale_factor = 1s ;
QCflag:add_offset = 0s ;
QCflag:units = "1" ;
QCflag:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
short OWTR_QC(TIME, DEPH, BEAR, RNGE) ;
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 = 1s ;
OWTR_QC:add_offset = 0s ;
OWTR_QC:units = "1" ;
OWTR_QC:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
short MDFL_QC(TIME, DEPH, BEAR, RNGE) ;
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 5 km, 30 deg, 1 m/s, " ;
MDFL_QC:FillValue = -32767s ;
MDFL_QC:scale_factor = 1s ;
MDFL_QC:add_offset = 0s ;
MDFL_QC:units = "1" ;
MDFL_QC:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
short VART_QC(TIME, DEPH, BEAR, RNGE) ;
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. Test not applicable to Direction Finding systems. The Temporal Derivative test is applied. Threshold set to 1 m/s." ;
VART_QC:FillValue = -32767s ;
VART_QC:scale_factor = 1s ;
VART_QC:add_offset = 0s ;
VART_QC:units = "1" ;
VART_QC:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
short CSPD_QC(TIME, DEPH, BEAR, RNGE) ;
CSPD_QC:long_name = "Velocity Threshold Quality Flags" ;
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 1.2 m/s." ;
CSPD_QC:FillValue = -32767s ;
CSPD_QC:scale_factor = 1s ;
CSPD_QC:add_offset = 0s ;
CSPD_QC:units = "1" ;
CSPD_QC:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
short AVRB_QC(TIME) ;
AVRB_QC:long_name = "Average Radial Bearing Quality Flag" ;
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. Thresholds set to [190-250] deg." ;
AVRB_QC:FillValue = -32767s ;
AVRB_QC:scale_factor = 1s ;
AVRB_QC:add_offset = 0s ;
AVRB_QC:units = "1" ;
short RDCT_QC(TIME) ;
RDCT_QC:long_name = "Radial Count Quality Flag" ;
RDCT_QC:valid_range = 0s, 9s ;
RDCT_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;

RDCT_QC:flag_meanings = "unknown good_data probably_good_data potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value" ;
RDCT_QC:comment = "OceanSITES quality flagging for Radial Count QC test. Thresholds set to 200 vectors." ;
RDCT_QC:FillValue = -32767s ;
RDCT_QC:scale_factor = 1s ;
RDCT_QC:add_offset = 0s ;
RDCT_QC:units = "1" ;

// global attributes:
:site_code = "HFR_TirLig" ;
:platform_code = "HFR_TirLig_MONT" ;
:data_mode = "R" ;
:DoA_estimation_method = "Direction Finding" ;
:calibration_type = "APM" ;
:last_calibration_date = "2016-06-22T11:23:40Z" ;
:calibration_link = "carlo.mantovani@cnr.it" ;
:title = "Near Real Time Surface Ocean Velocity by HFR_TirLig" ;
: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." ;
:source = "coastal structure" ;
:source_platform_category_code = "17" ;
:institution = "National Research Council - Institute of Marine Science, S.S. Lerici" ;
:institution_edmo_code = "134" ;
:data_assembly_center = "European HFR Node" ;
:id = "HFR_TirLig_MONT_2017-01-01T00:00:00Z" ;
:data_type = "HF radar radial data" ;
:feature_type = "surface" ;
:geospatial_lat_min = "43.68" ;
:geospatial_lat_max = "44.23" ;
:geospatial_lon_min = "9.2" ;
:geospatial_lon_max = "10.1" ;
:geospatial_vertical_max = "4" ;
:geospatial_vertical_min = "0" ;
:time_coverage_start = "2016-12-31T23:30:00Z" ;
:time_coverage_end = "2017-01-01T00:30:00Z" ;
:format_version = "v2.1" ;
:Conventions = "CF-1.6, OceanSITES-Manual-1.2, Copernicus-InSituTAC-SRD-1.4, CopernicusInSituTAC-ParametersList-3.1.0, Unidata, ACDD, INSPIRE" ;

:update_interval = "void" ;
:citation = "These data were collected and made freely available by the Copernicus project and the programs that contribute to it. Data collected and processed by CNR-ISMAR within RITMARE, Jerico-Next and IMPACT projects. " ;
:distribution_statement = "These data follow Copernicus standards; they are public and free of charge. User assumes all risk for use of data. User must display citation in any publication or product using data. User must contact PI prior to any commercial use of data." ;
:publisher_name = "Lorenzo Corgnati" ;
:publisher_url = "http://www.ismar.cnr.it/" ;
:publisher_email = "lorenzo.corgnati@sp.ismar.cnr.it" ;
: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/." ;
:acknowledgment = "ISMAR HF Radar Network has been established within RITMARE, Jerico-Next and IMPACT projects. The network has been designed, implemented and managed through the efforts of ISMAR S.S. Lerici." ;
:date_created = "2018-08-22T15:03:57Z" ;
:history = "2017-01-01T00:00:00Z data collected. 2018-08-22T15:03:57Z netCDF file created and sent to European HFR Node" ;
:date_modified = "2018-08-22T15:03:57Z" ;
:date_update = "2018-08-22T15:03:57Z" ;
:processing_level = "2B" ;
:contributor_name = "Vega Forneris, Cristina Tronconi" ;
:contributor_role = "THREDDS expert, metadata expert" ;
:contributor_email = "vega.forneris@artov.isac.cnr.it, cristina.tronconi@artov.isac.cnr.it" ;
:project = "RITMARE, Jerico-Next, IMPACT and SICOMAR Plus" ;
:naming_authority = "it.cnr.ismar" ;
:keywords = "OCEAN CURRENTS, SURFACE WATER, RADAR, SCR-HF" ;
:keywords_vocabulary = "GCMD Science Keywords" ;
: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." ;
:data_language = "eng" ;
:data_character_set = "utf8" ;
:metadata_language = "eng" ;
:metadata_character_set = "utf8" ;
:topic_category = "oceans" ;
:network = "ISMAR_HFR_TirLig" ;

:area = "Mediterranean Sea" ;
:geospatial_lat_units = "degrees_north" ;
:geospatial_lon_units = "degrees_east" ;
:geospatial_lat_resolution = "0.00048188" ;
:geospatial_lon_resolution = "0.00035611" ;
:geospatial_vertical_resolution = "4" ;
:geospatial_vertical_units = "m" ;
:geospatial_vertical_positive = "down" ;
:time_coverage_duration = "PT1H" ;
:time_coverage_resolution = "PT1H" ;
:reference_system = "EPSG:4806" ;
:cdm_data_type = "Grid" ;
:netcdf_version = "4.3.3.1" ;
:netcdf_format = "netcdf4_classic" ;
:metadata_contact = "lorenzo.corgnati@sp.ismar.cnr.it" ;
:metadata_date_stamp = "2018-08-22T15:03:57Z" ;
:standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table Version 1.6" ;
:sensor = "CODAR SeaSonde" ;
:institution_reference = "http://www.ismar.cnr.it/" ;
: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" ;
:software_name = "HFR_Combiner" ;
:software_version = "v3.1" ;
:date_issued = "2018-08-22T15:03:57Z" ;
:UUID = "DA27C5D5-F89E-4047-9A69-C7A80DF17D54" ;
:manufacturer = "CODAR Ocean Sensors. SeaSonde" ;
:RangeStart = "3" ;
:RangeEnd = "38" ;
:RangeResolutionKMeters = "0.994500" ;
:AntennaBearing = "219.0 True" ;
:ReferenceBearing = "0 True" ;
:AngularResolution = "5 Deg" ;
:SpatialResolution = "5 Deg" ;
:PatternResolution = "1.0 deg" ;
:TransmitCenterFreqMHz = "26.275000" ;
:DopplerResolutionHzPerBin = "0.001953125" ;
:FirstOrderMethod = "0" ;
:BraggSmoothingPoints = "2" ;
:BraggHasSecondOrder = "1" ;
:RadialBraggPeakDropOff = "79.430" ;

```
:RadialBraggPeakNull = "100.000" ;
:RadialBraggNoiseThreshold = "10.000" ;
:PatternAmplitudeCorrections = "1.7459  1.5100" ;
:PatternPhaseCorrections = "-115.30  -120.00" ;
:PatternAmplitudeCalculations = "1.3811  0.9963" ;
:PatternPhaseCalculations = "-120.60  -113.50" ;
: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" ;
```

E. Total velocity data file header example

```
netcdf HFR_TirLig_TOTL_2017_01_01_0100 {
dimensions:
 TIME = 1 ;
 LATITUDE = 31 ;
 LONGITUDE = 37 ;
 STRING50 = 50 ;
 STRING200 = 250 ;
 REFMAX = 1 ;
 DEPH = 1 ;
 MAXSITE = 50 ;
 STRING15 = 15 ;
variables:
 float TIME(TIME) ;
        TIME:long_name = "Time of Measurement UTC" ;
        TIME:standard_name = "time" ;
        TIME:units = "days since 1950-01-01T00:00:00Z" ;
        TIME:calendar = "Julian" ;
        TIME:axis = "T" ;
        TIME:sdn_parameter_name = "Elapsed time (since 1950-01-01T00:00:00Z)"
;
        TIME:sdn_parameter_urn = "SDN:P01::ELTJLD01" ;
        TIME:sdn_uom_name = "Days" ;
        TIME:sdn_uom_urn = "SDN:P06::UTAA" ;
        TIME:ancillary_variables = "TIME_SEADATANET_QC" ;
 float LATITUDE(LATITUDE) ;
        LATITUDE:long_name = "Latitude" ;
        LATITUDE:standard_name = "latitude" ;
        LATITUDE:units = "degrees_north" ;
        LATITUDE:axis = "Y" ;
        LATITUDE:sdn_parameter_name = "Latitude north" ;
        LATITUDE:sdn_parameter_urn = "SDN:P01::ALATZZ01" ;
        LATITUDE:sdn_uom_name = "Degrees north" ;
        LATITUDE:sdn_uom_urn = "SDN:P06::DEGN" ;
        LATITUDE:ancillary_variables = "POSITION_SEADATANET_QC" ;
 float LONGITUDE(LONGITUDE) ;
        LONGITUDE:long_name = "Longitude" ;
        LONGITUDE:standard_name = "longitude" ;
        LONGITUDE:units = "degrees_east" ;
        LONGITUDE:axis = "X" ;
        LONGITUDE:sdn_parameter_name = "Longitude east" ;
        LONGITUDE:sdn_parameter_urn = "SDN:P01::ALONZZ01" ;
```

```
        LONGITUDE:sdn_uom_name = "Degrees east" ;
        LONGITUDE:sdn_uom_urn = "SDN:P06::DEGE" ;
        LONGITUDE:ancillary_variables = "POSITION_SEADATANET_QC" ;
short crs(TIME) ;
        crs:grid_mapping_name = "latitude_longitude" ;
        crs:epsg_code = "EPSG:4326" ;
        crs:semi_major_axis = 6378137. ;
        crs:inverse_flattening = 298.257223563 ;
char SDN_CRUISE(TIME, STRING50) ;
        SDN_CRUISE:long_name = "Grid grouping label" ;
char SDN_STATION(TIME, STRING50) ;
        SDN_STATION:long_name = "Grid label" ;
char SDN_LOCAL_CDI_ID(TIME, STRING50) ;
        SDN_LOCAL_CDI_ID:long_name = "SeaDataCloud CDI identifier" ;
        SDN_LOCAL_CDI_ID:cf_role = "grid_id" ;
short SDN_EDMO_CODE(TIME) ;
        SDN_EDMO_CODE:long_name = "European Directory of Marine
Organisations code for the CDI partner" ;
char SDN_REFERENCES(TIME, STRING200) ;
        SDN_REFERENCES:long_name = "Usage metadata reference" ;
char SDN_XLINK(TIME, REFMAX, STRING200) ;
        SDN_XLINK:long_name = "External resource linkages" ;
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" ;
        DEPH:sdn_parameter_name = "Depth below surface of the water body" ;
        DEPH:sdn_parameter_urn = "SDN:P01::ADEPZZ01" ;
        DEPH:sdn_uom_name = "Metres" ;
        DEPH:sdn_uom_urn = "SDN:P06::ULAA" ;
        DEPH:ancillary_variables = "DEPTH_SEADATANET_QC" ;
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:sdn_parameter_name = "Eastward current velocity in the water body" ;
EWCT:sdn_parameter_urn = "SDN:P01::LCEWZZ01" ;
EWCT:sdn_uom_name = "Metres per second" ;
EWCT:sdn_uom_urn = "SDN:P06::UVAA" ;
EWCT:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
EWCT:valid_range = -10., 10. ;
EWCT:ancillary_variables = "QCflag, VART_QC, CSPD_QC, DDNS_QC, GDOP_QC" ;
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:sdn_parameter_name = "Northward current velocity in the water body" ;
NSCT:sdn_parameter_urn = "SDN:P01::LCNSZZ01" ;
NSCT:sdn_uom_name = "Metres per second" ;
NSCT:sdn_uom_urn = "SDN:P06::UVAA" ;
NSCT:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
NSCT:valid_range = -10., 10. ;
NSCT:ancillary_variables = "QCflag, VART_QC, CSPD_QC, DDNS_QC, GDOP_QC" ;
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 = -10., 10. ;
EWCS:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
EWCS:scale_factor = 1. ;
EWCS:add_offset = 0. ;
EWCS:sdn_parameter_name = "Eastward current velocity standard deviation in the water body" ;
EWCS:sdn_parameter_urn = "SDN:P01::SDEWZZZZ" ;
EWCS:sdn_uom_name = "Metres per second" ;
EWCS:sdn_uom_urn = "SDN:P06::UVAA" ;
EWCS:ancillary_variables = "QCflag, VART_QC" ;
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 = -10., 10. ;
NSCS:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
NSCS:scale_factor = 1. ;
NSCS:add_offset = 0. ;
NSCS:sdn_parameter_name = "Northward current velocity standard deviation in the water body" ;
NSCS:sdn_parameter_urn = "SDN:P01::SDNSZZZZ" ;
NSCS:sdn_uom_name = "Metres per second" ;
NSCS:sdn_uom_urn = "SDN:P06::UVAA" ;
NSCS:ancillary_variables = "QCflag, VART_QC" ;
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 = -10., 10. ;
CCOV:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
CCOV:scale_factor = 1. ;
CCOV:add_offset = 0. ;
CCOV:sdn_parameter_name = "" ;
CCOV:sdn_parameter_urn = "" ;
CCOV:sdn_uom_name = "Square metres per second squared" ;
CCOV:sdn_uom_urn = "SDN:P06::SQM2" ;
CCOV:ancillary_variables = "QCflag" ;
double GDOP(TIME, DEPH, LATITUDE, LONGITUDE) ;
GDOP:_FillValue = 9.96920996838687e+36 ;
GDOP:long_name = "Geometrical Dilution of precision" ;
GDOP:units = "1" ;
GDOP:valid_range = -20., 20. ;
GDOP:coordinates = "TIME DEPH LATITUDE LONGITUDE" ;
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. 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." ;
GDOP:sdn_parameter_name = "" ;
GDOP:sdn_parameter_urn = "" ;
GDOP:sdn_uom_name = "Dimensionless" ;
GDOP:sdn_uom_urn = "SDN:P06::UUUU" ;
GDOP:ancillary_variables = "QCflag, GDOP_QC" ;
short TIME_SEADATANET_QC(TIME) ;
TIME_SEADATANET_QC:_FillValue = -32767s ;
TIME_SEADATANET_QC:long_name = "Time SeaDataNet quality flag" ;
TIME_SEADATANET_QC:units = "1" ;
TIME_SEADATANET_QC:valid_range = 0s, 9s ;
TIME_SEADATANET_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
TIME_SEADATANET_QC:flag_meanings = "unknown good_data probably_good_data potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value" ;
TIME_SEADATANET_QC:comment = "OceanSITES quality flagging for temporal coordinate." ;
TIME_SEADATANET_QC:scale_factor = 1s ;
TIME_SEADATANET_QC:add_offset = 0s ;
short POSITION_SEADATANET_QC(TIME, DEPH, LATITUDE, LONGITUDE) ;
POSITION_SEADATANET_QC:_FillValue = -32767s ;
POSITION_SEADATANET_QC:long_name = "Position SeaDataNet quality flag" ;
POSITION_SEADATANET_QC:units = "1" ;
POSITION_SEADATANET_QC:valid_range = 0s, 9s ;
POSITION_SEADATANET_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
POSITION_SEADATANET_QC:flag_meanings = "unknown good_data probably_good_data potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value" ;
POSITION_SEADATANET_QC:comment = "OceanSITES quality flagging for position coordinates." ;
POSITION_SEADATANET_QC:scale_factor = 1s ;
POSITION_SEADATANET_QC:add_offset = 0s ;
short DEPTH_SEADATANET_QC(TIME) ;
DEPTH_SEADATANET_QC:_FillValue = -32767s ;
DEPTH_SEADATANET_QC:long_name = "Time SeaDataNet quality flag" ;
DEPTH_SEADATANET_QC:units = "1" ;
DEPTH_SEADATANET_QC:valid_range = 0s, 9s ;
DEPTH_SEADATANET_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
DEPTH_SEADATANET_QC:flag_meanings = "unknown good_data probably_good_data potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value" ;

DEPTH_SEADATANET_QC:comment = "OceanSITES quality flagging for depth coordinate." ;
DEPTH_SEADATANET_QC:scale_factor = 1s ;
DEPTH_SEADATANET_QC:add_offset = 0s ;
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 VART_QC(TIME, DEPH, LATITUDE, LONGITUDE) ;
VART_QC:_FillValue = -32767s ;
VART_QC:long_name = "Variance Threshold Quality flags" ;
VART_QC:units = "1" ;
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. Test not applicable to Direction Finding systems. The Temporal Derivative test is applied.Threshold set to 1.2 m/s. " ;
VART_QC:scale_factor = 1s ;
VART_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 2." ;
GDOP_QC:scale_factor = 1s ;
GDOP_QC:add_offset = 0s ;

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short DDNS_QC(TIME, DEPH, LATITUDE, LONGITUDE) ;
        DDNS_QC:_FillValue = -32767s ;
        DDNS_QC:long_name = "Data density Threshold Quality flags" ;
        DDNS_QC:units = "1" ;
        DDNS_QC:valid_range = 0s, 9s ;
        DDNS_QC:flag_values = 0s, 1s, 2s, 3s, 4s, 7s, 8s, 9s ;
        DDNS_QC:flag_meanings = "unknown good_data probably_good_data potentially_correctable_bad_data bad_data nominal_value interpolated_value missing_value" ;
        DDNS_QC:comment = "OceanSITES quality flagging for Data density threshold QC test. Threshold set to 3 radials." ;
        DDNS_QC:scale_factor = 1s ;
        DDNS_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 1.2 m/s." ;
        CSPD_QC:scale_factor = 1s ;
        CSPD_QC:add_offset = 0s ;
short NARX(TIME) ;
        NARX:_FillValue = -32767s ;
        NARX:long_name = "Number of Receive Antennas" ;
        NARX:units = "1" ;
        NARX:valid_range = 0s, 50s ;
        NARX:scale_factor = 1s ;
        NARX:add_offset = 0s ;
        NARX:sdn_parameter_name = "" ;
        NARX:sdn_parameter_urn = "" ;
        NARX:sdn_uom_name = "Dimensionless" ;
        NARX:sdn_uom_urn = "SDN:P06::UUUU" ;
short NATX(TIME) ;
        NATX:_FillValue = -32767s ;
        NATX:long_name = "Number of Transmit Antennas" ;
        NATX:units = "1" ;
        NATX:valid_range = 0s, 50s ;
        NATX:scale_factor = 1s ;
```

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		NATX:add_offset = 0s ;
		NATX:sdn_parameter_name = "" ;
		NATX:sdn_parameter_urn = "" ;
		NATX:sdn_uom_name = "Dimensionless" ;
		NATX:sdn_uom_urn = "SDN:P06::UUUU" ;
	float SLTR(TIME, MAXSITE) ;
		SLTR:_FillValue = 9.96921e+36f ;
		SLTR:long_name = "Receive Antennas Latitudes" ;
		SLTR:standard_name = "latitude" ;
		SLTR:units = "degrees_north" ;
		SLTR:valid_range = -90.f, 90.f ;
		SLTR:coordinates = "TIME MAXSITE" ;
		SLTR:scale_factor = 1.f ;
		SLTR:add_offset = 0.f ;
		SLTR:sdn_parameter_name = "Latitude north" ;
		SLTR:sdn_parameter_urn = "SDN:P01::ALATZZ01" ;
		SLTR:sdn_uom_name = "Degrees north" ;
		SLTR:sdn_uom_urn = "SDN:P06::DEGN" ;
	float SLNR(TIME, MAXSITE) ;
		SLNR:_FillValue = 9.96921e+36f ;
		SLNR:long_name = "Receive Antennas Longitudes" ;
		SLNR:standard_name = "longitude" ;
		SLNR:units = "degrees_east" ;
		SLNR:valid_range = -180.f, 180.f ;
		SLNR:coordinates = "TIME MAXSITE" ;
		SLNR:scale_factor = 1.f ;
		SLNR:add_offset = 0.f ;
		SLNR:sdn_parameter_name = "Longitude east" ;
		SLNR:sdn_parameter_urn = "SDN:P01::ALONZZ01" ;
		SLNR:sdn_uom_name = "Degrees east" ;
		SLNR:sdn_uom_urn = "SDN:P06::DEGE" ;
	float SLTT(TIME, MAXSITE) ;
		SLTT:_FillValue = 9.96921e+36f ;
		SLTT:long_name = "Transmit Antennas Latitudes" ;
		SLTT:standard_name = "latitude" ;
		SLTT:units = "degrees_north" ;
		SLTT:valid_range = -90.f, 90.f ;
		SLTT:coordinates = "TIME MAXSITE" ;
		SLTT:scale_factor = 1.f ;
		SLTT:add_offset = 0.f ;
		SLTT:sdn_parameter_name = "Latitude north" ;
		SLTT:sdn_parameter_urn = "SDN:P01::ALATZZ01" ;
		SLTT:sdn_uom_name = "Degrees north" ;
```

```
		SLTT:sdn_uom_urn = "SDN:P06::DEGN" ;
	float SLNT(TIME, MAXSITE) ;
		SLNT:_FillValue = 9.96921e+36f ;
		SLNT:long_name = "Transmit Antennas Longitudes" ;
		SLNT:standard_name = "longitude" ;
		SLNT:units = "degrees_east" ;
		SLNT:valid_range = -180.f, 180.f ;
		SLNT:coordinates = "TIME MAXSITE" ;
		SLNT:scale_factor = 1.f ;
		SLNT:add_offset = 0.f ;
		SLNT:sdn_parameter_name = "Longitude east" ;
		SLNT:sdn_parameter_urn = "SDN:P01::ALONZZ01" ;
		SLNT:sdn_uom_name = "Degrees east" ;
		SLNT:sdn_uom_urn = "SDN:P06::DEGE" ;
	char SCDR(TIME, MAXSITE, STRING15) ;
		SCDR:_FillValue = "" ;
		SCDR:long_name = "Receive antenna Codes" ;
		SCDR:sdn_parameter_name = "" ;
		SCDR:sdn_parameter_urn = "" ;
		SCDR:sdn_uom_name = "Dimensionless" ;
		SCDR:sdn_uom_urn = "SDN:P06::UUUU" ;
	char SCDT(TIME, MAXSITE, STRING15) ;
		SCDT:_FillValue = "" ;
		SCDT:long_name = "Transmit antenna Codes" ;
		SCDT:sdn_parameter_name = "" ;
		SCDT:sdn_parameter_urn = "" ;
		SCDT:sdn_uom_name = "Dimensionless" ;
		SCDT:sdn_uom_urn = "SDN:P06::UUUU" ;

// global attributes:
		:site_code = "HFR_TirLig" ;
		:platform_code = "HFR_TirLig_Total" ;
		:data_mode = "R" ;
		:DoA_estimation_method = "Direction Finding" ;
		:calibration_type = "APM" ;
		:last_calibration_date = "2016-09-07T00:00:00Z" ;
		:calibration_link = "carlo.mantovani@cnr.it" ;
		:title = "Near Real Time Surface Ocean Velocity by HFR_TirLig" ;
		: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." ;
		:source = "coastal structure" ;
```

:source_platform_category_code = "17" ;
:institution = "National Research Council - Institute of Marine Science, S.S. Lerici" ;
:institution_edmo_code = "134" ;
:data_assembly_center = "European HFR Node" ;
:id = "HFR_TirLig_Total_2017-01-01T01:00:00Z" ;
:data_type = "HF radar total data" ;
:feature_type = "surface" ;
:geospatial_lat_min = "43.68" ;
:geospatial_lat_max = "44.23" ;
:geospatial_lon_min = "9.2" ;
:geospatial_lon_max = "10.1" ;
:geospatial_vertical_min = "0" ;
:geospatial_vertical_max = "4" ;
:time_coverage_start = "2017-01-01T00:30:00Z" ;
:time_coverage_end = "2017-01-01T01:30:00Z" ;
:format_version = "v2.1" ;
:Conventions = "CF-1.6, OceanSITES-Manual-1.2, Copernicus-InSituTAC-SRD-1.4, CopernicusInSituTAC-ParametersList-3.1.0, Unidata, ACDD, INSPIRE" ;
:update_interval = "void" ;
:citation = "These data were collected and made freely available by the Copernicus project and the programs that contribute to it. Data collected and processed by CNR-ISMAR within RITMARE, Jerico-Next and IMPACT projects. " ;
:distribution_statement = "These data follow Copernicus standards; they are public and free of charge. User assumes all risk for use of data. User must display citation in any publication or product using data. User must contact PI prior to any commercial use of data." ;
:publisher_name = "Lorenzo Corgnati" ;
:publisher_url = "http://www.ismar.cnr.it/" ;
:publisher_email = "lorenzo.corgnati@sp.ismar.cnr.it" ;
: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/." ;
:acknowledgment = "ISMAR HF Radar Network has been established within RITMARE, Jerico-Next and IMPACT projects. The network has been designed, implemented and managed through the efforts of ISMAR S.S. Lerici." ;
:date_created = "2018-09-28T16:51:17Z" ;
:history = "2017-01-01T01:00:00Z data collected. 2018-09-28T16:51:17Z netCDF file created and sent to European HFR Node" ;
:date_modified = "2018-09-28T16:51:17Z" ;
:date_update = "2018-09-28T16:51:17Z" ;
:processing_level = "3B" ;

:contributor_name = "Vega Forneris, Cristina Tronconi" ;
:contributor_role = "THREDDS expert, metadata expert" ;
:contributor_email = "vega.forneris@artov.isac.cnr.it, cristina.tronconi@artov.isac.cnr.it" ;
:project = "RITMARE, Jerico-Next, IMPACT and SICOMAR Plus" ;
:naming_authority = "it.cnr.ismar" ;
:keywords = "OCEAN CURRENTS, SURFACE WATER, RADAR, SCR-HF" ;
:keywords_vocabulary = "GCMD Science Keywords" ;
: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." ;
:data_language = "eng" ;
:data_character_set = "utf8" ;
:metadata_language = "eng" ;
:metadata_character_set = "utf8" ;
:topic_category = "oceans" ;
:network = "ISMAR_HFR_TirLig" ;
:area = "Mediterranean Sea" ;
:geospatial_lat_units = "degrees_north" ;
:geospatial_lon_units = "degrees_east" ;
:geospatial_lat_resolution = "0.018" ;
:geospatial_lon_resolution = "0.024917" ;
:geospatial_vertical_resolution = "4" ;
:geospatial_vertical_units = "m" ;
:geospatial_vertical_positive = "down" ;
:time_coverage_duration = "PT1H" ;
:time_coverage_resolution = "PT1H" ;
:reference_system = "EPSG:4806" ;
:grid_resolution = "2" ;
:cdm_data_type = "Grid" ;
:netcdf_version = "4.3.3.1" ;
:netcdf_format = "netcdf4_classic" ;
:metadata_contact = "lorenzo.corgnati@sp.ismar.cnr.it" ;
:metadata_date_stamp = "2018-09-28T16:51:17Z" ;
:standard_name_vocabulary = "NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table Version 1.6" ;
:sensor = "CODAR SeaSonde" ;
:institution_reference = "http://www.ismar.cnr.it/" ;
:date_issued = "2018-09-28T16:51:17Z" ;
:software_name = "HFR_Combiner" ;
:software_version = "v3.1" ;

: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" ;