IMOS Integrated Marine Observing System

Ocean Radar Facility

Quality Control procedures for IMOS Ocean Radar

Manual version 3.0

January 2024

Table of Contents

Versioning

Version	Date	Comment	Author
1.0	September 2017	Creation of document for RT FV00 radials and vectors for Seasonde and WERA systems	Simone Cosoli
1.1	October 2017	Added documentation on QC procedures for DM FV01 radials and vectors for WERA system	Simone Cosoli
1.2	October 2017	Added documentation on QC procedures for DM FV01 wave and wind for WERA system	Simone Cosoli
1.3.1	January 2018	Updated documentation on QC procedures for RT FV00 vectors for WERA systems	Simone Cosoli
1.3.2	January 2018	Added documentation on QC procedures for RT FV00 vectors for WERA systems	Simone Cosoli Badema Grcic
1.3.3	March 2019	Updated Section 2.1, updated Section 2.2, added reference literature, added co-authorship, added DM QC test for Seasonde vectors; linked doi	Simone Cosoli
2.0	March 2019	Updated Facility name from ACORN to IMOS Ocean Radar Facility; updated versioning number. Corrected a number of typos and updated file content; changed Facility logo	Simone Cosoli
2.1	November 2019	Added DM Quality control procedure for SeaSonde systems (Section 2.6); updated versioning number. Added description of DM FV01 SeaSonde radial files. Updated citation.	Simone Cosoli
3.0	January 2024	Refreshed the entire document to reflect for software updates and newly implemented QC tests, Added specification and handling for WERA radial maps collected in single DF (Direction Finding) – hybrid DF-BF (Direction Finding – Beam Forming). Removed DM QC for met-ocean (wind, wave) products for WERA radars	Simone Cosoli

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1. Introduction

The IMOS Ocean Radar Facility Quality-Control and Data User's Manual is a comprehensive guide designed for individuals utilizing the Facility's data. A crucial element within Australia's Integrated Marine Observing System (IMOS), this manual outlines the data stream, data products, data formats, and the quality control procedures applicable to both real-time (RT) and delayed-mode (DM) data produced by the Facility.

1.1 The IMOS Ocean Radar program

HFR (HF Radar) systems offer a cost-effective solution to enhance existing in-situ measurements with unparalleled spatial and temporal resolutions. They provide data capable of capturing a wide range of time scales, from daily fluctuations, including near-inertial oscillations, to sub-mesoscale, mesoscale, basin-wide, and seasonal to inter-annual variations. These systems are instrumental in monitoring diverse processes such as upwelling, open ocean-shelf interactions, coastal return flow dynamics, sediment transport, and have significant potential for tsunami detection and early-warning systems. By integrating real-time data into regional circulation models, they can estimate surface flows, facilitating improved trajectory modeling for operations like search and rescue or oil spill response.

The Ocean Radar Facility deploys two primary types of ocean surface radars used globally: the Phased Array genre (WERA) made in Germany and the Direction Finding genre (SeaSonde or CODAR) manufactured in California (US). WERA systems comprise separate transmit and receive antenna arrays, while SeaSonde systems, though typically integrating transmit and receive elements, in the case of the Facility, require separate antennas for transmitting and receiving. The SeaSonde radar systems mandate a minimum separation of two radar wavelengths between the transmit and receive elements to function effectively.

Currently, WERA HFR systems are deployed along the Ningaloo peninsula and the Rottnest Shelf region (WA), South Australia Gulfs region (SA), and Coffs Harbour (NSW). Simultaneously, SeaSonde HFR systems are operational in the Turquoise and the Coral Coast (WA) and in the Newcastle area, north of Sydney (NSW).

The main purpose of both radar types is to gather data on sea surface currents within specified grids at 1-hour temporal resolution. To create surface current maps where radar stations overlap, two radar stations are necessary; these radars primarily detect the radial component of ocean currents moving toward or away from the radar receivers.

For SeaSonde HFR systems operated in purely monostatic configuration, radial currents are sampled using a polar coordinate grid, with the range resolution determined by transmit bandwidth and software controlling the angular resolution, typically set at 1˚ or 5˚. The accuracy of determining radial velocity direction (DOA) poses a significant uncertainty factor for these systems, reliant on precise calibration and proper selection of first-order limits for the Bragg peaks.

On the other hand, WERA HFR systems map radial currents onto a predetermined rectangular grid when operated in a beam-forming configuration, and in a polar grid when operated in direction-finding configuration. Several factors, including antenna sidelobes, noise, and interferences, influence the accuracy of radial current measurements. Calibration is crucial for improving measurement quality in these systems.

Both WERA and SeaSonde radars derive surface current maps on regular grids. SeaSonde systems employ a least-square approach, using radial observations within a specific search radius (R) around each grid point from contributing sites in the mapping process. The method's effectiveness depends on the geometry of intersecting radar beams and the relative contribution of radial velocities from each contributing station.
Similarly, WERA radars utilize a comparable inversion method, where intersecting radar beam geometry remains critical. For WERA systems a 1:1 contribution from the two radar stations is used, although the number of contributing radial information available at every mapping time step can differ.

Additional data products can be accessible, encompassing sea state parameters (such as significant wave height, wave period, and wave direction) and wind direction at the sea surface.
Similar to surface currents, obtaining sea state parameters (from either SeaSonde or WERA systems) and wind direction maps (from WERA systems) necessitates an overlapping coverage area between the radar systems. These data products also require longer integration times compared to currents, enhancing the reliability of estimates concerning second-order Bragg regions (wave parameters). Additionally, spatial averaging between adjacent grid cells might be necessary to minimize variance.

Within the IMOS Ocean Radar Facility, a blend of proprietary and custom software is employed to handle different data products.
Proprietary software is utilized for real-time (RT) and delayed-mode (DM) mapping of radial velocity and surface current vectors derived from SeaSonde systems. For WERA systems, a mix of proprietary and custom software is employed to handle RT and DM radial velocities and currents. Wind direction maps and wave parameters are exclusively available in DM mode, utilizing a customized version of the licensed SeaView software. These DM products have been discontinued since 2021.

This manual aims at detailing the quality-control (QC) procedures for real-time (RT) and delayed-mode (DM) products implemented within the IMOS Ocean Radar Facility. The QC tests for RT and DM described here align with the Level-0 to Level-3 categories as defined in the QARTOD documentation, and apply respectively to:

- Level 0: Doppler spectrum.
- Level 1: radial velocity data.
- Level 2: surface current data.
- Level 3: derived products.

All tests have been devised and implemented in alignment with, or as enhancements to, the existing real-time (RT) and delayed-mode (DM) quality control (QC) procedures prevalent within the HFR community. The IMOS Ocean Radar Facility primarily employs Level 1 and Level 2 QC tests. Efforts are underway to expand QC assessments to encompass Level 0 products, aiming to reduce the necessity for additional processing and optimize the data products. It is assumed that SeaSonde systems are appropriately calibrated with accurate antenna pattern measurements, while the WERA systems utilize proper phase calibrations and updated antenna locations.

Furthermore, the manual details the file formats and standards adopted by the IMOS Ocean Radar Facility, employing the NetCDF-4 file format with IMOS1.4 and CF-1.6 (Climate and Forecast) metadata conventions. The selection of data formats is based on the NetCDF format due to the following reasons:

- It is the standardized data format widely accepted within the HFR user community.
- It is a self-descriptive format for which tools are readily available.
- It is a reliable and efficient format facilitating data exchange.

The document's structure is as follows:

Real-Time (RT) FV00 Products:

- Quality control procedures for RT FV00 WERA radials and currents.
- Quality control procedures for RT FV00 SeaSonde radials and currents.
- File format for RT FV00 WERA radials and currents.
- File format for RT FV00 SeaSonde radials and currents.

Delayed-Mode (DM) FV01 Products:

- Quality control procedures for DM FV01 WERA radials and currents.
- Quality control procedures for DM FV01 SeaSonde radials and currents.
- File format for DM FV01 WERA radials and currents.
- File format for DM FV01 SeaSonde radials and currents.

1.2 Data Flagging conventions.

The QC flags utilized in this document align with the directives outlined in the IOC Manuals and guides No. 54 - Volume 3, established by the Intergovernmental Oceanographic Commission of UNESCO – International Oceanographic Data and Information Exchange (IODE).

Table 1. Quality flags in use for the real time and delayed mode and associated description.

Flag value	Meaning	Description
0	No QC performed	The level at which all data enter the working archive. They have not yet been quality controlled
1	Good data	Top quality data in which no malfunctions have been identified and all real features have been verified during the quality control process.
2	Probably good data	Good data in which some features (probably real) are present but these are unconfirmed. Code 2 data are also data in which minor malfunctions may be present but these errors are small and/or can be successfully corrected without seriously affecting the overall quality of the data.
3	Bad data that are potentially correctable	Suspect data in which unusual, and probably erroneous features are observed.
4	Bad data	Obviously erroneous values are observed.
5	Value changed	Altered by a QC centre, with original values

		(before the change) preserved in the history record of the data.
6	Not used	Reserved for future use.
7	Not used	Reserved for future use.
8	Interpolated value	Indicates that data values are interpolated.
9	Missing value	Indicates that the element is missing.

The Ocean Radar Facility utilizes various QC tests, as detailed in this document, to assess the reliability of measurements. When an individual test fails, a QC value of flag = 4 ('bad data') is attributed to the corresponding data point. These test outcomes are combined into a unified IODE-compliant QC flag value (see Table 1) and then stored in the resulting netCDF file.

For scalar delayed-mode products like radial velocities, an example presented in Table 2 demonstrates this methodology. Concerning vector products (such as ocean current maps depicting two velocity components), the results from QC tests on both components are merged into a single flag. If there's a "Fail = 4" in one component (e.g., UCUR or VCUR), the same flag is applied to the other component (VCUR or UCUR) to address potential biases in both current magnitude and direction.

Table 2. Aggregated QC flags and associated description.

Flags	Condition	Flag meaning
Fail = 4	All the four QC test failed	Bad data
Fail = 3	At least three QC tests failed	Bad data that are potentially correctable
Pass = 2	At least two QC tests passed	Probably good data
Pass = 1	All the four QC tests passed	Good data

2. Quality Control (QC) tests and procedures

2.1 Real-time Quality Control tests for WERA radials

2.1.1 Beam-Forming (BF) gridded data

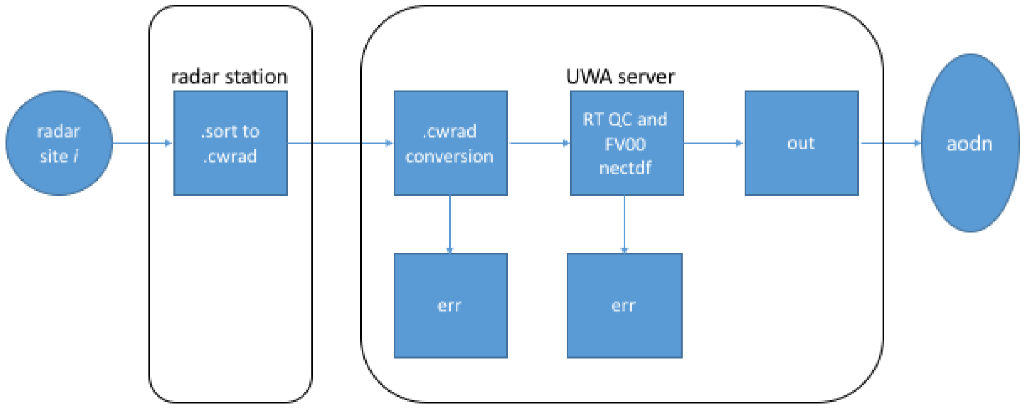


Figure 1*. The IMOS Ocean Radar Facility processing flow for real-time (FV00) data stream for WERA radial currents.*

The processing sequence for the real-time (RT) radial currents in the WERA systems is outlined in Figure 1. During regular operations, range time series measurements are recorded over a 5-minute integration interval occurring every 10 minutes. Processing scripts are invoked to generate radial surface currents once the data acquisition phase is complete. The script named process_SORT.sh is employed to process range time series files (.SORT) and produce .spec files, which, in turn, are utilized to generate radial surface current files (.crad) and wave spectrum files (.wrad).

The raw binary (.crad) files undergo processing, quality control checks, and conversion into netCDF-4 format at the UWA server[1]. The initial step in the quality control (QC) process involves converting the raw file. The binary file formats (.crad, .wrad) follow a standardized convention (Figure 2). They commence with a block-size indicator, followed by the data block, and conclude with a block-size cyclic redundancy check (CRC). Both the block-size indicator and CRC consist of a 4-byte Integer.
The majority of the data is structured in 4-byte chunks of Integer or Float types. The header comprises Char type elements, and there's an information block that can comprise mixed types. The block-size indicator denotes the total size of the data block, while the block-size CRC confirms the integrity of the data block, verifying that its value matches the block-size indicator before the data block. After conversion, QC tests are conducted, and the netCDF file is generated.

If any of the stages involving file conversions, QC procedures, or netCDF creation encounter any issues, the incoming data file is rerouted to an error directory for subsequent troubleshooting. Conversely, upon successful completion of all steps in the processing sequence, the raw file is moved to the processed directory. QC flags are generated and stored in the updated netCDF file format within the output folder. Simultaneously, a duplicate file is generated in the queued directory. Here, a cronjob initiates a metadata compliance check and verifies file integrity. If these checks fail, the file is relocated to an 'error' folder, and comprehensive details of the failure are logged.
However, if the checks are successful, the cronjob proceeds to trigger data upload to the AODN incoming directory for further processing and eventual upload to the thredds portal. After the upload process is complete, the file is automatically removed from the queued directory.

The automatic real-time (RT) quality control (QC) tests applied to the WERA radial currents include the following procedures:

1. Land masking.
2. Radial velocity threshold.
3. Signal-to-Noise Ratio (SNR) threshold.
4. SNR spatial filtering.
5. Radial velocity standard error threshold.

Test 1 – Land mask

[1] Starting from 2021 and following software (WERA user PC operating system and WERA processing software) and hardware upgrades, the customised (merged) version of the WERA radial files documented in previous version of the manual is no longer in use, with the standard output of the WERA processing software being used instead for operational purposes.

Flags	Condition	Codable Instructions
Fail = 4	Radial velocity on land	If POSITION=land, flag = 4
Pass = 1	Radial velocity on water	POSITION=water, flag = 1

Test 2 – Radial velocity threshold

Flags	Condition	Codable Instructions
Fail = 4	Radial velocity above a predefined regional threshold	If RPSD > RSPDMAX, flag =4;
Pass = 1	Radial velocity below a predefined regional threshold	If RSPD <= RSPDMAX, flag =1
Example: RSPDMAX=1.5 (m s-1)		

This test aims at ensuring that a radial current velocity is not unrealistically high. The IMOS Ocean Radar Facility defines the maximum values for radial velocity either based on long-terms statistics of the radial velocity or using available records from other instruments in the region [1].

***Figure 2**. Structure of a WERA merged (radial, wave and frequency scan) binary file. The first block contains radial current information; single-radar wave information is stored in the second block. The third block contains a spectrum scan performed 2 minutes before the beginning of the acquisition cycle. WERA systems have the capabilities to dynamically adapt the operating frequency within the allocated frequency band, in attempt to decrease interference to normal operations. WERA HFRs managed by the IMOS Ocean Radar Facility however do not currently implement this feature.*

Test 3 – Signal-to-Noise Ratio (SNR)

Flags	Condition	Codable Instructions
Fail = 4	SNR for the dominant Bragg peak less than a minimum value	If SNR < SNRMIN, flag = 4
Pass = 1	SNR for the dominant Bragg peak above a minimum value	If SNR >= SNRMIN, flag =1
Example: SNRMIN=10 (dB)		

This test is designed to ensure that the detected signal surpasses a minimum noise level [1]. Within the IMOS Ocean Radar Facility, the minimum Signal-to-Noise Ratio (SNR) threshold on radial velocity is established through quantitative assessments comparing it with independent measurements. These independent measurements may include subsurface current data from moorings or near-surface velocity measurements obtained from drifters within the radar coverage area. The determination of thresholds is based on optimizing the root-mean-square difference, correlation coefficients, and regression parameters of the best-fit model between radar data and independent datasets, considering the trade-off with data loss. Figure 3 provides an example illustrating the optimization process for the Guilderton (GUI) radar station.

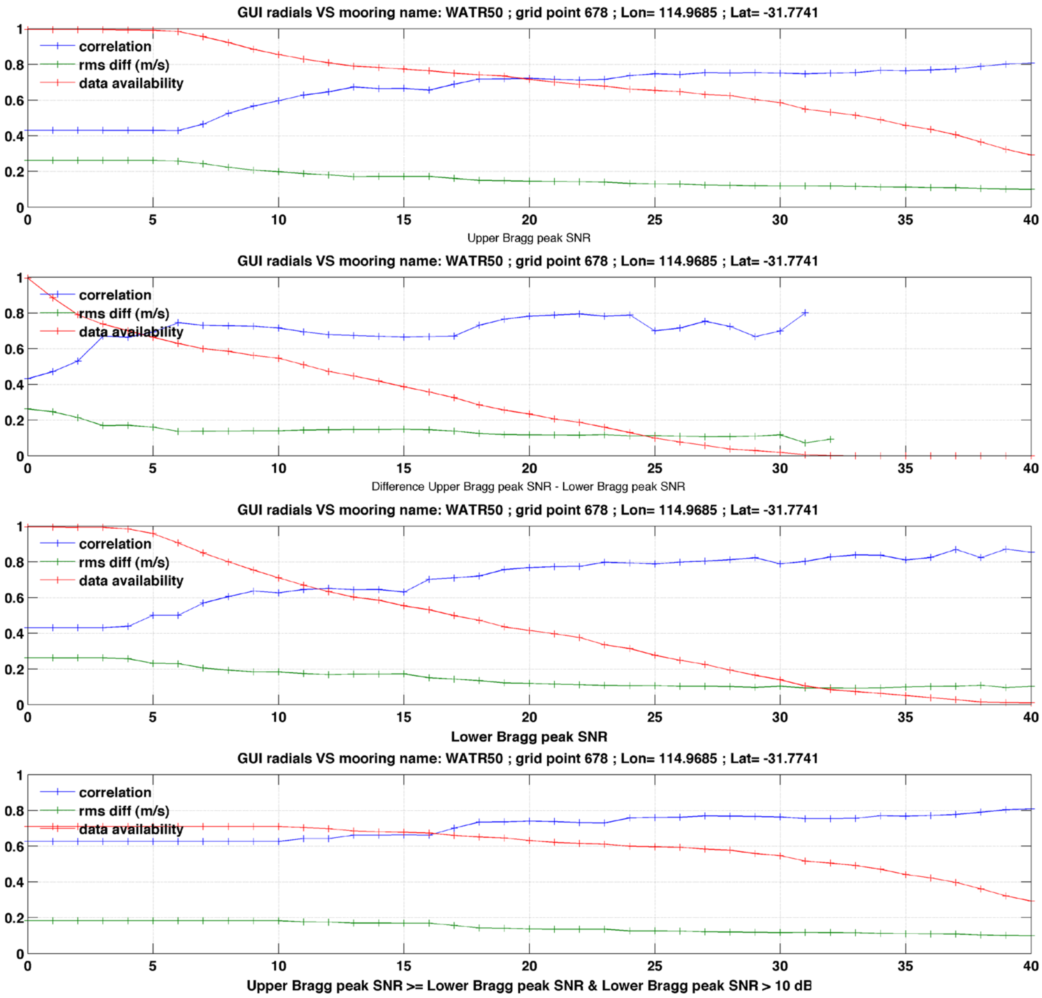


Figure 3. Example of the optimization process determining the minimum Signal-to-Noise Ratio (SNR) threshold for IMOS WERA radar systems. This procedure involves quantitative comparisons between subsurface velocity data and radar radial currents at the radar grid point nearest to the mooring location. Various SNR threshold values are evaluated, calculating correlation coefficients, root-mean-square (rms) differences, and the percentage of available data. The optimal SNR threshold is identified by observing statistically significant changes in correlation coefficients and rms differences, ensuring that data availability remains above 90%. This threshold is determined when notable alterations occur in correlation coefficients and rms differences, maintaining data availability at an acceptable level.

Test 4 – Spatial distribution of the Signal-to-Noise Ratio (SNR)

Flags	Condition	Codable Instructions
Fail = 4	SNR for the dominant Bragg peak above a range dependent threshold. Reject due to excess signal level.	abs(SNRfit- SNR)>3*fit_err, flag = 4
Pass = 1	SNR for the dominant Bragg peak above a minimum value	If abs(SNRfit- SNR)<3*fit_err, flag = 1
Example: SNRMIN=10 (dB)		

This test is aimed at detecting and marking suspicious radial velocities by analysing the spatial distribution of corresponding Signal-to-Noise Ratio (SNR) values along each radar beam. The IMOS Ocean Radar Facility employs the following strategies to identify and flag suspect data points [1]:

1. **Polynomial Function Fitting Approach:**
    - A polynomial function is fitted to the SNR values, and differences in statistics are calculated.
    - Data points exceeding an acceptable error threshold are flagged and removed.
    - The iteration continues with updated error statistics, flagging new data points.
    - This iterative process concludes for a specific radar beam when no additional data points are flagged or when reaching a pre-defined maximum number of iterations.

2. **2D Surface Function Fitting Approach:**
    - A 2D surface function is fitted to the SNR values, and differences in statistics are calculated.
    - Data points surpassing an acceptable error threshold are flagged and removed.
    - Iteration proceeds with updated error statistics, flagging new data points.
    - The iterative process terminates either when no additional data points are flagged or when reaching a pre-set number of iterations.

This method is specifically designed to address bias in radial velocity data resulting from contamination of the first-order Bragg region by the 50Hz signal interference. The interference at 50Hz originates from various sources, whether internal or external to the WERA hardware (power line interference, inadequate grounding, or insufficient electric insulation). It typically presents as a distinctive feature in the Doppler spectra, often appearing at multiples of the 50Hz frequency associated with the 220VAC power line. At a sampling rate of 2Hz, this signal becomes visible, notably at range cell (RC) 25 and its harmonics. This issue notably affects WERA systems in Coffs Harbour (NSW). Figure 4 provides an example displaying contaminated Doppler spectra along the boresight direction for the Red Rock (NSW) site, while Figure 5 illustrates the resultant effects on radial velocity and Signal-to-Noise Ratio (SNR) maps.

Test 5 – Radial error velocity threshold

Flags	Condition	Codable Instructions
Fail = 4	Radial velocity error above a predefined threshold	If RSPDERR > RSPDERRMAX, flag = 4
Pass = 1	Radial velocity error below a predefined threshold	If RSPDERR <= RSPDERRMAX, flag = 1
Example: RSPDERRMAX=0.10 (m s-1)		

This test aims at ensuring that the accuracy associated with a radial current velocity is not unrealistically low.

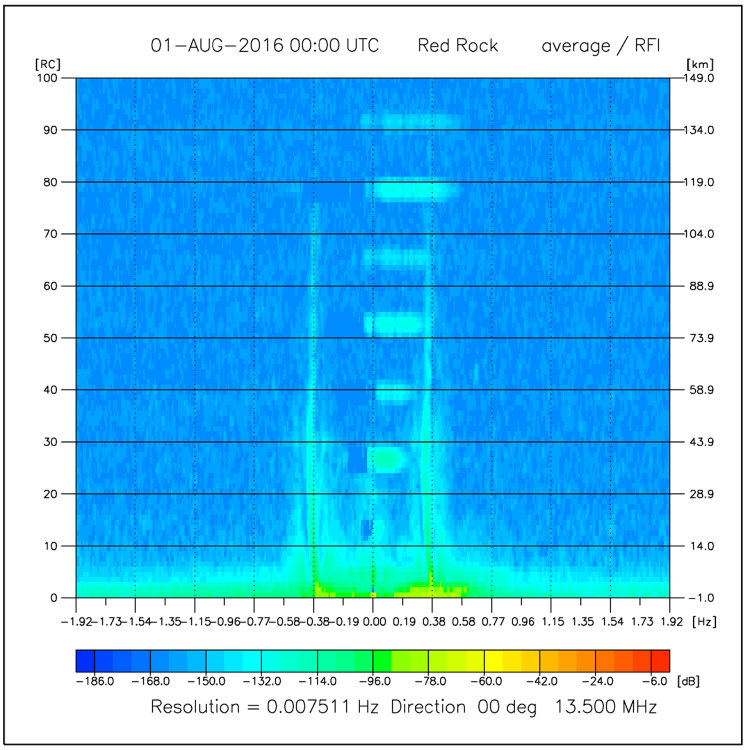


Figure 4. *Example of beam-formed Doppler spectra along the radar receive boresight angle for Red Rock (rrk) station in Coffs Harbour, New South Wales.*

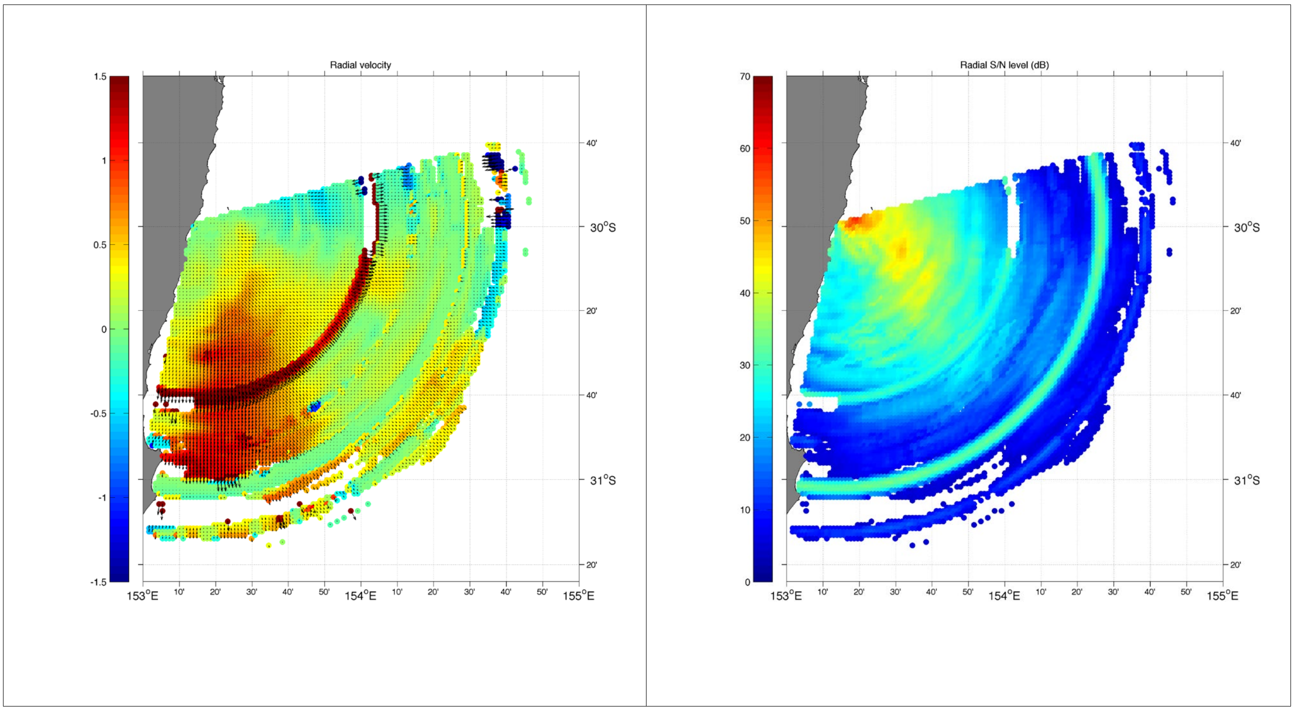


Figure 5a. *Radial current map and corresponding distribution of SNR.*

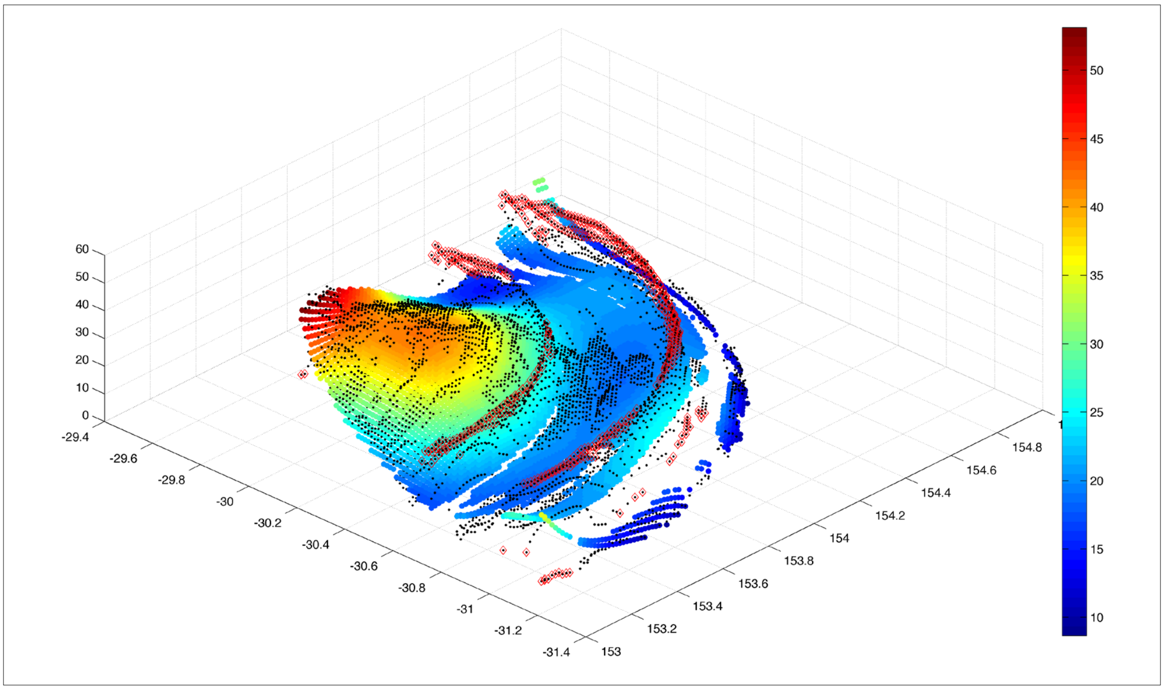


Figure 5b. *Example of 2D fit to SNR map for the radial map shown in Figure 5a. Anomalous data detected at the 1st iteration is flagged as red marks.*

2.1.2 Direction-Finding (DF) WERA radial maps

It is possible to operate a WERA system in simultaneous Direction Finding (DF) and Beamforming (BF) mode by reconfiguring the geometry of the receive array. This configuration alteration involves the addition of a pair of antennas and requires updates to the proprietary scripts and data acquisition configuration files to support this new configuration.

The primary purpose of this modification is to enhance the radar system's capabilities, enabling it to perform both DF and BF operations concurrently. This allows for improved signal processing techniques and expands functionalities, leveraging both DF and BF modes to gather more comprehensive and detailed information from the radar signals.

Similarly, to the BF output data, the DF binary file format (.rad) follow a standardized convention (Figure 2). They commence with a block-size indicator, followed by the data block, and conclude with a block-size cyclic redundancy check (CRC). Both the block-size indicator and CRC consist of a 4-byte Integer.

The majority of the data is structured in 4-byte chunks of Integer or Float types. The header comprises Char type elements, and there's an information block that can comprise mixed types. The block-size indicator denotes the total size of the data block, while the block-size CRC confirms the integrity of the data block, verifying that its value matches the block-size indicator before the data block.

The file contains radial velocity data that are mapped using a polar coordinate system with a resolution of 1 degree across a 360-degree angular sector, covering a set number of range bins from the receiver array. The data block within the file is organized into several sections:

- Azimuth Angles Vector: A set of azimuth angles representing the bearings of the radar measurements.
- Spatially Averaged Signal Levels: Signal level averages for each of the four receiving antenna elements at various ranges.
- Spatially Averaged Noise Levels: Average noise levels for each of the four receiving antennas at different ranges.
- Spatially Averaged Signal-to-Noise Ratios (SNR): Average SNR values calculated for each of the four receiving antennas at different ranges.
- Radial Velocity: The radial velocity data corresponding to each bearing and range.
- Variance: Variance data associated with each bearing and range, providing additional statistical information.

This structure organizes the information necessary for radial velocity mapping and includes crucial signal characteristics such as noise levels, SNR, and variance alongside the actual radial velocity measurements across different bearings and ranges.

Prior to converting to netCDF, the radial velocity data undergo remapping onto a Cartesian grid to maintain uniformity with the BF data output. This remapping process involves averaging polar radial velocity data within a 10km radius from each grid point to create the new grid.

The automatic real-time (RT) quality control (QC) tests applied to the WERA radial currents involve several procedures:

- Land masking (Test 1): Identifies and masks data points corresponding to land areas.
- Radial velocity threshold (Test 2): Flags suspect radial velocity values beyond a specified threshold.
- Radial velocity standard error threshold (Test 5): Flags data points based on thresholds for the standard error associated with radial velocities.

2.2 Real-time Quality Control tests for WERA vector maps.

The IMOS Radar Facility manages the creation of real-time (RT) FV00 vector current maps for the WERA systems. This process involves customised Python scripts utilizing the RT FV00 radials (as detailed in Section 2.1) to produce a 1-hour averaged velocity vector resolved on its zonal and meridional (U, V) velocity components, on a predefined Cartesian grid. Before initiating the vector mapping process, RT quality control (QC) flags associated with the RT FV00 radials [1] are implemented. Additionally, supplementary tests are conducted during the vector mapping stage to further guarantee the highest data quality for surface currents.

Several automatic real-time (RT) quality control (QC) tests are conducted specifically for surface currents:

- **Test 2-5 (Refer to Section 2.1).**
- **Test 6a: Number of observations[2] [2]**
- **Test 7: Geometry of the intersecting radar beam (GDOP) error**

Test 6 – Number of observations

Flags	Condition	Codable Instructions
Fail	Minimum number of radial velocities per site below a minimum value	NOBS1 or NOBS2 < NOBSMIN, U, V = nan; *(see note-3)*
Pass = 1	Minimum number of radial velocities per site above a minimum value	NOBS1 or NOBS2 >= NOBSMIN, flag =1
Example: NOBSMIN = 3		

Test 6a – Number of observations

Flags	Condition	Codable Instructions
Fail	Minimum number of radial velocities per site below a minimum value	NOBS1 or NOBS2 < NOBSMIN, U, V = nan;
Pass = 3	Minimum number of radial velocities per site above a minimum value	NOBS1 or NOBS2 == 3, flag =3
Pass = 2	Minimum number of radial velocities per site above a minimum value	NOBS1 or NOBS2 == 4, flag =2
Pass = 1	Minimum number of radial velocities per site above a minimum value	NOBS1 or NOBS2 >= NOBSMIN, flag =1
Example: NOBSMIN = 3		

This test is targeted at minimizing biases generated during the vector mapping process due to inadequate temporal coverage from either of the radar stations at each grid point. Unbalanced distribution of radial velocities results in a total vector exhibiting excessive directional uncertainty, rendering it invalid. Within the IMOS Ocean Radar Facility, a minimum threshold of **NOBSMIN = 3** valid observations from each site are required to ensure proper vector mapping.

This test marks an advancement over past methods that might have disregarded a vector map when an insufficient number of radial velocities were present, as outlined in Figure 6 where examples are provided for the real-time (RT) QC FV00 vectors generated using two distinct methodologies applied to surface current maps for the COF (NSW) and ROT (WA) WERA radar systems. In this visual representation, the left panels correspond to the RT FV00 produced using the updated approach, while the right panels depict the RT FV00 generated with the original approach.

The approach currently adopted and utilized at the IMOS Ocean Radar Facility offers evident advantages. Notably, it enhances the mitigation of the 50Hz artefacts observed in Figures 4-5 specifically at the COF WERA node. As a result, it significantly reduces the necessity for subsequent post-processing and delayed mode QC tests. Moreover, this updated approach notably enhances spatial coverage without requiring spatial and/or temporal interpolation methods.

[2] Test 6a is implemented in replacement of Test 6 for both RT and DM vector maps

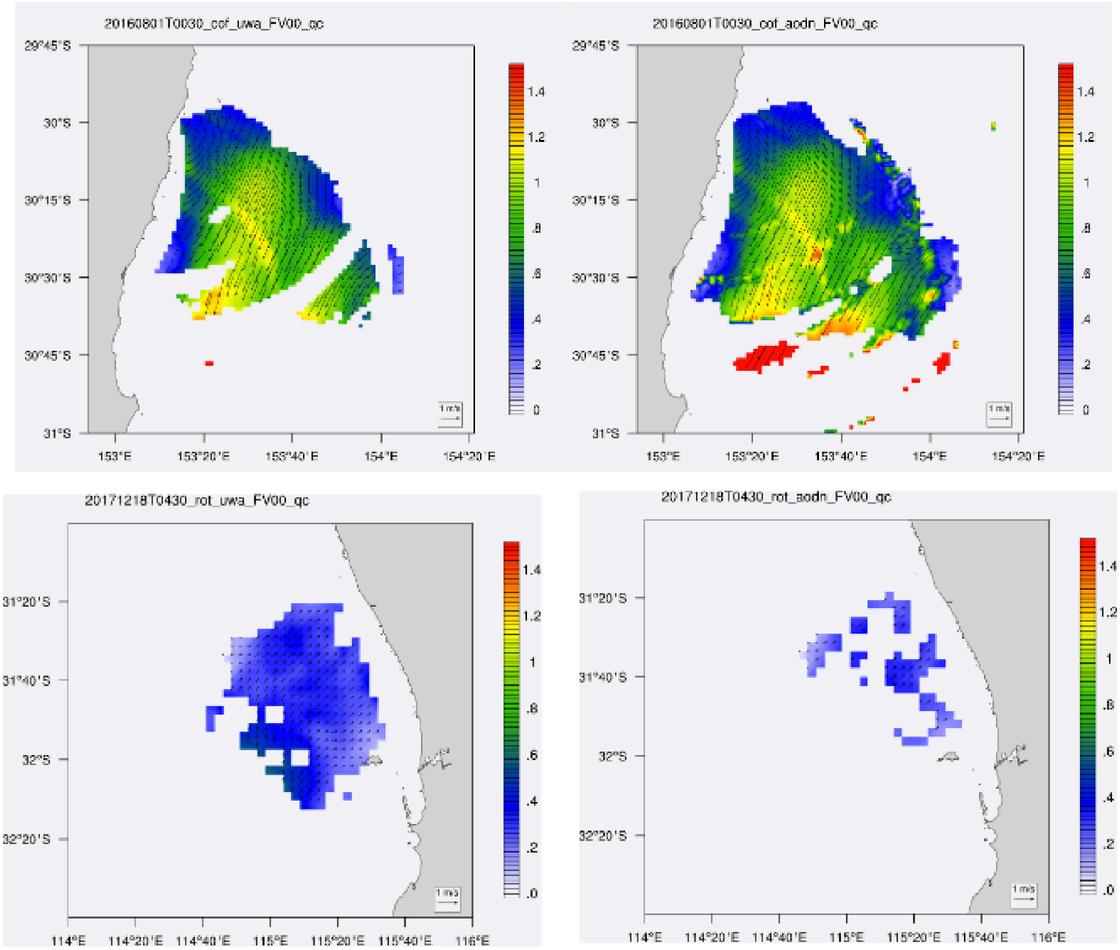


***Figure 6**. Examples of the RT QC FV00 vectors created with the two vector mapping approaches currently in use at UWA (left panels), compared to same vector maps with RT procedures previously in use in use at AODN. Examples refer to COF (NSW) and ROT (WA) WERA radar systems. Left panels refer to RT FV00 created with the modified approach in use at UWA; right panels refer to RT FV00 created with the modified approach in use at AODN.*

Test 7 – Geometry of the intersecting radar beam (GDOP test)

Flags	Condition	Codable Instructions
Fail = 4	Poor orthogonality constraints	If GDOPMAX<GDOP<GDOPMIN, flag = 4;
Pass = 1	Good orthogonality constraints	If GDOPMIN=<GDOP=<GDOPMAX, flag = 1; *(see note-4)*
No QC = 0		flag = 0; *(see note-4)*
Example: GDOPMIN = 30˚; GDOPMAX = 150˚		

This test is targeted at minimizing errors generated during the vector mapping process due to inadequate orthogonality constraints in the intersection angles of radar beams. Poor geometric constraints result in a total vector exhibiting excessive uncertainty, rendering it invalid. Within the IMOS Ocean Radar Facility, the Geometric Dilution of Precision (GDOP) is defined as the intersection angle between the radar-look angles of the two radar stations. The facility imposes constraints on these angles within the range of [30˚, 150˚] to ensure proper alignment, as illustrated in Figure 7 [3].

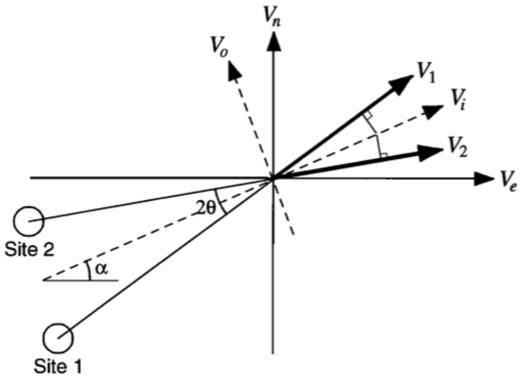


***Figure** 7. Radar beam intersecting geometry, illustrating the parameters adopted by the Ocean Radar Facility for defining the Geometric Dilution of Precision (GDOP) angular constraints specifically tailored for surface currents. This figure likely demonstrates the angular relationships or constraints between radar beams, emphasizing the criteria used to define acceptable or constrained angles to ensure precise and reliable surface current measurements.*

Instead of utilizing the formulation proposed in [3], the Integrated Ocean Observing System (IOOS) defines the Geometric Dilution of Precision (GDOP) differently. In this context, GDOP is considered as the trace of the covariance matrix, intending to broaden the application of this quality control (QC) test to radar nodes that involve more than two contributing sites. In this framework, GDOP is represented as a scalar, signifying the impact of radial (bearing) geometry on the uncertainty in velocity at a specific grid point, rather than being delineated within a range of angles. Higher GDOP values indicate larger covariances linked with the least squares fit used to obtain the solution. Essentially, GDOP, in this context, serves as an indicator of the extent of uncertainty associated with the least squares fitting process utilized in deriving the solution, emphasizing higher uncertainties with increased GDOP values.

2.3 Real-time Quality Control tests for SeaSonde radials

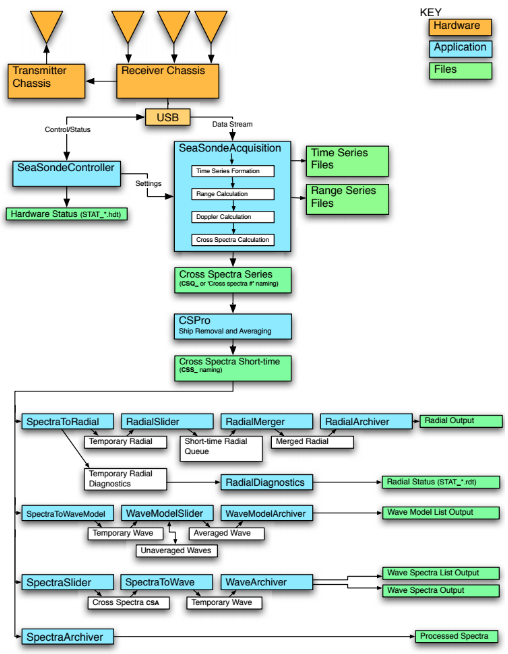


Figure 8. *The IMOS Ocean Radar Facility processing flow for real-time (FV00) data stream for SeaSonde radial currents*

The processing workflow for real-time (RT) radial currents from SeaSonde systems is summarized in Figure 8. During standard operation, voltage time series data from the antenna are continuously collected and converted into range-gated data files and Doppler spectra. At regular intervals, the CSPro proprietary software merges cross spectra files to create time-averaged Doppler spectra. Before merging, CSPro conducts quality-control tests to eliminate interference and ship-echo signatures. Following spectral averaging, the SpectraToRadial application produces a transient, short-term output radial file in ASCII format. Once per hour (typically), the RadialMerger application combines these short-term radial files into the final hourly file. This file contains radial currents in a polar coordinate system along with quality statistics for each data point, including merged segment counts, temporal and spatial standard deviations, and the maximum and minimum values of the merged radial current distributions.

The standard file format employed for SeaSonde radials is known as the Codar CTL format. It is a tabular-text file encoded in Roman ASCII. Each text line within this format may terminate with '\r' (return, char 13) or '\n' (newline, char 10), or '\r\n' or '\n\r'. The maximum permissible line length is 4096 characters, excluding one or two end-of-line characters '\r\n'.

This file structure comprises several sections:

1. **Header**: It stores essential information such as file version, radar location, processing options, parameters, transmit frequency, bandwidth, and column count/type (Refer to Figure 9).
2. **Table Data**: This section contains grid coordinates, radial velocity, and radial quality statistics.
3. **Footer**: Additional tables within the footer provide diagnostics related to radial data and diagnostic status.

```
%CTF: 1.00
%FileType: LLUV rdls "RadialMap"
%LLUVSpec: 1.14  2010 07 18
%UUID: CCED4422-1839-403A-8AE8-5B367E3DF99C
%Manufacturer: CODAR Ocean Sensors. SeaSonde
%Site: GHED ""
%TimeStamp: 2014 01 01  00 00 00
%TimeZone: "UTC" +0.000 0
%TimeCoverage: 49.983 Minutes
%Origin: -30.0732167  114.9667167
%GreatCircle: "WGS84" 6378137.000  298.257223562997
%GeodVersion: "CGEO" 1.57  2009 03 10
%LLUVTrustData: all %% all lluv xyuv rbvd
%RangeStart: 1
%RangeEnd: 76
%RangeResolutionKMeters: 2.912400
%AntennaBearing: 286.0 True
%ReferenceBearing: 0 True
%AngularResolution: 5 Deg
%SpatialResolution: 5 Deg
%PatternType: Measured
%PatternDate: 2015 05 05  19 45 48
%PatternResolution: 1.0 deg
%PatternUUID: 75A45862-BE7B-49B5-BC5D-3B0738142CE8
%TransmitCenterFreqMHz: 5.211500
%DopplerResolutionHzPerBin: 0.000976563
%FirstOrderMethod: 0
%BraggSmoothingPoints: 3
%CurrentVelocityLimit: 200.0
%BraggHasSecondOrder: 0
%RadialBraggPeakDropOff: 150.000
%RadialBraggPeakNull: 100.000
%RadialBraggNoiseThreshold: 4.000
%PatternAmplitudeCorrections: 2.6317  1.5794
%PatternPhaseCorrections: 89.00  103.00
%PatternAmplitudeCalculations: 0.2810  0.0739
%PatternPhaseCalculations: 15.80  21.10
%RadialMusicParameters: 40.000 20.000 2.000
%MergedCount: 3
%RadialMinimumMergePoints: 2
%FirstOrderCalc: 0
%MergeMethod: 1 MedianVectors
%PatternMethod: 1 PatternVectors
%TransmitSweepRateHz: 1.000000
%TransmitBandwidthKHz: -51.467827
%SpectraRangeCells: 191
%SpectraDopplerCells: 1024
%TableType: LLUV RDL9
%TableColumns: 18
%TableColumnTypes: LOND LATD VELU VELV VFLG ESPC ETMP MAXV MINV ERSC ERTC XDST YDST RNGE BEAR VELO HEAD SPRC
%TableRows: 835
%TableStart:
%%   Longitude   Latitude    U comp   V comp  VectorFlag    Spatial    Temporal     Velocity    Velocity  Spat
%%     (deg)       (deg)     (cm/s)   (cm/s)  (GridCode)    Quality     Quality     Maximum     Minimum    Cou
   114.9489578 -30.0944703   -5.777   -7.949           0     27.705      34.694      44.985     -59.014     2
```

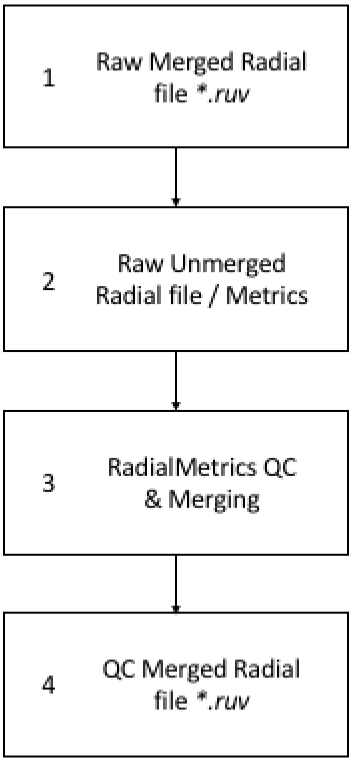
Figure 9. *Header content in a Codar CTL tabular format from a merged radial file collected at Greeh Head SeaSonde system*

2.4 Real-time Quality Control tests for SeaSonde radial maps

The procedure operates at the level of each Doppler velocity contributing to the radial velocity map for each (range, bearing pair). This approach can be viewed as a hybrid combining features from Level-0 (Doppler spectrum) and Level-1 (radial velocity) QC processing. Its implementation relies on specific assumptions and requires proprietary software prerequisites, including:

- The assumption that Signal-to-Noise Ratio (SNR) serves as a reliable indicator of data quality, particularly regarding the SNR values of individual Doppler lines within the Doppler spectra from three orthogonal receive channels.
- Dependency on the RadialMetrics output from manufacturer software (e.g., SeaSondeRadialSuiteR7 and subsequent releases) to access individual Doppler lines within the first-order region, along with their SNR values and additional metrics like: the MUSIC metrics for single- and dual-angle solutions, the MUSIC angular width of dominant peaks, and SNR values of Doppler lines.

The processing scheme, outlined below (also illustrated in Figure 10), consists of a series of sequential steps:



1, Retrieve and extract the sequence of radial metric files/short-term radial maps using the timestamps provided in Table 2 within the radial file's footer.

2, Determine the Doppler lines corresponding to each radial current in the file. Upon identifying the sequence of short-term radial velocity files and their associated radial metrics files, concatenate them to establish a unified data structure containing pertinent information. Iterate over radar range cells and angular bearings to pinpoint the Doppler velocity lines contributing to the final radial velocity map across the radar coverage.

3, Apply data filtering based on Signal-to-Noise Ratio (SNR) threshold values and maximum Doppler velocity. For instance, 6dB thresholds for SNR of individual Doppler velocities at each receive channel (SNR_i, i=1:3) to eliminate poorly-constrained data. Apply the final threshold on the maximum Doppler velocity post SNR filtering.

4, Calculate an average radial current for each range-bearing pair. There are presently two options:

a) Unweighted average: A simple average calculation.

b) Weighted average: The weights applied to the Doppler lines are determined by the Signal-to-Noise Ratio (SNR) values of the Doppler velocities that have successfully passed the Quality Control (QC) tests. These averages are computed within a 5˚ radius around each radial bearing.

Figure 10. *Flowchart of the proposed DM QC chain for the SeaSonde radial maps*

5, Generate a *.ruv radial file preserving compatibility with the SeaSonde proprietary software. Ensure it contains updated information and strictly adheres to their file structure guidelines.

In order to understand fully the proposed quality control approach, it is necessary to provide some details on the way SeaSonde HFR system obtain radial velocity maps. SeaSonde radars conventionally acquire sea-echo signals derived from reflecting a frequency-modulated interrupted continuous waveform (FMICW) signal transmitted within the 4 (5) - MHz-frequency band. Complex-valued voltage time series are collected at three antenna elements at intervals of either 512 s or 1024 s. At a sampling rate of 1 Hz, these intervals translate to sampling durations of 8 minutes and 32 seconds (or 17 minutes and 3 seconds). The signals received by the three antennas undergo range gating and Fast Fourier transform to obtain raw spectra for each antenna. These raw spectra are then cross-multiplied to produce auto- and cross-spectra, and subsequently ensemble-averaged in blocks of three consecutive datasets to generate short-term cross-spectra.

Directional information for the radial currents is extracted from analyzing the ensemble-averaged short-term cross-spectra. SeaSonde radars employ a Direction Finding (DF) algorithm called MUSIC to derive the arrival direction of 2(N - 1) signals for each Doppler line, with N representing the number of antenna elements (N = 3). The multiplication factor is associated with the independent processing of Doppler spectra from advancing or receding waves. The inversion process of the short-term cross-spectra generates a temporary output termed the short-term radial map (i.e., the short-term radial) and a corresponding radial metric output with detailed signal processing results as described earlier. On an hourly basis, a series of up to five or seven consecutive short-term maps collected around the hour are merged. This merging results in a surface current map containing the surface currents for each radar station across the radar's coverage area.

The metadata within the radial file contains comprehensive information regarding the sequence of short-term radials that have contributed to forming the ultimate radial velocity maps. Utilizing the SeaSonde RadialMetrics suite provides access to specific details such as signal power levels, noise levels, and whether single- or dual-angle solutions were used for each Doppler line inverted into radial velocity maps. Consequently, it is relatively simple to correlate the short-term radial velocity map with the respective radial metric output and follow the procedural steps outlined above (steps 1-5).

In standard real-time operations, the following constraints are implemented:

1. Maximum radial speed (150 cm/s).
2. Minimum signal-to-noise ratio at loop 1, 2, 3: $min\_snr_{1,2,3}$, 6 dB.
3. Maximum threshold on Doppler speed (max_DopVel; 100 cm/s).

The threshold values specified here have been finely adjusted for the Australian Ocean Radar SeaSonde systems by comparing them with independent data within their coverage area. It's important to note that these thresholds may not be universally applicable to other installations elsewhere. Comparative analyses with mooring data indicate that various comparison metrics (such as correlation, root-mean-square differences, and angular offset) demonstrate optimization and marked improvement with the proposed quality-control method. Presented below (Figure 11) are examples of radial maps before and after the QC filtering, showcasing evidence of reduced directional errors. This data corresponds to the SeaSonde system stationed at Lancelin (WA; site code: LANC).

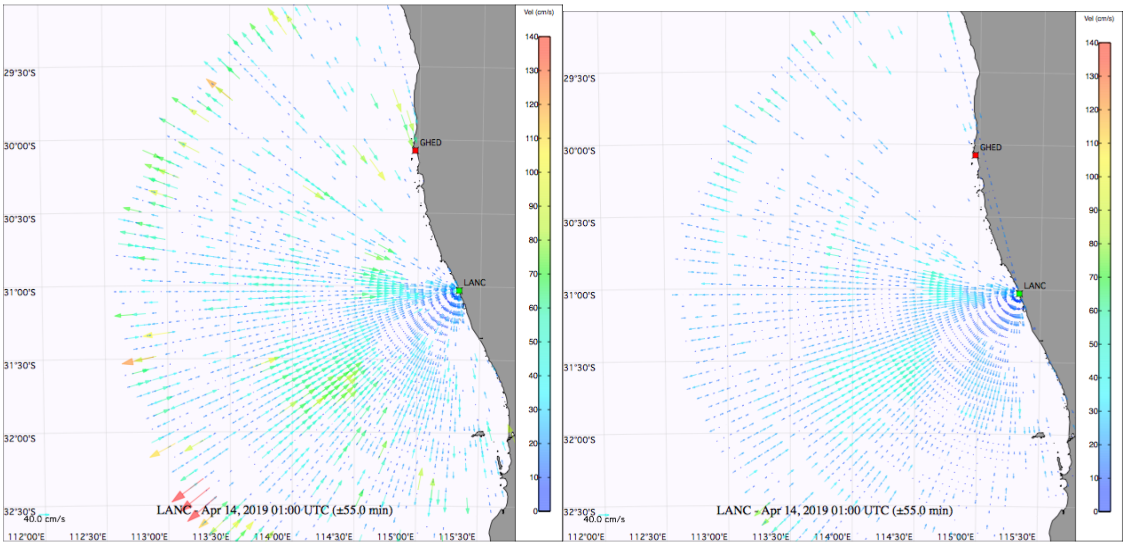


***Figure 11**. An instance of the RT QC FV00 implemented on LANC radial data is displayed. The left panel illustrates RT FV00 data lacking quality control, whereas the right panel depicts RT FV00 data post quality control measures.*

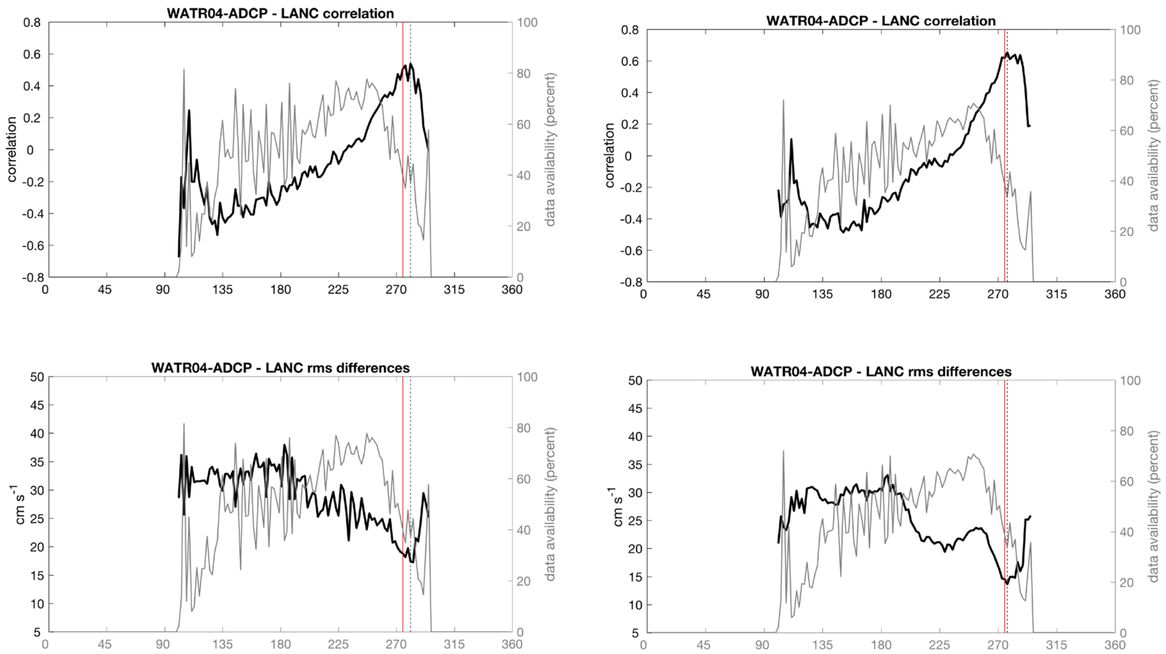


***Figure 12**. Example of the effects of RT QC FV00 applied to LANC radials on bearing errors. Left panel refers to RT FV00 without quality control; right panel refers to RT FV01 with quality control. Statistically significant improvement in correlation magnitude and rms differences can be observed when comparing RT data and DM QC FV01 data against current meter data.*

Summarising, the following QC tests are applied to the individual Doppler velocities that contribute to the final radial velocity:

Test 8, threshold on Doppler velocity

Flags	Condition	Codable Instructions
Fail = 4	Doppler velocity exceeds a predefined maximum threshold value; Doppler line removed	if DopplerVel> threshold, DopplerVel=nan; flag = 4;
Pass = 1	Doppler velocity below a predefined maximum threshold value; Doppler line retained	if DopplerVel<=threshold, flag = 1;

Test 9, threshold on Doppler Signal-to-Noise Ratio (SNR)

Flags	Condition	Codable Instructions
Fail = 4	Doppler velocity below a predefined minimum threshold value at loop1, loop2, and loop 3; Doppler line removed	if min_snr1=> threshold OR min_snr2=> threshold OR min_snr1=> threshold, DopplerVel = nan; flag = 4;
Pass = 1	Doppler velocity exceeds a predefined maximum threshold value; Doppler line removed	if DopplerVel<=threshold, flag = 1;

2.5 Real-time Quality Control tests for SeaSonde vector maps

The IMOS Ocean Radar Facility uses SeaSondeCombine, a proprietary software, to generate hourly vectors on a predetermined latitude-longitude grid. The computation of vector components at each grid point involves a least-squares method, incorporating radial data from two stations within a specified search radius, denoted as R.
Furthermore, custom MATLAB® scripts are employed to convert these vectors into netCDF-4 format.

Similar to radial files, SeaSonde vectors follow the Codar CTL format, a tabular-text file encoded in Roman ASCII. Each line within this file represents a single current vector, containing Lon, Lat, U, V data as primary components. Additionally, it includes supplementary details such as x-y coordinates, range, bearing, velocity, and direction data, serving as extra reference information for data analysis.

While converting the hourly vector maps into netCDF files, a series of QC checks are executed, comprising the following assessments:

- Test 7: Geometry of the intersecting radar beam (GDOP test).
- Test 10: Maximum velocity threshold.
- Test 11: Number of observations.
- Test 12: Radial balance distribution.

Test 10, maximum velocity threshold

Flags	Condition	Codable Instructions
Fail = 4	Total velocity above a predefined regional threshold	If TPSD > TSPDMAX, flag = 4;
Pass = 1	Total velocity below a predefined regional threshold	If TSPD <= TSPDMAX, flag =1
Example: TSPDMAX=2.0 (m s-1)		

Test 11, number of observations

Flags	Condition	Codable Instructions
Fail = 4	Number of radials from each site (NOBS1, NOBS2) less than a minimum number MINOBS	If (NOBS1 or NOBS2) < MINOBS, flag = 4;
Pass = 1	Number of radials from each site (NOBS1, NOBS2) above a minimum number MINOBS	If (NOBS1 or NOBS2) >= MINOBS, flag = 1;
Example: MINOBS = 2		

Test 12, radial balance distribution

Flags	Condition	Codable Instructions
Fail = 4	Number of radials from one site (NOBS1) is significantly larger than number of radials from the second radar site (NOBS2)	If (NOBS1/NOBS2 or NOBS2/NOBS1) >= 10, flag = 3;
Pass = 2	Number of radials from one site (NOBS1) is comparable to, or larger than number of radials from the second radar site (NOBS2)	If (NOBS1/NOBS2>=1 AND NOBS1/NOBS2<10) OR (NOBS2/NOBS1>=1 AND NOBS2/NOBS1<10), flag = 2;
Pass = 1	Equal number of radials from each site (NOBS1, NOBS2)	If (NOBS1/NOBS2=1) OR (NOBS2/NOBS1=1), flag = 1;

Tests 11, 12 are meant to ensure an improved reliability in the estimates of the current vector components and enforces at least two observations from each radar station at each grid point [2].

2.6 Delayed-time Quality Control tests for WERA radial maps.

The Quality-Control (QC) process for WERA radial velocity maps in Delayed-Mode (DM) comprises evaluations in time and space domains. Within the time domain, analyses are conducted on the radial velocity time series at each grid point.

Tests include:

- Test 13: Statistical assessment of radial velocity distribution.
- Test 14: Application of median filtering.
- Test 15: Examination of the distribution of the 1st order derivative.
- Test 16: Analysis of the distribution of the 1st order derivative from high-pass filtered data.

The QC Tests 13-16 are complementary and redundant and are capable of handling the majority of the anomalous observations. They are aggregated into a single IODE-compliant QC flag value as follows based on the number of QC tests that are failed or passed.

In conjunction with tests 13 through 16, spatial domain assessments include the implementation of the following QC examinations:

- Test 2: Radial velocity threshold.
- Test 3: Signal-to-Noise Ratio (SNR).
- Test 4: Spatial distribution of Signal-to-Noise Ratio (SNR) (1D and 2D cases).

A detailed explanation of QC tests 2-4 can be found in Section 2.1 and will not be reiterated here.

The assumptions made are as follows:

a. Radial currents at individual grid points are considered independent and uncorrelated with neighbouring grid cells.

b. Radial velocity exhibits temporal continuity.

c. Radial velocity time series adhere to a Gaussian-type distribution.

Time instances without radial measurements are populated with NaN-valued maps. These blank maps are subsequently eliminated during the conversion process to netCDF files.

Test 13, statistics of the radial velocity distribution

Flags	Condition	Codable Instructions
Fail = 4	Radial velocities are found in the tails of the distribution	if radVel>upper_CL | radVel<lower_CL , flag = 4;
Pass = 1	Radial velocities are not found in the tails of the distribution	if radVel<=upper_CL AND radVel>=lower_CL , flag = 4;

Anomalies within the velocity components are detected by examining the 99% confidence limits based on the assumption of Gaussian-type distributions. Any values surpassing these thresholds are flagged as spikes. The reliability of this procedure heavily relies on assuming Gaussian distribution for the radial velocities, which may necessitate further in-depth investigation or refinement. Nevertheless, the procedure demonstrates robustness in identifying and flagging anomalous data and has been implemented in the Taiwan Ocean Radar Network (TORI) as per the recommendation from IOOS.

Test 14, median absolute deviation (median filtering)

Flags	Condition	Codable Instructions
Fail = 4	Radial velocities deviation from the median value exceeds a predefined threshold	If abs(radVel - median) > nSigma * Ust; flag = 4
Pass = 1	Radial velocities deviation from the median value within a predefined threshold	If abs(radVel - median) <= nSigma * Ust; flag = 1
Example: nSigma = 3		

Test 15, distribution of the 1st order derivative

Flags	Condition	Codable Instructions

Fail = 4	Radial acceleration found in the tails of the distribution	if D(radVel)>upper_CL | D(radVel)<lower_CL , flag = 4;
Pass = 1	Radial acceleration not found in the tails of the distribution	if D(radVel)<=upper_CL AND D(radVel)>=lower_CL , flag = 4;

This quality control (QC) test relies on computing the first difference of the radial current time series at each point. Employing the first difference operator ensures that the data conform to a normal distribution. Consequently, the 95% (99%) confidence limits of this distribution are utilized to spot anomalous values within the dataset. Similar to the process used for vector components, estimates of the distributions for the first-order difference are determined, along with their respective upper and lower confidence limits. First-differenced data exceeding these boundaries are identified, and the corresponding data in the original time series are flagged accordingly.

Test 16, distribution of the 1st order derivative of the high-pass filtered data

Flags	Condition	Codable Instructions
Fail = 4	Extract a low-frequency signal; distribution of the high-frequency radial velocity found in the tails of the distribution	if $radVel_{HF}$>upper_CL | $radVel_{HF}$ <lower_CL , flag = 4;
Pass = 1	Extract a low-frequency signal; distribution of the high-frequency radial velocity not found in the tails of the distribution	if $radVel_{HF}$<=upper_CL AND $radVel_{HF}$>=lower_CL , flag = 1;

This QC test revolves around the statistics related to the high-frequency components observed in the radial velocity series at each grid point. The premise lies in the notion that noise and spikes often manifest within the high-frequency segment of the velocity time series. To extract this high-frequency portion, a low-pass filter is applied to the radial currents, effectively removing the signal from the time series.

Subsequently, tests are conducted on the distribution of this extracted high-frequency segment. Assuming a Gaussian-type distribution, the 95% (99%) confidence limits are calculated. Any data points surpassing these limits are identified as spikes and flagged accordingly.

The low-pass signal is extracted through a Savitzky-Golay filter, which operates as a generalized moving average. This filter employs filter coefficients determined by an unweighted linear least-squares regression along with a specified degree polynomial model (default is 2).

To ensure accuracy and reliability and to prevent artefacts stemming from gaps or missing data in the time series, this test is executed only when at least 50% of the data is available.

2.7 Delayed-Mode (DM) Quality Control tests for WERA and SeaSonde vector maps.

The Quality-Control (QC) procedures for vector maps in the delayed-mode (DM) setting are uniform across different HFR platforms and as such are applicable to both WERA and SeaSonde vector maps. These procedures include specific time-domain tests that are separately implemented for the two horizontal current components (UCUR and VCUR) and share similar approach as to radial currents:

- Test 11: number of observations[3].
- Test 12: Radial balance test.
- Test 13: Distribution statistics.
- Test 14: Median filtering.
- Test 15: Distribution of the 1st order derivative.
- Test 16: Distribution of the 1st order derivative of the high-pass filtered data.

The QC Tests 11, 14-16 encompass overlapping functionalities and redundancy, thus collectively addressing most anomalous observations. These tests are conducted individually on the two horizontal components of surface current velocity (UCUR – VCUR). The outcomes of the QC tests for both velocity components are combined into a unified flag. For instance, if an observation fails for UCUR (VCUR) with a "Fail = 4" flag, the same flag applies reciprocally for VCUR (UCUR). This approach aims to maintain consistency in both current magnitude and direction even if one component registers an error.
Subsequently, the results of these QC tests are merged into a single IODE-compliant QC flag value. The aggregation considers the number of QC tests failed or passed.

Table 3. Aggregated QC flags for DM QC tests on WERA radial velocity time series

Flags	Condition	Flag meaning
Fail = 4	All QC test failed	Bad data
Fail = 3	At least three QC tests failed	Bad data that are potentially correctable
Pass = 2	At least two QC tests passed	Probably good data
Pass = 1	All QC tests passed	Good data

The assumptions guiding the processing of vector velocity components are as follows:

- Vector velocity components measured at each grid point are regarded as independent and uncorrelated from neighbouring grid cells.
- Vector velocity maintains continuity in time across measurements.
- Vector velocity components adhere to a Gaussian-type distribution.

During time instances where vector measurements are unavailable, NaN-valued maps are utilized to fill in the gaps. Subsequently, these empty maps are eliminated during the conversion to netCDF files.

[3] This test was introduced in response to issue #406 (HF radar - Standard deviation is zero for quality control == 1) reported by AODN

3. File format for RT products

3.1 File format for RT WERA radial data

The file format in use for the FV00 WERA radial data complies with the IMOS-1.4 and CF-1.6 conventions. A detailed description of the file format, variables and metadata is provided in the following sections in the document.

3.1.1 File naming convention

The naming conventions for RT netcdf files from the WERA HF radar systems follow the IMOS convention for RT FV00 products (also described in [4]), as detailed below (Table 4):

IMOS_ACORN_<data-code>_<date> _ <platform-code> _FV <file-version> _<product-type>.nc

An example for the RT FV00 radial current for Fremantle radar station is given below:

IMOS_ACORN_RV_20240101T060500Z_FRE_FV00_radial.nc

Table 4. *Elements of file-naming convention*

Part of filename	Description
data-code	RV: radial velocity
date	Start date and time of the measurements in UTC. Date format is: yyyymmddTHHMMSSZ where T is the delimiter between date and time, and Z indicates that time is in UTC. Example: 20240101T060500Z is 1st January 2024, 06:05AM
platform-code	A three-letter code for the WERA HFR stations: JTC: Jurabi Turtle Centre (WA) PTB: Point Billie (WA) FRE: Fremantle station (WA) GUI: Guilderton station (WA) CSP: Cape Spencer station (SA) CWI: Cape Wiles station (SA) RRK: Red Rock station (NSW) NNB: North Nambucca Head (NSW)
file-version	Value representing the version of the file. This value is preceded by two characters: 'FV'. 00: Level 0 – raw data. Raw data is defined as data processed with the acquisition software provided by the manufacturer, and data products that have undergone RT quality control procedures. Data are available in physical units. Level 0 data is suitable for public access. Metadata exists for the data. 01: Level 1 – quality controlled data. Quality controlled data have passed offline, delayed mode quality control procedures. Data are in physical units using standard SI metric units. Metadata exists for the data.
product-type	This code gives information about the product included in the dataset. Example: radial, for maps of sea surface current component towards or away from the radar receiver

3.1.2 Global attributes

The following attributes are included in the RT F00 radial current files.

Table 5. *netcdf files global attributes for RT radial currents in use at the IMOS Ocean Radar Facility*

Name	Example	Definition
project	char('Integrated Marine Observing System (IMOS)');	The scientific project that produced the data
Conventions	char('CF-1.6,IMOS-1.4');	Format convention used by the dataset
institution	char(IMOS Ocean Radar Facility');	Name of the institute or facility where the original data was produced.
title	char(['Fremantle, Western Australia, Radial,2024-01-01 06:05:00Z']);	Short description of the dataset indicating the radar station that collect the data, the type of product and the acquisition date.
Instrument	char('WERA Oceanographic HF Radar/Helzel Messtechnik, GmbH')	Type of instrument used to collect the data
platform_code	char('FRE');	Three-letter code for the HFR site
site_code	char('ROT")	Three-letter code for the HFR node

date_created	char('2024-01-01T06:07:50Z');	Date and time at which the file was created. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2024-01-01T06:07:50Z : January 1st 2024 06:07:50AM
abstract	char('The IMOS Ocean Radar Facility is producing NetCDF files containing quality controlled radial current maps at 5 min time intervals in real-time. Radials are calculated from the shift of the Bragg peaks in a power spectrum. A set of python tools is adopted to read data files, perform real-time quality controls on radial current components, and convert the files into netcdf format. Each radial current value has a quality control flag. Quality control flags are defined on the basis of threshold values for radial current speed, signal-to-noise ratio (SNR), and radial velocity accuracy values. Threshold values are: 1.5m/s, 10dB, and 0.10m/s. An additional quality control is performed on the spatial distribution of radial Signal-to-Noise Ratio (SNR) after thresholding for SNR and radial velocity. More information on the data processing is available through the document: Quality Control procedures for ACORN radars Manual Version 3.0 Integrated Marine Observing System. DOI:10.26198/5c89b59a931cb (http://dx.doi.org/10.26198/5c89b59a931cb))	A paragraph describing the dataset: type of data contained, how it was created, who collected it, what instruments were used, etc.
source	char('Terrestrial HF radar');	Method of production of the original data.
keywords	char('Oceans');	A comma separated list of key words and phrases.
standard_name_vocabulary	Char('NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table 27')	Reference for CF standard names
netcdf_version	char('4.0')	NetCDF file version
naming_authority	char('IMOS');	Naming authority will always be IMOS.
file_version	char('Level 0 - Real Time Quality Controlled data')	Version of data processing
file_version_quality_control	char('Data in this file has been through the quality control procedure as described in the document: Quality Control procedures for ACORN radars Manual Version 3.0. Integrated Marine Observing System. DOI: 10.26198/5c89b59a931cb (http://dx.doi.org/10.26198/5c89b59a931cb). Every data point in this file has an associated quality flag.');	Version of the quality control applied to the data
geospatial_lat_min	double(-33.03699493408203);	Southernmost latitude (positive north) from which dataset was obtained; a value between -90 and 90 degrees.
geospatial_lat_max	double(-30.222900390625);	Northernmost latitude (positive north) from which dataset was obtained; a value between -90 and 90 degrees.
geospatial_lat_units	char('Degrees_north')	Units used for geospatial_lat_min/max attributes.
geospatial_lon_min	double(113.23686981201172);	Westernmost longitude (positive east) from which dataset was obtained; a value between -180 and 180 degrees.
geospatial_lon_max	double(115.74121856689453);	Easternmost longitude (positive east) from which dataset was obtained; a value between -180 and 180 degrees.
geospatial_lon_units	char('Degrees_east')	Units used for geospatial_lon_min/max attributes.
geospatial_vertical_min	double(0.0);	Minimum depth of measurements, in metres.
geospatial_vertical_max	double(0.0);	Maximum depth of measurements, in metres.
geospatial_vertical_units	char('meter')	Units used for geospatial_vertical_min/max

		attributes.
positive	char('up')	Direction of vertical coordinates
reference_datum	char('sea surface')	Reference origin for the vertical coordinate
time_coverage_start	char('2024-01-01T06:05:00Z')	Start date and time in UTC, for which data in the dataset was collected. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2024-01-01T06:05:00Z: January 1st 2024 06:05:00AM
time_coverage_end	char('2024-01-01T06:05:00Z')	End date and time in UTC, for which data in the dataset was collected. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2024-01-01T06:05:00Z: January 1st 2024 06:05:00AM
time_coverage_duration	char('PT4M26S')	
local_time_zone	double(8)	Local time zone (UTC+)
data_center	char(' Australian Ocean Data Network (AODN)')	Data center in charge of management and distribution of the data resource.
data_centre_email	char('info@aodn.org.au')	Data centre contact email address.
author	char('Simone Cosoli')	Name of person responsible for the creation of the dataset.
author_email	char('simone.cosoli@uwa.edu.au')	Email address for the data creator
institution_references	char('http://imos.org.au/facilities/oceanradar/')	Reference to the data provider and producer.
principal_investigator	char('Cosoli, Simone')	Name of principal investigator in charge of the glider unit.
principal_investigator_email	char('simone.cosoli@uwa.edu.au')	Principal investigator's email address.
citation	char('Citation to be used in publications should follow the format: "IMOS.[year-of-data-download],[Title],[Data access URL],accessed [date-of access]".')	Citation used for usage of this data.
acknowledgement	char('Any users (including re-packagers) of IMOS data are required to clearly acknowledge the source of the material in this format: "Data was sourced from the Integrated Marine Observing System (IMOS) - IMOS is enabled by the National Collaborative Research Infrastructure (NCRIS). It is operated by a consortium of institutions as an unincorporated joint venture, with the University of Tasmania as Lead Agent."')	Any users (including re-packers) of IMOS data are required to acknowledge the source of the data in this format.
distribution_statement	char('Data may be re-used, provided that related metadata explaining the data has been reviewed by the user, and the data is appropriately acknowledged. Data, products and services from IMOS are provided \"as is\" without any warranty as to fitness for a particular purpose.')	Statement describing data distribution policy.
license	char('http://creativecommons.org/licenses/by/4.0/')	Reference for the license for the data
disclaimer	char(' Data, products and services from IMOS are provided "as is" without any warranty as to fitness for a particular purpose.')	Statement describing data fitness policy
ssr_Stations	char('"ssr_Station_FRE')	Configuration file for FRE
ssr_Data_Type	char('Radial')	Type of product
ssr_Radar	char('WERA')	Type of instrument
ssr_Technology	char('Beam_Forming')	
ssr_Ranging	char('Chirp')	
ssr_Rx_N_Elements	int32(12)	Number of receive elements
ssr_Rx_Longitude	double(115.74648, 115.74655, 115.746706, 115.746631, 115.746781, 115.746857, 115.746932, 115.747008, 115.747083, 115.747158, 115.747234, 115.747309)	Longitudes of the receive array elements
ssr_Rx_Longitude_units	char('degree_east');	Units for Longitude

ssr_Rx_Latitude	double(-32.031608, -32.031479, -32.031349, -32.031219, -32.031089, -32.03096, -32.03083, -32.0307, -32.03057, -32.030441, -32.030311, -32.030181)	Latitudes of the receive array elements
ssr_Rx_Latitude_units	char('degree_north)	Units for Latitude
ssr_Tx_Longitude	double(115.7451012)	Longitude of the transmitter
ssr_Tx_Longitude_units	char('degree_east')	Units of Longitude
ssr_Tx_Latitude	double(32.035398825)	Latitude of the transmitter
ssr_Tx_Latitude_units	char(' degree_north')	Units for Latitude
ssr_Rx_Boresight	double(-64.0)	Direction of the transmitter main lobe
ssr_Rx_Boresight_units	char('degree_true')	
ssr_RF_Frequency	single(9335000.0)	Transmit frequency
ssr_RF_Frequency_units	char('Hz')	Units for Transmit frequency
ssr_RF_Bandwidth	single(33310.273)	Transmit Bandwidth
ssr_RF_Bandwidth_units;	char('Hz')	Units for Transmit Bandwidth
ssr_N_Chirps	int32(1024)	Number of chirps per acquisition cycle
ssr_Chirp_Shape	char(' Sawtooth')	Type of waveform
ssr_Chirp_Direction	char('Up')	Direction of the frequency sweep
ssr_Chirp_Duration	single(0.260028)	Duration of the frequency sweep
ssr_Chirp_Duration_units	char('s')	Units for the duration if the frequency sweep

3.1.3 Dimensions

The IMOS Ocean Radar Facility radial data are snapshots of the radial component of the sea surface current. They have two-dimensional coordinates of latitude, longitude coordinates, along with various measured parameters. All variables are sparse, and the size of data varies mostly on external interference or hardware problems. FV00 files include the following dimension: TIME; POSITION; FREQUENCY; WERA_HEADER_SIZE

Table 6. *Dimension*

Dimension	Definition
TIME	Number of time steps over which data was sampled (UNLIMITED)
POSITION	Number of grid points in which data has been collected. The dimension may change but it is always present in the file.
FREQUENCY	Number of frequency steps used for the spectrum scan before each acquisition cycle.
WERA_HEADER_SIZE	Dimension (byte) of the header in the raw file before extraction of variables and before conversion to physical units

3.1.4 Variables

Variables and attributes in FV00 netcdf data files are listed in Table 7 for WERA radial data. Table 8 contains the parameters included in the netcdf file, with Table 6 lists the quality control indicator and the flags in use for Ocean Radar radial data.

Table 7. *Variables and attributes for the RT FV00 WERA radial data*

Variable	Attributes	Definition

TIME	double TIME;
	standard_name = "time";
	long_name = "time";
	units = "days since 1950-01-01 00:00:00 UTC";
	calendar = "gregorian";
	axis = "T";
	valid_min = 0.0;
	valid_max = 90000.0;
		Time at which <PARAM> measurements were made. Values are recorded as days since 12 am of 1st January 1950.

POSITION	int POSITION long_name = "Grid position index"; units = "1"; valid_min = 1;	Adimensional variable that contains the position in the measurement grid

	valid_max = 5704;	

WERA_HEADER	char wera_Header_FRE
	long_name = "WERA Radial 512-byte header";
	comment = "Original WERA 512-byte header is stored in variable data. WERA 512-byte header fields are also stored as variable attributes.";
	wera_Data_Type = "Radial";
	wera_Signature = "FMRADG";
	wera_Frequency = 9335000.0f;
	wera_Frequency_units = "Hz";
	wera_Range_Resolution = 4500.0f;
	wera_Range_Resolution_units = "m";
	wera_Bandwidth = 33310.273f;
	wera_Bandwidth_units = "Hz";
	wera_Site_Name = "Fremantle";
	wera_Comment = "Fremantle, Western Australia.";
	wera_Time_Zone_Id = "UTC";
	wera_Date = "2017-09-11";
	wera_Time = "06:05:00Z";
	wera_Longitude = 115.74583333333334
	wera_Longitude_units = "degree_east";
	wera_Latitude = -32.03333333333333;
	wera_Latitude_units = "degree_north";
	wera_Rx_Boresight = -75.0f;
	wera_Rx_Boresight_units = "degree_true";
	wera_N_Samples = 1024;
	wera_Chirp_Duration = 0.260028f;
	wera_Chirp_Duration_units = "s";
	wera_N_Ranges = 60;
	wera_Range_Blanking = 100.0f;
	wera_Range_Blanking_units = "m";
	wera_FFT_Width = 512;
	wera_FFT_Shift = 128;
	wera_Grid_N_X = 62;
	wera_Grid_N_Y = 92;
	wera_Grid_File_Name = "grid_aodn_rot.txt";
	wera_Grid_Latitude = -30.150743;
	wera_Grid_Latitude_units = "degree_north";
	wera_Grid_Longitude = 113.151977;
	wera_Grid_Longitude_units = "degree_east";
	wera_Grid_Spacing = 4009.0f;
	wera_Grid_Spacing_units = "m";	

LONGITUDE	double LONGITUDE(POSITION)
	_FillValue = 9.969209968386869E36;
	standard_name = "longitude";
	long_name = "Longitude";
	reference_datum = "World Geodetic System 1984";
	units = "degrees_east";
	axis = "X";
	valid_min = -180.0;
	valid_max = 180.0;	

LATITUDE	double LATITUDE(POSITION)
	_FillValue = 9.969209968386869E36;
	standard_name = "latitude";
	long_name = "Latitude";
	reference_datum = "World Geodetic System 1984";
	units = "degrees_north";
	axis = "Y";
	valid_min = -90.0;
	valid_max = 90.0;	

<PARAM>	float <PARAM>(POSITION); <PARAM>_FillValue =<X> <PARAM>long_name = <X>; <PARAM>units = <X> <PARAM>valid_min = <X> <PARAM>valid_max = <X>; <PARAM>ancillary_variables = <X> <PARAM>coordinates;	<PARAM> contains the values of a parameter listed in reference table 5. <X>: this field is specified in the reference table 5. The quality_control_indicator values are as listed in Table 6.
<PARAM_quality_control>	byte <PARAM_quality_control>(POSITION); <PARAM_quality_control>long_name; <PARAM_quality_control>quality_control_set = <X>;	Quality flag applied on the <PARAM> values as result of the RT quality checks.

	<PARAM_quality_control>quality_control_conventions<X>;; <PARAM_quality_control>_FillValue = <X>; <PARAM_quality_control>valid_min = <X>; <PARAM_quality_control>valid_max = <X>; <PARAM_quality_control>flag_values = <X>; <PARAM_quality_control>flag_meanings = <X>; <PARAM_quality_control>coordinates;	Information on flag meanings is found in Table 6.

Table 8 contains the parameters included in the netCDF file, with Table 9 listing the quality control indicator and the flags in use for IMOS Ocean Radar Facility radial data.

Table 8. *List of parameters included in the netcdf files*

Code	standard_name	long_name (for non-CF)	_FillValue	valid_min	valid_max	coordinates	Ancillary _variables	units
ssr_Surface_Radial_Sea_Water_Speed		Magnitude of surface sea water current radial component	9.96921E36	-5.0	5.0	TIME, LATITUDE, LONGITUDE	ssr_Surface_Radial_Sea_Water_Speed_quality_control	m s-1
ssr_Surface_Radial_Direction_Of_Sea_Water_Velocity		Direction from receive antenna to grid position	-1	0	360	TIME, LATITUDE, LONGITUDE	ssr_Surface_Radial_Direction_Of_Sea_Water_Velocity_quality_control	arc_degree
ssr_Surface_Radial_Sea_Water_Speed_Standard_Error		Estimate of error in magnitude of surface sea water current radial component	-1	0	100	TIME, LATITUDE, LONGITUDE	ssr_Surface_Radial_Sea_Water_Speed_Standard_Error_quality_control	m s-1
ssr_Power_Spectrum_Noise		Power spectrum noise level	-1	0	10e6	TIME, LATITUDE, LONGITUDE	ssr_Power_Spectrum_Noise_quality_control	1
ssr_Bragg_Signal_To_Noise		Power spectrum signal to noise ratio	-1	0	10e6	TIME, LATITUDE, LONGITUDE	ssr_Bragg_Signal_To_Noise_quality_control	1
wera_Sum_N		Number of frequency components in Bragg peaks	0	0	50	TIME, LATITUDE, LONGITUDE		1

Table 9. *Quality control indicator and the flags in use for FV00 RT WERA radial data*

Flag value	Meaning	Description
0	No QC performed	The level at which all data enter the working archive. They have not yet been quality controlled
1	Good data	Top quality data in which no malfunctions have been identified and all real features have been verified during the quality control process.
2	Probably good data	Good data in which some features (probably real) are present, but these are unconfirmed. Code 2 data are also data in which minor malfunctions may be present, but these errors are small and/or can be successfully corrected without seriously affecting the overall quality of the data.
3	Bad data that are potentially correctable	Suspect data in which unusual, and probably erroneous features are observed.
4	Bad data	Obviously erroneous values are observed.
5	Value changed	Altered by a QC centre, with original values (before the change) preserved in the history

		record of the data.
6	Not used	Reserved for future use.
7	Not used	Reserved for future use.
8	Interpolated value	Indicates that data values are interpolated.
9	Missing value	Indicates that the element is missing.

3.2 File format for RT WERA vector data

At the time of writing (November 2019) UWA is managing the creation of RT WERA vector data files. A detailed description of the file format, the variable, the metadata is given in the following Section.

3.2.1 File naming convention

The naming conventions for RT netcdf files for surface currents from WERA HF radar systems follow the IMOS convention for RT FV00 products (also described in [4]), as detailed below (Table 10):

IMOS_ACORN_<data-code>_<date> _ <node-code> _FV <file-version> _<product-type>.nc

An example for the RT FV00 vector current map for South Australia Gulfs (SAG) region is given below:

IMOS_ACORN_V_20240106T003000Z_SAG_FV00_1-hour-avg.nc

***Table 10**. Elements of file-naming convention*

Part of filename	Description
data-code	V: 2D surface current velocity map
Date	Start date and time of the measurements in UTC. Date format is: yyyymmddTHHMMSSZ where T is the delimiter between date and time, and Z indicates that time is in UTC. Example: 20170922T083000Z is 22nd September 2017, 08:30AM
node-code	A three-letter code for the regional deployment: NWA: Northwestern Australia (WA) ROT: Rottnest Shelf region (WA) SAG: South Australia Gulfs region (SA) COF: Coffs Harbour region (NSW)
file-version	Value representing the version of the file. This value is preceded by two characters: ‘FV’. 00: Level 0 – raw data. Raw data is defined as data processed with the acquisition software provided by the manufacturer, and data products that have undergone RT quality control procedures. Data are available in physical units. Level 0 data is suitable for public access. Metadata exists for the data. 01: Level 1 – quality controlled data. Quality controlled data have passed offline, delayed mode quality control procedures. Data are in physical units using standard SI metric units. Metadata exists for the data.
product-type	This code gives information about the product included in the dataset. Example: 1-hour-avg, for surface current maps

3.2.2 Global attributes

The following attributes are included in the RT F00 radial current files.

***Table 11**. IMOS Ocean Radar Facility netcdf files global attributes for RT surface currents*

Name	Example	Definition
Project	char('Integrated Marine Observing System (IMOS)');	The scientific project that produced the data
Conventions	char('CF-1.6,IMOS-1.4');	Format convention used by the dataset
institution	char('*IMOS Ocean Radar Facility*');	Name of the institute or facility where the original data was produced.
Title	char(['IMOS *Ocean Radar Facility* South Australia Gulf (SAG), one hour averaged current RT QC data, 2024-01-06T00:30:00Z']);	Short description of the dataset indicating the radar station that collect the data, the type of product and the acquisition date.
Instrument	char('WERA Oceanographic HF Radar/Helzel Messtechnik, GmbH')	Type of instrument used to collect the data
site_code	char('SAG, South Australia Gulf')	HF radar node
ssr_Stations	char('Cape Wiles (CWI), Cape Spencer (CSP)')	Three-letter code for the HFR node
date_created	char('2024-01-06T01:05:10Z');	Date and time at which the file was created. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2017-09-22T09:00:06Z : December 22nd September 2017 09:00:06AM
abstract	char('The IMOS Ocean Radar Facility is producing NetCDF files containing quality controlled vector current maps at 1 hour time intervals. They are produced from radial currents, which represent the surface sea water current component along the radial direction from a receiver antenna. Radials are extracted from the 5 minutes Doppler spectra at each grid point and then averaged over 1 hour period. The software provided by the manufacturer of the instrument is used to calculate the radial velocity from shift of the Bragg peaks in a power spectrum. ACORN performs quality-control on the radials on the basis of threshold values for radial current speed, signal-to-noise ratio (SNR), and radial velocity accuracy. Threshold values are: 1.5m/s, 10dB, and 0.10m/s. An additional quality-control is performed on the spatial distribution of radial signal-to-noise ratio (SNR) after thresholding for SNR and radial velocity. ACORN is using python scripts to import all the NetCDF files with real time quality control flags for two different stations and produce a one hour averaged product with U and V components of the current. Only radial velocities with quality control flag 1 are considered valid in the radial averaging process. At least three valid measurements for each radar station (this number of observations is recorded in the NOBS1 and NOBS2 variables) are required for the vector computation. GDOP angles are >=30 and <=150. A threshold of 1.5m/s is applied on current velocity. The U, V current component are then flagged based on the number of radial velocities from each site that contribute to the velocity vector. The final product is produced on a regular geographic grid. More information on the data processing is available through the document: Quality Control procedures for ACORN radars Manual Version 3.0. Integrated Marine Observing System. DOI: 10.26198/5c89b59a931cb (http://dx.doi.org/10.26198/5c89b59a931cb)	A paragraph describing the dataset: type of data contained, how it was created, who collected it, what instruments were used, etc.
source	char('Terrestrial HF radar');	Method of production of the original data.
keywords	char('Oceans');	A comma separated list of key words and phrases.

standard_name_vocabulary	Char('NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table 27')	Reference for CF standard names
netcdf_version	Char('4.1.1')	NetCDF file version
naming_authority	char('IMOS');	Naming authority will always be IMOS.
file_version	char('Level 0 – Raw data')	Version of data processing
file_version_quality_control	char('Data in this file has been through the quality control procedure as described in the document: Quality Control procedures for IMOS Ocean Radar Facility Manual Version 3.0. Integrated Marine Observing System. DOI: 10.26198/5c89b59a931cb (http://dx.doi.org/10.26198/5c89b59a931cb). Every data point in this file has an associated quality flag.');	Version of the quality control applied to the data
geospatial_lat_min	double(-37.4551594);	Southernmost latitude (positive north) from which dataset was obtained; a value between -90 and 90 degrees.
geospatial_lat_max	double(-34.8234228);	Northernmost latitude (positive north) from which dataset was obtained; a value between -90 and 90 degrees.
geospatial_lat_units	char('Degrees_north')	Units used for geospatial_lat_min/max attributes.
geospatial_lon_min	double(132.953971);	Westernmost longitude (positive east) from which dataset was obtained; a value between -180 and 180 degrees.
geospatial_lon_max	double(137.462663);	Easternmost longitude (positive east) from which dataset was obtained; a value between -180 and 180 degrees.
geospatial_lon_units	char('Degrees_east')	Units used for geospatial_lon_min/max attributes.
geospatial_vertical_min	double(0.0);	Minimum depth of measurements, in metres.
geospatial_vertical_max	double(0.0);	Maximum depth of measurements, in metres.
geospatial_vertical_units	char('meter')	Units used for geospatial_vertical_min/max attributes.
time_coverage_start	char('2017-09-22T08:30:00Z')	Start date and time in UTC, for which data in the dataset was collected. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2017-09-11T06:05:00Z : September 11 2017 06:05:00AM
time_coverage_end	char('2017-09-22T08:30:00Z')	End date and time in UTC, for which data in the dataset was collected. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2017-09-11T06:05:00Z : September 11 2017 06:05:00AM
local_time_zone	double(9.5)	Local time zone (UTC+)
data_center	char(' Australian Ocean Data Network (AODN)')	Data center in charge of management and distribution of the data resource.
data_centre_email	char('info@aodn.org.au')	Data centre contact email address.
author	char('Cosoli, Simone')	Name of person responsible for the creation of the dataset.
author_email	char('simone.cosoli@uwa.edu.au')	Email address for the data creator
institution_references	char('http://imos.org.au/facilities/oceanradar/')	Reference to the data provider and producer.
principal_investigator	char('Cosoli, Simone')	Name of principal investigator in charge of the radar
citation	char(' The citation in a list of references is: IMOS, [year-of-data-download], [Title], [data-access-URL], accessed [date-of-access]'')	Citation used for usage of this data.
acknowledgement	char('Any users (including re-packagers) of IMOS data are required to clearly acknowledge the source of the material in this format: "Data was sourced from the Integrated Marine Observing System (IMOS) - IMOS is enabled	Any users (including re-packers) of IMOS data are required to acknowledge the source of the data in this format.

	by the National Collaborative Research Infrastructure (NCRIS). It is operated by a consortium of institutions as an unincorporated joint venture, with the University of Tasmania as Lead Agent."')	
distribution_statement	char('Data may be re-used, provided that related metadata explaining the data has been reviewed by the user, and the data is appropriately acknowledged. Data, products and services from IMOS are provided \"as is\" without any warranty as to fitness for a particular purpose.')	Statement describing data distribution policy.
license	char('http://creativecommons.org/licenses/by/4.0/')	Reference for the license for the data
Comment	char('This NetCDF file has been created using the IMOS NetCDF Conventions v1.4.')	

3.2.3 Dimensions

The IMOS Ocean Radar Facility vector current maps are 1-hour averages of the sea surface current. They have two-dimensional coordinates of latitude, longitude coordinates, along with various measured parameters. All variables are defined on a regular latitude – longitude grid; the size of data is fixed.
FV00 files include the following dimension: TIME; LATITUDE; LONGITUDE.

Table 12 *Dimension*

Dimension	Definition
TIME	Temporal interval over which the data was averaged (UNLIMITED)
LATITUDE	Number of the unique latitude coordinate values
LONGITUDE	Number of the unique longitude coordinate values

3.2.4 Variables

Variables and attributes in FV00 netCDF data files for WERA surface currents are listed in Table 13. Table 14 contains the parameters included in the netCDF file, with Table 15 listing the quality control indicator and the flags in use.

Table 13. *Variables and attributes for the RT FV00 WERA vector maps*

Variable	Attributes	Definition

TIME	double TIME;
	standard_name = "time";
	long_name = "time";
	units = "days since 1950-01-01 00:00:00 UTC";
	calendar = "gregorian";
	axis = "T";
	valid_min = 0.0;
	valid_max = 90000.0;
		Time at which <PARAM> measurements were made. Values are recorded as days since 12 am of 1st January 1950.

LONGITUDE	double LONGITUDE
	standard_name = "longitude";
	long_name = "longitude";
	units = "degrees_east";
	axis = "X";
	valid_min = -180.0;
	valid_max = 180.0;
	reference_datum = "geographical coordinates, WGS84 datum";	

LATITUDE	double LATITUDE
	standard_name = "latitude";
	long_name = "latitude";
	units = "degrees_north";
	axis = "Y";
	valid_min = -90.0;
	valid_max = 90.0;
	reference_datum = "geographical coordinates, WGS84 datum";	

<PARAM>	float <PARAM>(LATITUDE,LONGITUDE); <PARAM>_FillValue =<X> <PARAM>long_name = <X>; <PARAM>units = <X> <PARAM>valid_min = <X> <PARAM>valid_max = <X>; <PARAM>cell_method = <X>; <PARAM>ancillary_variables = <X>; <PARAM>coordinates;	<PARAM> contains the values of a parameter listed in reference table 5. <X>: this field is specified in the reference table 11. The quality_control_indicator values are as listed in Table 6.
<PARAM_quality_control>	byte <PARAM_quality_control>(POSITION); <PARAM_quality_control>long_name; <PARAM_quality_control>quality_control_set = <X>; <PARAM_quality_control>quality_control_conventions<X>;; <PARAM_quality_control>_FillValue = <X>; <PARAM_quality_control>valid_min = <X>; <PARAM_quality_control>valid_max = <X>; <PARAM_quality_control>flag_values = <X>; <PARAM_quality_control>flag_meanings = <X>; <PARAM_quality_control>coordinates;	Quality flag applied on the <PARAM> values as result of the RT quality checks. Information on flag meanings is found in Table 12.

Table 14 contains the parameters included in the netCDF file, with Table 15 listing the quality control indicator and the flags in use for IMOS Ocean Radar Facility vector current maps.

***Table 14**. List of parameters included in the netcdf files*

Code	standard_name	long_name (for non-CF)	_FillValue	valid_min	valid_max	coordinates	Ancillary _variables	units
GDOP		Radar beam intersection angles	999999	0	180.0	TIME, LATITUDE, LONGITUDE		degrees
UCUR	eastward_sea_water_velocity	Mean of sea water velocity U component values in 1 hour, after rejection of obvious bad data (see abstract).	999999	-10	10	TIME, LATITUDE, LONGITUDE	UCUR_quality_control	m s-1
VCUR	northward_sea_water_velocity	Mean of sea water velocity V component values in 1 hour, after rejection of obvious bad data (see abstract).	999999	-10	10	TIME, LATITUDE, LONGITUDE	VCUR_quality_control	m s-1
UCUR_sd		Standard deviation of sea water velocity U component values in 1 hour, after rejection of obvious bad data (see abstract).	999999	-10	10	TIME, LATITUDE, LONGITUDE	UCUR_quality_control	m s-1
VCUR_sd		Standard deviation of sea water velocity V component values in 1 hour, after rejection of obvious bad data (see abstract).	999999	-10	10	TIME, LATITUDE, LONGITUDE	VCUR_quality_control	m s-1
NOBS1		Number of observations of sea water velocity in 1 hour from station 1, after rejection of obvious bad data (see abstract).	-99B			TIME, LATITUDE, LONGITUDE		1
NOBS2		Number of observations of sea water velocity in 1 hour from station 2, after rejection of obvious bad data (see abstract).	-99B			TIME, LATITUDE, LONGITUDE		1

Table 15. *Quality control indicator and the flags in use for FV00 RT WERA vector current maps*

Flag value	**Meaning**	**Description**
0	No QC performed	The level at which all data enter the working archive. They have not yet been quality controlled
1	Good data	Top quality data in which no malfunctions have been identified and all real features have been verified during the quality control process.
2	Probably good data	Good data in which some features (probably real) are present but these are unconfirmed. Code 2 data are also data in which minor malfunctions may be present but these errors are small and/or can be successfully corrected without seriously affecting the overall quality of the data.
3	Bad data that are potentially correctable	Suspect data in which unusual, and probably erroneous features are observed.
4	Bad data	Obviously erroneous values are observed.
5	Value changed	Altered by a QC centre, with original values (before the change) preserved in the history record of the data.
6	Not used	Reserved for future use.
7	Not used	Reserved for future use.
8	Interpolated value	Indicates that data values are interpolated.
9	Missing value	Indicates that the element is missing.

3.3 File format for RT SeaSonde radial data

The file format in use for the FV00 SeaSonde radial data is netCDF-4 file format compliant with the IMOS-1.4 and CF-1.6. A description of the global attributes, dimensions, variables is given below.

3.3.1 File naming convention

The naming conventions for RT netcdf files from IMOS Ocean Radar Facility SeaSonde HF radar systems follow the IMOS convention for RT FV00 products (also described in [4]), as detailed below (Table 16):

IMOS_ACORN_<data-code>_<date> _ <platform-code> _FV <file-version> _<product-type>.nc

An example for the RT FV00 radial current for Green Head radar station is given below:

IMOS_ACORN_RV_20170922T110000Z_GHED_FV00_radial.nc

Table 16*. Elements of file-naming convention*

Part of filename	Description
data-code	RV: radial velocity
Date	Start date and time of the measurements in UTC. Date format is: yyyymmddTHHMMSSZ where T is the delimiter between date and time, and Z indicates that time is in UTC. Example: 20170911T060500Z is 11th September 2017, 06:05AM
platform-code	A four-letter code for the SeaSonde HFR stations: DONG: Dongara – Port Denison station (WA) GHED: Green Head station (WA) LANC: Lancelin station (WA) RHED: Red Head station (NSW) SEAL: Seal Rocks station (NSW)
file-version	Value representing the version of the file. This value is preceded by two characters: 'FV'. 00: Level 0 – raw data. Raw data is defined as data processed with the acquisition software provided by the manufacturer, and data products that have undergone RT quality control procedures. Data are available in physical units. Level 0 data is suitable for public access. Metadata exists for the data. 01: Level 1 – quality controlled data. Quality controlled data have passed offline, delayed mode quality control procedures. Data are in physical units using standard SI metric units. Metadata exists for the data.
product-type	This code gives information about the product included in the dataset. Example: radial, for maps of sea surface current component towards or away from the radar receiver

3.3.2 Global attributes

A detailed description of the global attributes for RT FV00 SeaSonde radial data files is provided in Table 17.

Table 17. IMOS Ocean Radar Facility *netCDF files global attributes for RT radial currents*

Name	Example	Definition
Project	char('Integrated Marine Observing System (IMOS)');	The scientific project that produced the data
Conventions	char('CF-1.6,IMOS-1.4');	Format convention used by the dataset
institution	char('IMOS Ocean Radar Facility');	Name of the institute or facility where the original data was produced.
title	char(['Turquoise Coast (WA), Green Head (WA), Radial, 2017-09-22 11:00:00Z']);	Short description of the dataset indicating the radar station that collect the data, the type of product and the acquisition date.
Instrument	char('CODAR Ocean Sensors/SeaSonde')	Type of instrument used to collect the data
platform_code	char('GHED');	Four-letter code for the HFR site
site_code	char('TURQ")	Four-letter code for the HFR node
date_created	char('2017-09-22T11:50:07Z');	Date and time at which the file was created. Format: yyyy-mm-ddTHH:MM:SSZ'

		Example: 2017-09-22T11:50:07Z : 22nd September 2017 11:50:07AM
abstract	char('Radial data, CODAR Ocean Sensors/SeaSonde sea surface radar located at Green Head (WA), Turquoise Coast (WA), for time 2017-09-22 11:00:00Z. Radials represent the surface sea water state component along the radial direction from the receive antenna and are calculated using the MUSIC algorithm to perform direction finding. Geospatial bounds are Longitude:(113.476,115.000) and Latitude:(-31.271,-29.138). Total data acquisition time is 4799 s. Data produced by the IMOS Ocean Radar Facility .'));	A paragraph describing the dataset: type of data contained, how it was created, who collected it, what instruments were used, etc.
source	char('Terrestrial HF radar');	Method of production of the original data.
keywords	char('Oceans');	A comma separated list of key words and phrases.
standard_name_vocabulary	Char('NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table 27')	Reference for CF standard names
netcdf_version	Char('4.1.3')	NetCDF file version
naming_authority	char('IMOS');	Naming authority will always be IMOS.
file_version	char('Level 0 - Non Quality Controlled data')	Version of data processing
file_version_quality_control	char('Data in this file has been through the quality control procedure as described in the document: Quality Control procedures for IMOS Ocean Radar Facility Manual Version 3.0. Integrated Marine Observing System. DOI: 10.26198/5c89b59a931cb (http://dx.doi.org/10.26198/5c89b59a931cb). Every data point in this file has an associated quality flag.');	Version of the quality control applied to the data
geospatial_lat_min	double(-31.2705754);	Southernmost latitude (positive north) from which dataset was obtained; a value between -90 and 90 degrees.
geospatial_lat_max	double(-29.1379066;	Northernmost latitude (positive north) from which dataset was obtained; a value between -90 and 90 degrees.
geospatial_lat_units	char('degrees_north')	Units used for geospatial_lat_min/max attributes.
geospatial_lon_min	double(113.4762907);	Westernmost longitude (positive east) from which dataset was obtained; a value between -180 and 180 degrees.
geospatial_lon_max	double(115.0004429);	Easternmost longitude (positive east) from which dataset was obtained; a value between -180 and 180 degrees.
geospatial_lon_units	char('degrees_east')	Units used for geospatial_lon_min/max attributes.
geospatial_vertical_min	double(0.0);	Minimum depth of measurements, in metres.
geospatial_vertical_max	double(0.0);	Maximum depth of measurements, in metres.
geospatial_vertical_units	char('meter')	Units used for geospatial_vertical_min/max attributes.
Positive	char('up')	Direction of vertical coordinates
reference_datum	char('sea surface')	Reference origin for the vertical coordinate
time_coverage_start	char('2017-09-22T11:00:00Z')	Start date and time in UTC, for which data in the dataset was collected. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2017-09-11T06:05:00Z : September 11 2017 06:05:00AM
time_coverage_end	char('2017-09-22T11:00:00Z')	End date and time in UTC, for which data in the dataset was collected. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2017-09-11T06:05:00Z : September 11 2017 06:05:00AM

local_time_zone	double(8)	Local time zone (UTC+)
data_center	char(' Australian Ocean Data Network (AODN)')	Data center in charge of management and distribution of the data resource.
data_centre_email	char(‘info@aodn.org.au’)	Data centre contact email address.
author	char(‘Simone Cosoli’)	Name of person responsible for the creation of the dataset.
author_email	char(‘simone.cosoli@uwa.edu.au’)	Email address for the data creator
institution_references	char(‘http://imos.org.au/facilities/oceanradar/’)	Reference to the data provider and producer.
principal_investigator	char(‘Cosoli, Simone’)	Name of principal investigator in charge of the glider unit.
principal_investigator_email	char(‘simone.cosoli@uwa.edu.au’)	Principal investigator’s email address.
Citation	char('Citation to be used in publications should follow the format: "IMOS.[year-of-data-download],[Title],[Data access URL],accessed [date-of access]".')	Citation used for usage of this data.
acknowledgement	char(‘Any users (including re-packagers) of IMOS data are required to clearly acknowledge the source of the material in this format: "Data was sourced from the Integrated Marine Observing System (IMOS) - IMOS is enabled by the National Collaborative Research Infrastructure (NCRIS). It is operated by a consortium of institutions as an unincorporated joint venture, with the University of Tasmania as Lead Agent."’)	Any users (including re-packers) of IMOS data are required to acknowledge the source of the data in this format.
distribution_statement	char(‘Data may be re-used, provided that related metadata explaining the data has been reviewed by the user, and the data is appropriately acknowledged. Data, products and services from IMOS are provided \"as is\" without any warranty as to fitness for a particular purpose.’)	Statement describing data distribution policy.
license	char('http://creativecommons.org/licenses/by/4.0/')	Reference for the license for the data
disclaimer	char(' Data, products and services from IMOS are provided "as is" without any warranty as to fitness for a particular purpose.')	Statement describing data fitness policy

3.3.3 Dimensions

IMOS Ocean Radar Facility radial data are snapshots of the radial component of the sea surface current. They have one-dimensional coordinates of latitude, longitude coordinates, along with various measured parameters. All variables are sparse, and the size of data varies mostly on external interference or hardware problems. FV00 files include the following dimension (Table 18): TIME; POSITION; DATE; SEASONDE_RADS_TIME; SEASONDE_RCVR_TIME; SEASONDE_HEADER_SIZE

Table 18 *Dimension*

Dimension	Definition
TIME	Number of time steps over which data was sampled (UNLIMITED)
POSITION	Number of grid points in which data has been collected. The dimension may change but it is always present in the file.
DATE	
SEASONDE_RADS_TIME	Number of time steps over which radial diagnostic data are sampled
SEASONDE_RCVR_TIME	Number of time steps over which receiver diagnostic data are sampled
SEASONDE_HEADER_SIZE	Dimension (byte) of the header in the raw file before extraction of variables and before conversion to physical units

3.3.4 Variables

Variables and attributes in FV00 netcdf data files for SeaSonde surface radial velocity mas are listed in Table 19. Table 20 contains the parameters included in the netcdf file, with Table 21 lists the quality control indicator and the flags in use for the SeaSonde IMOS Ocean Radar Facility radial data.

Table 19. *Variables and attributes for the RT FV00 SeaSonde radial data*

Variable	Attributes	Definition

TIME	double TIME;
	standard_name = "time";
	long_name = "time";
	units = "days since 1950-01-01 00:00:00 UTC";
	calendar = "gregorian";
	axis = "T";
	valid_min = 0.0;
	valid_max = 90000.0;
		Time at which <PARAM> measurements were made. Values are recorded as days since 12 am of 1st January 1950.

POSITION	int POSITION
	long_name = "Grid position index";
	units = "1";
	valid_min = 1;
	valid_max = 5704;
		Adimensional variable that contains the position in the measurement grid

seasonde_CTF_Header	char seasonde_CTF_Header_GHED
	long_name = "CODAR Radial header";
	comment = "Original CODAR CTF header is stored in variable data. CTF header fields are also stored as variable attributes..";
	easonde_Version = "1.00";
	seasonde_File_Type = "LLUV";
	seasonde_Data_Type = "Radial";
	seasonde_File_Version = "rdls";
	seasonde_File_Label = "RadialMap";
	seasonde_LLUV_Version = "1.14";
	seasonde_LLUV_Date = "2010-07-18";
	seasonde_UUID = "98030FE6-8A8D-4BE0-B2BC-87B84FC19A2D";
	seasonde_Manufacturer = "CODAR Ocean Sensors. SeaSonde";
	seasonde_Site_Code = "GHED";
	seasonde_Date = "2017-09-22T11:00:00Z";
	seasonde_Time_Zone_Id = "UTC";
	seasonde_Time_Zone = 0; // int
	seasonde_Time_Zone_units = "min";
	seasonde_Time_Zone_Daylight = "No";
	seasonde_Duration = "PT1H19M58S";
	seasonde_Origin_Longitude = 114.9667167; // double
	seasonde_Origin_Longitude_units = "degree_east";	

	seasonde_Origin_Latitude = -30.0732167; // double
	seasonde_Origin_Latitude_units = "degree_north";
	seasonde_Rx_Longitude = 114.9667167; // double
	seasonde_Rx_Longitude_units = "degree_east";
	seasonde_Rx_Latitude = -30.0732167; // double
	seasonde_Rx_Latitude_units = "degree_north";
	seasonde_Spheroid_Name = "WGS84";
	seasonde_Spheroid_Radius = 6378137.0; // double
	seasonde_Spheroid_Radius_units = "m";
	seasonde_Spheroid_Flattening = 0.0033528106647475143; // double
	sseasonde_Project_Method = "CGEO";
	seasonde_Project_Version = "1.57";
	seasonde_Project_Date = "2009-03-10";
	seasonde_LLUV_Trust = "[ll,xy,rb,uv,vd]";
	seasonde_Range_Blanking = 1.0f; // float
	seasonde_Range_Blanking_units = "seasonde_Range_Resolution";
	seasonde_Range_Limit = 30.0f; // float
	seasonde_Range_Limit_units = "seasonde_Range_Resolution";
	seasonde_Range_Resolution = 5828.9f; // float
	seasonde_Range_Resolution_units = "m";
	seasonde_Rx_Boresight = 286.0f; // float
	seasonde_Rx_Boresight_units = "degree_true";
	seasonde_Reference_Angle = 0.0f; // float
	seasonde_Reference_Angle_units = "degree_true";
	seasonde_Angular_Resolution = 2.0f; // float
	seasonde_Angular_Resolution_units = "arc_degree";
	seasonde_Spatial_Resolution = 5.0f; // float
	seasonde_Spatial_Resolution_units = "arc_degree";
	seasonde_Ideal = "No";
	seasonde_Cal_Date = "2017-02-15T01:47:03";
	seasonde_Cal_Resolution = 1.0f; // float
	seasonde_Cal_Resolution_units = "arc_degree";
	seasonde_Cal_Smooth = NaNf; // float
	seasonde_Cal_Smooth_units = "arc_degree";
	seasonde_Cal_UUID = "F1A7DE88-DBCF-49BA-835D-617F4CB65B0A";
	seasonde_Frequency = 4463000.0f; // float
	seasonde_Frequency_units = "Hz";
	seasonde_Doppler_Resolution = 0.001953125f; // float
	seasonde_Doppler_Resolution_units = "Hz";
	seasonde_First_Order_Method = "[Default]";
	seasonde_Bragg_Smooth_Width = 1; // int
	seasonde_Current_Speed_Max = 1.5f; // float
	seasonde_Current_Speed_Max_units = "m s-1";
	seasonde_Second_Order = "No";
	seasonde_Bragg_Envelope_Ratio_Min = 151.36f; // float
	seasonde_Bragg_Envelope_Dip_Ratio_Max = 100.0f; // float
	seasonde_Bragg_Envelope_SN_Ratio_Min = 4.0f; // float
	seasonde_Cal_Amplitude = 0.45f, 0.58f; // float
	seasonde_Cal_Phase = 87.3f, 109.0f; // float
	seasonde_Cal_Phase_units = "arc_degree";
	seasonde_Cal_Amplitude_Dynamic = 0.26f, 0.43f; // float
	seasonde_Cal_Phase_Dynamic = 88.7f, 104.67f; // float
	seasonde_Cal_Phase_Dynamic_units = "arc_degree";
	seasonde_Music_Parameters = 40.0f, 20.0f, 2.0f; // float
	seasonde_Radial_N_Merge = 5; // int
	seasonde_Radial_N_Merge_Min = 2; // int
	seasonde_First_Order_Source = "Standard";
	seasonde_Radial_Merge_Method = "Averaged";	

	seasonde_Radial_Region_Mask = "Pattern";
	seasonde_Chirp_Duration = 1.0f; // float
	seasonde_Chirp_Duration_units = "s";
	seasonde_Bandwidth = 25733.912f; // float
	seasonde_Bandwidth_units = "Hz";
	seasonde_Chirp_Direction = "Down";
	seasonde_N_Ranges = 127; // int
	seasonde_N_Samples = 512; // int
	seasonde_Processed_Date = "2017-09-22T11:48:18Z";
	seasonde_Processing_Tool = "RadialMerger 10.7.1, SpectraToRadial 10.9.1, RadialSlider 11.2.2, RadialArchiver 11.2.8, AnalyzeSpectra 10.7.6";	

LONGITUDE	double LONGITUDE(POSITION)
	_FillValue = 9.969209968386869E36;
	standard_name = "longitude";
	long_name = "Longitude";
	reference_datum = "World Geodetic System 1984";
	units = "degrees_east";
	axis = "X";
	valid_min = -180.0;
	valid_max = 180.0;	

LATITUDE	double LATITUDE(POSITION)
	_FillValue = 9.969209968386869E36;
	standard_name = "latitude";
	long_name = "Latitude";
	reference_datum = "World Geodetic System 1984";
	units = "degrees_north";
	axis = "Y";
	valid_min = -90.0;
	valid_max = 90.0;	

<PARAM>	float <PARAM>(POSITION); <PARAM>_FillValue =<X> <PARAM>long_name = <X>; <PARAM>units = <X> <PARAM>valid_min = <X> <PARAM>valid_max = <X>; <PARAM>ancillary_variables = <X> <PARAM>coordinates;	<PARAM> contains the values of a parameter listed in reference table 5. <X>: this field is specified in the reference table 5. The quality_control_indicator values are as listed in Table 6.
<PARAM_quality_control>	byte <PARAM_quality_control>(POSITION); <PARAM_quality_control>long_name; <PARAM_quality_control>quality_control_set = <X>; <PARAM_quality_control>quality_control_conventions<X>;; <PARAM_quality_control>_FillValue = <X>; <PARAM_quality_control>valid_min = <X>; <PARAM_quality_control>valid_max = <X>; <PARAM_quality_control>flag_values = <X>; <PARAM_quality_control>flag_meanings = <X>; <PARAM_quality_control>coordinates;	Quality flag applied on the <PARAM> values as result of the RT quality checks. Information on flag meanings is found in Table 6.

Table 20 contains the parameters included in the netcdf file, with Table 21 lists the quality control indicator and the flags in use for IMOS Ocean Radar Facility radial data.

Table 20. *List of parameters included in the netcdf files*

Code	**standard_name**	**long_name (for non-CF)**	**_FillValue**	**valid_min**	**valid_max**	**coordinates**	**Ancillary _variables**	**units**
ssr_Surface_Radial_Sea_Water_Speed		Magnitude of surface sea water current radial component	9.96921E36			TIME, LATITUDE, LONGITUDE	ssr_Surface_Radial_Sea_Water_Speed_quality_control	m s-1
ssr_Surface_Radial_Direction_Of_Sea_Water_Velocity		Direction from receive antenna to grid position	-1	0	360	TIME, LATITUDE, LONGITUDE	ssr_Surface_Radial_Direction_Of_Sea_Water_Velocity_quality_control	arc_degree

seasonde_LLUV_VFLG		Vector indicator flag	-32767S			LATITUDE,LONGITUDE		1
seasonde_LLUV_ESPC		Standard deviation of current speed over the scatter patch	9.96921E36			LATITUDE,LONGITUDE		m s-1
seasonde_LLUV_ETMP		Standard deviation of current speed during coverage period	9.96921E36			LATITUDE,LONGITUDE		ms-1
seasonde_LLUV_MAXV		Maximum current speed found during coverage time	9.96921E36			LATITUDE,LONGITUDE		ms-1
seasonde_LLUV_MINV		Minimum current speed found during coverage time	9.96921E36			LATITUDE,LONGITUDE		ms-1
seasonde_LLUV_ERSC		Number of radials at the same range and bearing that went into the spatial value	-127			LATITUDE,LONGITUDE		1
seasonde_LLUV_ERTC		Number of radials at the same range and bearing that went into the temporal value	-127			LATITUDE,LONGITUDE		1
seasonde_LLUV_SPRC		Range cell number	-127			LATITUDE,LONGITUDE		1
seasonde_rads_TIME		Seconds around cardinal hour at which radial diagnostics are calculated	-2147483647					S
seasonde_rads_AMP1		Calculated antenna amplitude correction for loop 1 to monopole	9.96921E36					V^-2
seasonde_rads_AMP2		Calculated antenna amplitude correction for loop 2 to monopole	9.96921E36					V^-2
seasonde_rads_PH13		Calculated antenna phase correction for loop 1 to monopole	9.96921E36					arc_degree
seasonde_rads_PH23		Calculated antenna phase correction for loop 2 to monopole	9.96921E36					arc_degree
seasonde_rads_CPH1		Used antenna phase correction for loop 1 to monopole	9.96921E36					arc_degree

seasonde_rads _CPH2		Used antenna phase correction for loop 2 to monopole	9.96921E36					arc_degree
seasonde_rads _SNF1		Power spectrum noise floor of loop 1	9.96921E36					Dbm
seasonde_rads _SNF2		Power spectrum noise floor of loop 2	9.96921E36					Dbm
seasonde_rads _SNF3		Power spectrum noise floor of monopole	9.96921E36					Dbm
seasonde_rads _SSN2		Power spectrum signal to noise ratio of loop 2	9.96921E36					decibel
seasonde_rads _SSN3		Power spectrum signal to noise ratio of monpole	9.96921E36					decibel
seasonde_rads _DGRC		Range cell which had the highest signal to noise ratio for monopole	-127					1
seasonde_rads _DOPV		Number of doppler cells which were processed into radials	-32767					1
seasonde_rads _DDAP		Percentage of doppler cells that had dual angle MUSIC solutions	-127					Percent
seasonde_rads _RADV		Number of radial solutions found at different bearings and ranges	-32767					1
seasonde_rads _RAPR		Average number of radial solutions per range cell	-32767					1
seasonde_rads _RARC		Number of range cells processed	-32767					1
seasonde_rads _RADR		Maximum range calculated by where the number of radials drops to below 20% of the average number of radial solutions per range	9.96921E36					M
seasonde_rads _RMCV		Maximum current speed	9.96921E36					ms-1

seasonde_rads_RACV		Average absolute current speed	9.96921E36					ms-1
seasonde_rads_RABA		Average current velocity bearing	9.96921E36					degrees_true
seasonde_rads_RTYP		Type of radial being processed	-127					1
seasonde_rads_STYP		Type of cross spectra being processed	-127					1
seasonde_rads_DATE		ISO8601 compatible date and time string						1
seasonde_rcvr_TIME		Seconds around cardinal hour at which receiver diagnostics are calculated	-2147483647					S
seasonde_rcvr_RTMP		Receiver front panel board temperature	-127					degrees_celsius
seasonde_rcvr_MTMP		Receiver AWGIII model temperature	-127					degrees_celsius
seasonde_rcvr_XTRP		Hexadecimal code for transmit watch tripped settings	-127					1
seasonde_rcvr_RUNT		Receiver run time since it was last powered or the AWG module restarted	-2147483647					S
seasonde_rcvr_SP24		External supply voltage for DC powered receivers	9.96921E36					V
seasonde_rcvr_SP05		+5VDC supply voltage on the receiver front panel board	9.96921E36					V
seasonde_rcvr_SN05		-5VDC supply voltage on the receiver front panel board	9.96921E36					V
seasonde_rcvr_SP12		+12VDC supply voltage on the receiver front panel board	9.96921E36					V
seasonde_rcvr_XPHT		Temperature on the transmitter front panel board	-127					degrees_Celsius
seasonde_rcvr_XAHT		Temperature on the transmitter	-127					degrees_Celsius

		amplifier						
seasonde_rcvr _XAFW		Measured forward power inside the transmitter	-32767					W
seasonde_rcvr _XARW		Measured reflected power inside the transmitter	-32767					W
seasonde_rcvr _XP28		+28VDC supply voltage on the transmitter front panel board	9.96921E36					V
seasonde_rcvr _XP05		+5VDC supply voltage on the transmitter front panel board	9.96921E36					V
seasonde_rcvr _GRMD		GPS receive mode	-127					1
seasonde_rcvr _GDMD		GPS discipline mode	-127					1
seasonde_rcvr _GSLK		GPS satellite lock	-127					1
seasonde_rcvr _GSUL		GPS satellite lock	-127					1
seasonde_rcvr _PLLL		Number of times the receiver PLL was found to lose lock to the GPS timing	-32767					1
seasonde_rcvr _HTMP		Receiver front panel high accuracy temperature	9.96921E36					degree_Celsiu s
seasonde_rcvr _HUMI		Receiver front panel high accuracy humidity	-127					Percent
seasonde_rcvr _RBIA		Receiver DC powered current draw	9.96921E36					A
seasonde_rcvr _EXTA		Receiver external signal input A logic high level count	-32767					1
seasonde_rcvr _EXTB		Receiver external signal input B logic high level count	-32767					1
seasonde_rcvr _CRUN		Computer run time	9.96921E36f					min

Table 21. *Quality control indicator and the flags in use for FV00 RT IMOS Ocean Radar Facility SeaSonde radial data*

Flag value	**Meaning**	**Description**
0	No QC performed	The level at which all data enter the working archive. They have not yet been quality controlled

1	Good data	Top quality data in which no malfunctions have been identified and all real features have been verified during the quality control process.
2	Probably good data	Good data in which some features (probably real) are present but these are unconfirmed. Code 2 data are also data in which minor malfunctions may be present but these errors are small and/or can be successfully corrected without seriously affecting the overall quality of the data.
3	Bad data that are potentially correctable	Suspect data in which unusual, and probably erroneous features are observed.
4	Bad data	Obviously erroneous values are observed.
5	Value changed	Altered by a QC centre, with original values (before the change) preserved in the history record of the data.
6	Not used	Reserved for future use.
7	Not used	Reserved for future use.
8	Interpolated value	Indicates that data values are interpolated.
9	Missing value	Indicates that the element is missing.

3.4 File format for RT SeaSonde vector data

Surface current vector maps are created in RT mode at the UWA server using the manufacturer proprietary software. The output ascii file is then converted to netCDF-4 file compliant with the IMOS-1.4 and CF-1.6 conventions. A detailed description of the file format, the variable, the metadata is given in the following Section.

3.4.1 File naming convention

The naming conventions for RT netcdf files for surface currents from ACORN SeaSonde HF radar systems follow the IMOS convention for RT FV00 products (also described in [4]), as detailed below (Table 22):

IMOS_ACORN_<data-code>_<date> _ <node-code> _FV <file-version> _<product-type>.nc

An example for the RT FV00 vector current map for the Turquoise Coast (TURQ) region is given below:

IMOS_ACORN_V_20170926T160000Z_TURQ_FV00_1-hour-avg.nc

***Table 22**. Elements of file-naming convention*

Part of filename	Description
data-code	V: 2D surface current velocity map
date	Start date and time of the measurements in UTC. Date format is: yyyymmddTHHMMSSZ where T is the delimiter between date and time, and Z indicates that time is in UTC. Example: 20170926T160000Z is 26th September 2017, 16:30
node-code	A four-letter code for the regional deployment: TURQ: Turquoise Coast (WA) CORL: Coral Coast (WA) BONC: Bonney Coast (SA) NEWC: Newcastle (NSW)
file-version	Value representing the version of the file. This value is preceded by two characters: 'FV'. 00: Level 0 – raw data. Raw data is defined as data processed with the acquisition software provided by the manufacturer, and data products that have undergone RT quality control procedures. Data are available in physical units. Level 0 data is suitable for public access. Metadata exists for the data. 01: Level 1 – quality controlled data. Quality controlled data have passed offline, delayed mode quality control procedures. Data are in physical units using standard SI metric units. Metadata exists for the data.
product-type	This code gives information about the product included in the dataset. Example: 1-hour-avg, for surface current maps

3.4.2 Global attributes

The following attributes are included in the RT F00 radial current files (Table 23).

***Table 23**. IMOS Ocean Radar Facility netcdf files global attributes for RT surface currents*

Name	Example	Definition
project	char('Integrated Marine Observing System (IMOS)');	The scientific project that produced the data
Conventions	char('CF-1.6,IMOS-1.4');	Format convention used by the dataset
institution	char(IMOS Ocean Radar Facility');	Name of the institute or facility where the original data was produced.
title	char([IMOS Ocean Radar Facility Turqoise Coast (TURQ), one hour averaged current RT-QC data, 2017-09-26T16:00:00Z]);	Short description of the dataset indicating the radar station that collect the data, the type of product and the acquisition date.
Instrument	char('CODAR Ocean Sensors/SeaSonde')	Type of instrument used to collect the data
site_code	char('TURQ, Turqoise Coast')	HF radar node
ssr_Stations	char('Lancelin (LANC), Green Head (GHED)')	Four-letter code for the HFR node
date_created	char('2017-09-26T16:54:32Z');	Date and time at which the file was created. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 20170926T160000Z is 26^{th} September 2017, 16:30
abstract	char('The IMOS Ocean Radar Facility (formerly ACORN) is producing NetCDF files containi current maps at 1 hour time interval for time ins 09-26 16:00:00Z in the region extending Longitude: (112.124,115.827) and Latitude: 29.307). The final product is produced on geographic grid. They are produced from radial (the Turquoise Coast (WA), which represent the s water current component along the radial directi receiver antenna. Radials are calculated from th the Bragg peaks in a power spectrum. They ar onto specific angles through a Direction-Finding and are converted into current vector component unweighted least-squares fit. Radials and vector computed using the standard software provid ocean radar manufacturer, CODAR Ocean Senso Radials are extracted from the Doppler spectra calibrated antenna pattern. Thresholds for radial velocities are set to 6dB, and 150 cm s-1. V produced at each grid point using an unweigl squares fit. Radial velocities from the two si within a search radius R=20 km around each gri used in the computation. At least two radials p required in computation of the velocity compo procedures apply first to intersection angle (GD GDOP<=150); a threshold of 150 cm s-1 is a current velocity. the U, V current components flagged based on the number of radial velocities site that contribute to the velocity vector. Quality to 4 if NOBS1==1 or NOBS2==1; it is se NOBS1/NOBS2>=10 or NOBS2/NOBS1<=10; 2 if (NOBS1/NOBS2>=1 & NOBS2/NOBS1< (NOBS2/NOBS1>=1 & NOBS1/NOBS2<10). product is produced on a regular geographic g information on the data processing is available t document: Quality Control procedures for IM Radar Facility Manual Version 3.0. Integrated Marine Observing System. DOI: 10.26198/5c89b59a931cb (http://dx.doi.org/10.26198/5c89b59a931cb));	A paragraph describing the dataset: type of data contained, how it was created, who collected it, what instruments were used, etc.
source	char('Terrestrial HF radar');	Method of production of the original data.
keywords	char('Oceans');	A comma separated list of key words and phrases.
standard_name_vocabulary	Char('NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table 27')	Reference for CF standard names
netcdf_version	Char('4.1.3')	NetCDF file version

naming_authority	char('IMOS');	Naming authority will always be IMOS.
file_version	char('Level 0 - RT Quality Controlled data')	Version of data processing
file_version_quality_control	char('Data in this file has been through the quality control procedure as described in the document: Quality Control procedures for IMOS Ocean Radar Facility Manual Version 3.0. Integrated Marine Observing System. DOI: 10.26198/5c89b59a931cb (http://dx.doi.org/10.26198/5c89b59a931cb). Every data point in this file has an associated quality flag.');	Version of the quality control applied to the data
geospatial_lat_min	double(-32.5151159);	Southernmost latitude (positive north) from which dataset was obtained; a value between -90 and 90 degrees.
geospatial_lat_max	double(-29.3070009);	Northernmost latitude (positive north) from which dataset was obtained; a value between -90 and 90 degrees.
geospatial_lat_units	char('Degrees_north')	Units used for geospatial_lat_min/max attributes.
geospatial_lon_min	double(112.1237434);	Westernmost longitude (positive east) from which dataset was obtained; a value between -180 and 180 degrees.
geospatial_lon_max	double(115.8266081);	Easternmost longitude (positive east) from which dataset was obtained; a value between -180 and 180 degrees.
geospatial_lon_units	char('Degrees_east')	Units used for geospatial_lon_min/max attributes.
geospatial_vertical_min	double(0.0);	Minimum depth of measurements, in metres.
geospatial_vertical_max	double(0.0);	Maximum depth of measurements, in metres.
geospatial_vertical_units	char('m)	Units used for geospatial_vertical_min/max attributes.
time_coverage_start	char('2017-09-26T16:00:00Z')	Start date and time in UTC, for which data in the dataset was collected. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2017-09-11T06:05:00Z : September 11 2017 06:05:00AM
time_coverage_end	char('2017-09-26T16:00:00Z')	End date and time in UTC, for which data in the dataset was collected. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2017-09-11T06:05:00Z : September 11 2017 06:05:00AM
local_time_zone	double(8)	Local time zone (UTC+)
data_center	char(' Australian Ocean Data Network (AODN)')	Data center in charge of management and distribution of the data resource.
data_centre_email	char('info@aodn.org.au')	Data centre contact email address.
author	char('Cosoli, Simone)	Name of person responsible for the creation of the dataset.
author_email	char('simone.cosoli@uwa.edu.au)	Email address for the data creator
institution_references	char('http://imos.org.au/facilities/oceanradar/')	Reference to the data provider and producer.
principal_investigator	char('Cosoli, Simone')	Name of principal investigator in charge of the radar
citation	char(' The citation in a list of references is: IMOS, [year-of-data-download], [Title], [data-access-URL], accessed [date-of-access]'')	Citation used for usage of this data.
acknowledgement	char('Data was sourced from the Integrated Marine Observing System (IMOS) - IMOS is a national collaborative research infrastructure, supported by Australian Government."')	Any users (including re-packers) of IMOS data are required to acknowledge the source of the data in this format.
distribution_statement	char('Data may be re-used, provided that related metadata explaining the data has been reviewed by the user, and the data is	Statement describing data distribution policy.

	appropriately acknowledged. Data, products and services from IMOS are provided \"as is\" without any warranty as to fitness for a particular purpose.')	
license	char('http://creativecommons.org/licenses/by/4.0/')	Reference for the license for the data
Comment	char('This NetCDF file has been created using the IMOS NetCDF Conventions v1.4.')	

3.4.3 Dimensions

SeaSonde radar vector currents are 1-hour averages of the sea surface current. They have two-dimensional coordinates of I, J indexes instead of longitude latitude, along with various measured parameters. Longitude and Latitude variables are also provided although for a non-Mercator projection. All variables are defined on a regular latitude – longitude grid; the size of data is fixed. FV00 files include the following dimension (Table 24): TIME; I, J; LATITUDE, LONGITUDE.

Table 24 *Dimension*

Dimension	Definition
TIME	Temporal interval over which the data was averaged (UNLIMITED)
I	Row indexes for the grid coordinated along the x-axis
J	Row indexes for the grid coordinated along the y-axis
LATITUDE	Number of the unique latitude coordinate values
LONGITUDE	Number of the unique longitude coordinate values

3.4.4 Variables

Variables and attributes in FV00 netCDF data files for SeaSonde surface currents are listed in Table 25. Table 26 contains the parameters included in the netcdf file, with Table 27 listing the quality control indicator and the flags in use for IMOS Ocean Radar Facility SeaSonde current data.

Table 25. *Variables and attributes for the RT FV00 SeaSonde vector maps*

Variable	Attributes	Definition

TIME	double TIME;
	standard_name = "time";
	long_name = "time";
	units = "days since 1950-01-01 00:00:00 UTC";
	calendar = "gregorian";
	axis = "T";
	valid_min = 0.0;
	valid_max = 90000.0;
		Time at which <PARAM> measurements were made. Values are recorded as days since 12 am of 1st January 1950.

I	int(I); long_name = "row index (top most value is 1)"; units = "1";	Starting point for the vector grid definition along the X axis
J	int(J); long_name = "column index (left most value is 1)"; units = "1";	Starting point for the vector grid definition along the Y axis

LONGITUDE	double LONGITUDE
	standard_name = "longitude";
	long_name = "longitude";
	units = "degrees_east";
	axis = "X";
	valid_min = -180.0;
	valid_max = 180.0;
	reference_datum = "geographical coordinates, WGS84 datum";	

LATITUDE	double LATITUDE
	standard_name = "latitude";
	long_name = "latitude";
	units = "degrees_north";
	axis = "Y";
	valid_min = -90.0;
	valid_max = 90.0;
	reference_datum = "geographical coordinates, WGS84 datum";	

<PARAM>	float <PARAM>(LATITUDE,LONGITUDE); <PARAM>_FillValue =<X> <PARAM>long_name = <X>; <PARAM>units = <X> <PARAM>valid_min = <X> <PARAM>valid_max = <X>; <PARAM>cell_method = <X>; <PARAM>ancillary_variables = <X>; <PARAM>coordinates;	<PARAM> contains the values of a parameter listed in reference table 5. <X>: this field is specified in the reference table 11. The quality_control_indicator values are as listed in Table 6.
<PARAM_quality_control>	byte <PARAM_quality_control>(POSITION); <PARAM_quality_control>long_name; <PARAM_quality_control>quality_control_set = <X>; <PARAM_quality_control>quality_control_conventions<X>;; <PARAM_quality_control>_FillValue = <X>; <PARAM_quality_control>valid_min = <X>; <PARAM_quality_control>valid_max = <X>; <PARAM_quality_control>flag_values = <X>; <PARAM_quality_control>flag_meanings = <X>; <PARAM_quality_control>coordinates;	Quality flag applied on the <PARAM> values as result of the RT quality checks. Information on flag meanings is found in Table 12.

Table 26 contains the parameters included in the netCDF file, with Table 27 listing the quality control indicator and the flags in use for IMOS Ocean Radar Facility SeaSonde current data.

Table 26. *List of parameters included in the netCDF files*

Code	**standard_name**	**long_name (for non-CF)**	**_FillValue**	**valid_min**	**valid_max**	**coordinates**	**Ancillary _variables**	**units**
GDOP		Radar beam intersection angles	999999	0	180.0	TIME, LATITUDE, LONGITUDE		degrees
UCUR	eastward_sea_water_velocity	Mean of sea water velocity U component values in 1 hour, after rejection of obvious bad data (see abstract).	999999	-10	10	TIME, LATITUDE, LONGITUDE	UCUR_quality_control	m s-1
VCUR	northward_sea_water_velocity	Mean of sea water velocity V component values in 1 hour, after rejection of obvious bad data (see abstract).	999999	-10	10	TIME, LATITUDE, LONGITUDE	VCUR_quality_control	m s-1
UCUR_sd		Standard deviation of sea water velocity U component values in 1 hour, after rejection of obvious bad data (see abstract).	999999	-10	10	TIME, LATITUDE, LONGITUDE	UCUR_quality_control	m s-1
VCUR_sd		Standard deviation of sea water velocity V component values in 1 hour, after rejection of obvious bad data (see abstract).	999999	-10	10	TIME, LATITUDE, LONGITUDE	VCUR_quality_control	m s-1
NOBS1		Number of observations of sea water velocity in 1 hour from station 1, after rejection of obvious bad data (see abstract).	-99B			TIME, LATITUDE, LONGITUDE		1
NOBS2		Number of observations of sea water velocity in 1 hour from station 2, after rejection of obvious bad data (see abstract).	-99B			TIME, LATITUDE, LONGITUDE		1

Table 27. *Quality control indicator and the flags in use for FV00 RT SeaSonde vector current maps*

Flag value	**Meaning**	**Description**
0	No QC performed	The level at which all data enter the working archive. They have not yet been quality controlled
1	Good data	Top quality data in which no malfunctions have been identified and all real features have been verified during the quality control process.
2	Probably good data	Good data in which some features (probably real) are present but these are unconfirmed. Code 2 data are also data in which minor malfunctions may be present but these errors are small and/or can be successfully corrected without seriously affecting the overall quality of the data.
3	Bad data that are potentially correctable	Suspect data in which unusual, and probably erroneous features are observed.
4	Bad data	Obviously erroneous values are observed.
5	Value changed	Altered by a QC centre, with original values (before the change) preserved in the history record of the data.
6	Not used	Reserved for future use.
7	Not used	Reserved for future use.
8	Interpolated value	Indicates that data values are interpolated.
9	Missing value	Indicates that the element is missing.

4. File format for DM products

4.1 File format for DM WERA radial data

At the time of writing (November 2019) the file format in use for the FV01 WERA radial data complies with the IMOS-1.4 and CF-1.6 conventions. A description of the file format, compliant with the IMOS-1.4 and CF-1.6 conventions, is provided in detail below.

4.1.1 File naming convention

The naming conventions for DM netcdf files from IMOS Ocean Radar Facility WERA HF systems follow the IMOS convention for DM FV01 products (also described in [4]), as detailed below (Table 28):

IMOS_ACORN_<data-code>_<date> _ <platform-code> _FV <file-version> _<product-type>.nc

An example for the DM FV01 radial current for Tannum Sands (TAN) radar station is given below:

IMOS_ACORN_RV_20170417T152000Z_TAN_FV01_radial.nc

***Table 28**. Elements of file-naming convention*

Part of filename	Description
data-code	RV: radial velocity
date	Start date and time of the measurements in UTC. Date format is: yyyymmddTHHMMSSZ where T is the delimiter between date and time, and Z indicates that time is in UTC. Example: 20170911T060500Z is 11th September 2017, 06:05AM
platform-code	A three-letter code for the WERA HFR stations: FRE: Fremantle station (WA) GUI: Guilderton station (WA) CSP: Cape Spencer station (SA) CWI: Cape Wiles station (SA) RRK: Red Rock station (NSW) NNB: North Nambucca Head (NSW) LEI: Lady Elliot Island (QLD) TAN: Tannum Sands (QLD)
file-version	Value representing the version of the file. This value is preceded by two characters: 'FV'. 00: Level 0 – raw data. Raw data is defined as data processed with the acquisition software provided by the manufacturer, and data products that have undergone RT quality control procedures. Data are available in physical units. Level 0 data is suitable for public access. Metadata exists for the data. 01: Level 1 – quality controlled data. Quality controlled data have passed offline, delayed mode quality control procedures. Data are in physical units using standard SI metric units. Metadata exists for the data.
product-type	This code gives information about the product included in the dataset. Example: radial, for maps of sea surface current component towards or away from the radar receiver

4.1.2 Global attributes

The following attributes are included in the DM F01 radial current files (Table 29).

Table 29. *IMOS Ocean Radar Facility netcdf files global attributes for DM radial currents*

Name	Example	Definition
project	char('Integrated Marine Observing System (IMOS)');	The scientific project that produced the data
Conventions	char('CF-1.6,IMOS-1.4');	Format convention used by the dataset
institution	char(' IMOS Ocean Radar Facility');	Name of the institute or facility where the original data was produced.
title	char(['Capricorn Bunker Group (Qld), Tannum Sands (Qld), Radial, 2017-04-17 15:20:00Z']);	Short description of the dataset indicating the radar station that collect the data, the type of product and the acquisition date.
Instrument	char('WERA Oceanographic HF Radar/Helzel Messtechnik, GmbH')	Type of instrument used to colect the data
platform_code	char('TAN');	Three-letter code for the HFR site
site_code	char('CBG")	Three-letter code for the HFR node
ssr_Stations	char('ssr_Station_TAN')	
date_created	char('2017-05-05T07:29:53Z');	Date and time at which the file was created. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2017-09-11T06:47:50Z : December 11st September 2017 06:47:50AM
abstract	char('The IMOS Ocean Radar Facility (formerly known as ACORN) is producing NetCDF files containing quality controlled radial current maps at 5 min time intervals. Radials are calculated from the shift of the Bragg peaks in a power spectrum. A set of Matlab tools is adopted to read data files, perform additional quality controls on radial current components, and convert the files into netcdf format. Each radial current value has a quality control flag. Four different statistical methods are used to define them: absolute deviation from the median (MAD); statistics of the velocity distributions; statistics of the distributions of the 1st derivative; statistics of the distributions of the high-frequency components. Data are flagged based on the results of the statistical tests: 4, if three or more tests fail; 3, if two tests fail; 2, if one test fails; 1, no test fails. Additional quality control is performed on the spatial distribution of radial Signal-to-Noise Ratio (SNR) after threshold of 10dB to the SNR values and a site-depending velocity threshold thresholds are applied. Radial velocities are flagged as 4 if their SNR values do not fit the spatial distribution. Similar fags are applied to the corresponding SNR values. More information on the data processing is available through the document: Quality Control procedures for IMOS Ocean Radar Facility Manual Version 2.0. Integrated Marine Observing System. DOI: 10.26198/5c89b59a931cb (http://dx.doi.org/10.26198/5c89b59a931c	A paragraph describing the dataset: type of data contained, how it was created, who collected it, what instruments were used, etc.

	b)');	
source	char('Terrestrial HF radar');	Method of production of the original data.
keywords	char('Oceans');	A comma separated list of key words and phrases.
standard_name_vocabulary	Char('NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table 27')	Reference for CF standard names
netcdf_version	Char('4.1.3')	NetCDF file version
naming_authority	char('IMOS');	Naming authority will always be IMOS.
file_version	char('Level 1 - Quality Controlled data')	Version of data processing
file_version_quality_control	char('Data in this file has been through the quality control procedure as described in the document: Quality Control procedures for IMOS Ocean Radar Facility Manual Version 2.0. Integrated Marine Observing System. DOI: 10.26198/5c89b59a931cb (http://dx.doi.org/10.26198/5c89b59a931cb). Every data point in this file has an associated quality flag.');	Version of the quality control applied to the data
geospatial_lat_min	double(-23.979097);	Southernmost latitude (positive north) from which dataset was obtained; a value between -90 and 90 degrees.
geospatial_lat_max	double(-22.281501);	Northernmost latitude (positive north) from which dataset was obtained; a value between -90 and 90 degrees.
geospatial_lat_units	char('Degrees_north')	Units used for geospatial_lat_min/max attributes.
geospatial_lon_min	double(151.406305);	Westernmost longitude (positive east) from which dataset was obtained; a value between -180 and 180 degrees.
geospatial_lon_max	double(153.475305);	Easternmost longitude (positive east) from which dataset was obtained; a value between -180 and 180 degrees.
geospatial_lon_units	char('degrees_east')	Units used for geospatial_lon_min/max attributes.
geospatial_vertical_min	double(0.0);	Minimum depth of measurements, in metres.
geospatial_vertical_max	double(0.0);	Maximum depth of measurements, in metres.
geospatial_vertical_units	char('m')	Units used for geospatial_vertical_min/max attributes.
positive	char('up')	Direction of vertical coordinates
time_coverage_start	char('2017-04-17T15:20:00Z')	Start date and time in UTC, for which data in the dataset was collected. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2017-09-11T06:05:00Z : September 11 2017 06:05:00AM
time_coverage_end	char('2017-04-17T15:20:00Z')	End date and time in UTC, for which data in the dataset was collected. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2017-09-11T06:05:00Z : September 11 2017 06:05:00AM

local_time_zone	double(10)	Local time zone (UTC+)
data_center	char(' Australian Ocean Data Network (AODN)')	Data center in charge of management and distribution of the data resource.
data_centre_email	char('info@aodn.org.au')	Data centre contact email address.
author	char('Cosoli, Simone')	Name of person responsible for the creation of the dataset.
author_email	char('simone.cosoli@uwa.edu.au')	Email address for the data creator
institution_references	char('http://imos.org.au/facilities/oceanradar/')	Reference to the data provider and producer.
principal_investigator	char('Cosoli, Simone')	Name of principal investigator in charge of the glider unit.
citation	char('Citation to be used in publications should follow the format: "IMOS.[year-of-data-download],[Title],[Data access URL],accessed [date-of access]".')	Citation used for usage of this data.
acknowledgement	char('Any users (including re-packagers) of IMOS data are required to clearly acknowledge the source of the material in this format: \"Data was sourced from the Integrated Marine Observing System (IMOS) - IMOS is a national collaborative research infrastructure, supported by Australian Government."')	Any users (including re-packers) of IMOS data are required to acknowledge the source of the data in this format.
distribution_statement	char('Data may be re-used, provided that related metadata explaining the data has been reviewed by the user, and the data is appropriately acknowledged. Data, products and services from IMOS are provided \"as is\" without any warranty as to fitness for a particular purpose.')	Statement describing data distribution policy.
license	char('http://creativecommons.org/licenses/by/4.0/')	Reference for the license for the data
disclaimer	char(' Data, products and services from IMOS are provided "as is" without any warranty as to fitness for a particular purpose.')	Statement describing data fitness policy

4.1.3 Dimensions

Radial data are snapshots of the radial component of the sea surface current. They have two-dimensional coordinates of latitude, longitude coordinates, along with various measured parameters. All variables are sparse, and the size of data varies mostly on external interference or hardware problems. FV01 files include the following dimension: TIME; POSITION; WERA_HEADER_SIZE

Table 30. *Dimension*

Dimension	Definition
TIME	Number of time steps over which data was sampled (UNLIMITED)
POSITION	Number of grid points in which data has ben collected. The dimension may change but it is always present in the file.
WERA_HEADER_SIZE	Dimension (byte) of the header in the raw file before extraction of variables and before conversion to physical units

4.1.4 Variables

Variables and attributes in FV01 netcdf data files are listed in Table 31 for WERA radial data. Table 32 contains the parameters included in the netcdf file, with Table 33 lists the quality control indicator and the flags in use for IMOS Ocean Radar Facility radar radial data.

Table 31. *Variables and attributes for the DM FV01 WERA radial data*

Variable	Attributes	Definition

TIME	double TIME;
	standard_name = "time";
	long_name = "time";
	units = "days since 1950-01-01 00:00:00 UTC";
	calendar = "gregorian";
	axis = "T";
	valid_min = 0.0;
	valid_max = 90000.0;
		Time at which <PARAM> measurements were made. Values are recorded as days since 12 am of 1st January 1950.

POSITION	int POSITION
	long_name = "Grid position index";
	units = "1";
	valid_min = 1;
	valid_max = 5704;
		Adimensional variable that contains the position in the measurement grid

WERA_HEADER	char wera_Header_FRE
	long_name = "WERA Radial 512-byte header";
	comment = "Original WERA 512-byte header is stored in variable data. WERA 512-byte header fields are also stored as variable attributes.";
	wera_Data_Type = "Radial";
	wera_Signature = "FMRADG";
	wera_Frequency = 9335000.0f;
	wera_Frequency_units = "Hz";
	wera_Range_Resolution = 4500.0f;
	wera_Range_Resolution_units = "m";
	wera_Bandwidth = 33310.273f;
	wera_Bandwidth_units = "Hz";
	wera_Site_Name = "Tannum";
	wera_Comment = "Tannum Sands.Sands";
	wera_Time_Zone_Id = "UTC";
	wera_Date = "2017-04-17";
	wera_Time = "15:20:00Z";
	wera_Longitude = 151.3686111111111
	wera_Longitude_units = "degree_east";
	wera_Latitude = -23.939166666666665;
	wera_Latitude_units = "degree_north";
	wera_Rx_Boresight = 47.0f;
	wera_Rx_Boresight_units = "degree_true";
	wera_N_Samples = 1024;
	wera_Chirp_Duration = 0.260028f;
	wera_Chirp_Duration_units = "s";
	wera_N_Ranges = 50;
	wera_Range_Blanking = 450.0f;
	wera_Range_Blanking_units = "m";
	wera_FFT_Width = 512;
	wera_FFT_Shift = 128;
	wera_Grid_N_X = 72;
	wera_Grid_N_Y = 64;
	wera_Grid_File_Name = "cbg.grd";
	wera_Grid_Latitude = -21.92031;
	wera_Grid_Latitude_units = "degree_north";
	wera_Grid_Longitude = 150.781701;
	wera_Grid_Longitude_units = "degree_east";
	wera_Grid_Spacing = 4014.0f;	

	wera_Grid_Spacing_units = "m";	

LONGITUDE	double LONGITUDE(POSITION)
	_FillValue = 9.969209968386869E36;
	standard_name = "longitude";
	long_name = "Longitude";
	reference_datum = "World Geodetic System 1984";
	units = "degrees_east";
	axis = "X";
	valid_min = -180.0;
	valid_max = 180.0;	

LATITUDE	double LATITUDE(POSITION)
	_FillValue = 9.969209968386869E36;
	standard_name = "latitude";
	long_name = "Latitude";
	reference_datum = "World Geodetic System 1984";
	units = "degrees_north";
	axis = "Y";
	valid_min = -90.0;
	valid_max = 90.0;	

<PARAM>	float <PARAM>(POSITION); <PARAM>_FillValue =<X> <PARAM>long_name = <X>; <PARAM>units = <X> <PARAM>valid_min = <X> <PARAM>valid_max = <X>; <PARAM>ancillary_variables = <X> <PARAM>coordinates;	<PARAM> contains the values of a parameter listed in reference table 5. <X>: this field is specified in the reference table 5. The quality_control_indicator values are as listed in Table 6.
<PARAM_quality_control>	byte <PARAM_quality_control>(POSITION); <PARAM_quality_control>long_name; <PARAM_quality_control>quality_control_set = <X>; <PARAM_quality_control>quality_control_conventions<X>;; <PARAM_quality_control>_FillValue = <X>; <PARAM_quality_control>valid_min = <X>; <PARAM_quality_control>valid_max = <X>; <PARAM_quality_control>flag_values = <X>; <PARAM_quality_control>flag_meanings = <X>; <PARAM_quality_control>coordinates;	Quality flag applied on the <PARAM> values as result of the RT quality checks. Information on flag meanings is found in Table 6.

Table 32 contains the parameters included in the netcdf file, with Table 33 lists the quality control indicator and the flags in use for IMOS Ocean Radar Facility radial data.

Table 32*. List of parameters included in the netcdf files*

Code	standard_name	long_name (for non-CF)	_FillValue	valid_min	valid_max	coordinates	Ancillary_variables	units
ssr_Surface_Radial_Sea_Water_Speed		Magnitude of surface sea water current radial component	9.96921E36	-5.0	5.0	TIME, LATITUDE, LONGITUDE	ssr_Surface_Radial_Sea_Water_Speed_quality_control	m s-1
ssr_Surface_Radial_Direction_Of_Sea		Direction from receive antenna to	-1	0	360	TIME, LATITUDE, LONGITUD		arc_degree

_Water_Velocity		grid position				E		
ssr_Surface_Radial_Sea_Water_Speed_Standard_Error		Estimate of error in magnitude of surface sea water current radial component	-1	0	100	TIME, LATITUDE, LONGITUDE	ssr_Surface_Radial_Sea_Water_Speed_Standard_Error_quality_control	m s-1
ssr_Power_Spectrum_Noise		Power spectrum noise level	-1	0	10e6	TIME, LATITUDE, LONGITUDE		1
ssr_Bragg_Signal_To_Noise		Power spectrum signal to noise ratio	-1	0	10e6	TIME, LATITUDE, LONGITUDE	ssr_Bragg_Signal_To_Noise_quality_control	1
ssr_Bragg_Power_L		Height of the left Bragg peak in power spectrum	-1	0	10e6	TIME, LATITUDE, LONGITUDE		1
ssr_Bragg_Power_R		Height of the right Bragg peak in power spectrum	-1	0	10e6	TIME, LATITUDE, LONGITUDE		1

Table 33. *Quality control indicator and the flags in use for FV01 DM WERA radial data*

Flag value	**Meaning**	**Description**
0	No QC performed	The level at which all data enter the working archive. They have not yet been quality controlled
1	Good data	Top quality data in which no malfunctions have been identified and all real features have been verified during the quality control process.
2	Probably good data	Good data in which some features (probably real) are present but these are unconfirmed. Code 2 data are also data in which minor malfunctions may be present but these errors are small and/or can be successfully corrected without seriously affecting the overall quality of the data.
3	Bad data that are potentially correctable	Suspect data in which unusual, and probably erroneous features are observed.
4	Bad data	Obviously erroneous values are observed.
5	Value changed	Altered by a QC centre, with original values (before the change) preserved in the history record of the data.
6	Not used	Reserved for future use.
7	Not used	Reserved for future use.
8	Interpolated value	Indicates that data values are interpolated.
9	Missing value	Indicates that the element is missing.

4.2 File format for DM WERA vector data

The IMOS Ocean Radar Facility generates DM WERA vector data in netcdf-4 file format, in compliance with the IMOS-1.4 and CF-1.6 conventions. A detailed description of the file format, the variable, the metadata is given in the following Section.

4.2.1 File naming convention

The naming conventions for DM netcdf files for surface currents from IMOS Ocean Radar Facility WERA HF radar systems follow the IMOS convention for DM FV01 products (also described in [4]), as detailed below (Table 34):

IMOS_ACORN_<data-code>_<date> _ <node-code> _FV <file-version> _<product-type>.nc

An example for the DM FV01 vector current map for South Australia Gulfs (SAG) region is given below:

IMOS_ACORN_V_20170630T233000Z_SAG_FV01_1-hour-avg.nc

***Table 34**. Elements of file-naming convention*

Part of filename	Description
data-code	V: 2D surface current velocity map
Date	Start date and time of the measurements in UTC. Date format is: yyyymmddTHHMMSSZ where T is the delimiter between date and time, and Z indicates that time is in UTC. Example: 20170922T083000Z is 22^{nd} September 2017, 08:30AM
node-code	A three-letter code for the regional deployment: ROT: Rottnest Shelf region (WA) SAG: South Australia Gulfs region (SA) COF: Coffs Harbour region (NSW)
file-version	Value representing the version of the file. This value is preceded by two characters: ‘FV’. 00: Level 0 – raw data. Raw data is defined as data processed with the acquisition software provided by the manufacturer, and data products that have undergone RT quality control procedures. Data are available in physical units. Level 0 data is suitable for public access. Metadata exists for the data. 01: Level 1 – quality controlled data. Quality controlled data have passed offline, delayed mode quality control procedures. Data are in physical units using standard SI metric units. Metadata exists for the data.
product-type	This code gives information about the product included in the dataset. Example: 1-hour-avg, for surface current maps

4.2.2 Global attributes

The following attributes are included in the DM F01 vector current maps.

***Table 35**. IMOS Ocean Radar Facility netcdf files global attributes for DM surface currents*

Name	Example	Definition
Project	char('Integrated Marine Observing System (IMOS)');	The scientific project that produced the data
Conventions	char('CF-1.6,IMOS-1.4');	Format convention used by the dataset
institution	char(IMOS Ocean Radar Facility');	Name of the institute or facility where the original data was produced.
Title	char(IMOS Ocean Radar Facility South Australian Gulf (SAG), one hour averaged current QC data, 2017-06-30T23:30:00Z);	Short description of the dataset indicating the radar station that collect the data, the type of product and the acquisition date.
Instrument	char('WERA Oceanographic HF Radar/Helzel Messtechnik, GmbH')	Type of instrument used to colect the data
site_code	char('SAG, South Australia Gulf')	HF radar node
ssr_Stations	char('Cape Wiles (CWI), Cape Spencer (CSP)')	Three-letter code for the HFR node
date_created	char('2017-08-02T09:26:45Z');	Date and time at which the file was created. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2017-09-22T09:00:06Z : December 22nd September 2017 09:00:06AM
abstract	char('The IMOS Ocean Radar Facility (known as ACORN) is producing NetC containing vector current maps at 1 h intervals. They are produced from radial which represent the surface sea water component along the radial direction from a antenna. Radials are calculated from the sh Bragg peaks in a power spectrum. Ra extracted from the 5-minutes Doppler s each grid point and then averaged over period. A minimum first order signal-to-no of 8 dB is set for the radials. A set of Matla read reprocessed data files, perform a quality-controls on radial and vector components, and convert the files into netcd Each current value computed in the selected points has a quality control flag. A set of 4 statistical methods are used to define them: deviation from the median (MAD); statisti velocity distributions; statistics of the dis of the 1st derivative; statistics of the distrib the high-frequency components. Data are based on the results of the statistical tests: 4 or more tests fail; 3, if two tests fail; 2, if fails; 1, no test fails. Additional thresh applied on maximum current velocity and t beam intersecting angles (GDOP). The fina is mapped on a regular geographic gri information on the data processing is through the document: Quality Control pr for IMOS Ocean Radar Facility Manual Ve Integrated Marine Observing System. DOI: 10.26198/5c89b59a931cb (http://dx.doi.org/10.26198/5c89b59a931c b));	A paragraph describing the dataset: type of data contained, how it was created, who collected it, what instruments were used, etc.
source	char('Terrestrial HF radar');	Method of production of the original data.
keywords	char('Oceans');	A comma separated list of key words and

		phrases.
standard_name_vocabulary	Char('NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table 27')	Reference for CF standard names
netcdf_version	Char('4.3.3.1')	NetCDF file version
naming_authority	char('IMOS');	Naming authority will always be IMOS.
file_version	char('Level 1 - Quality Controlled data')	Version of data processing
file_version_quality_control	char('Data in this file has been through the quality control procedure as described in the document: Quality Control procedures for IMOS Ocean Radar Facility Manual Version 2.0. Integrated Marine Observing System. DOI: 10.26198/5c89b59a931cb (http://dx.doi.org/10.26198/5c89b59a931cb). Every data point in this file has an associated quality flag.');;	Version of the quality control applied to the data
geospatial_lat_min	double(-37.4551594);	Southernmost latitude (positive north) from which dataset was obtained; a value between -90 and 90 degrees.
geospatial_lat_max	double(-34.8234228);	Northernmost latitude (positive north) from which dataset was obtained; a value between -90 and 90 degrees.
geospatial_lat_units	char('degrees_north')	Units used for geospatial_lat_min/max attributes.
geospatial_lon_min	double(132.953971);	Westernmost longitude (positive east) from which dataset was obtained; a value between -180 and 180 degrees.
geospatial_lon_max	double(137.462663);	Easternmost longitude (positive east) from which dataset was obtained; a value between -180 and 180 degrees.
geospatial_lon_units	char('degrees_east')	Units used for geospatial_lon_min/max attributes.
geospatial_vertical_min	double(0.0);	Minimum depth of measurements, in metres.
geospatial_vertical_max	double(0.0);	Maximum depth of measurements, in metres.
geospatial_vertical_units	char('m')	Units used for geospatial_vertical_min/max attributes.
time_coverage_start	char('2017-06-30T23:30:00Z')	Start date and time in UTC, for which data in the dataset was collected. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2017-09-11T06:05:00Z : September 11 2017 06:05:00AM
time_coverage_end	char('2017-06-30T23:30:00Z')	End date and time in UTC, for which data in the dataset was collected. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2017-09-11T06:05:00Z : September 11 2017 06:05:00AM
local_time_zone	double(9.5)	Local time zone (UTC+)
data_center	char(' Australian Ocean Data Network (AODN)')	Data center in charge of management and distribution of the data resource.
data_centre_email	char('info@aodn.org.au')	Data centre contact email address.
author	char('Cosoli, Simone')	Name of person responsible for the creation of the dataset.

author_email	char('simone.cosoli@uwa.edu.au')	Email address for the data creator
institution_references	char('http://imos.org.au/facilities/oceanradar/')	Reference to the data provider and producer.
principal_investigator	char('Cosoli, Simone')	Name of principal investigator in charge of the radar
citation	char(' The citation in a list of references is: IMOS, [year-of-data-download], [Title], [data-access-URL], accessed [date-of-access]'')	Citation used for usage of this data.
acknowledgement	char('Any users (including re-packagers) of IMOS data are required to clearly acknowledge the source of the material in this format: \"Data was sourced from the Integrated Marine Observing System (IMOS) - IMOS is a national collaborative research infrastructure, supported by Australian Government.')	Any users (including re-packers) of IMOS data are required to acknowledge the source of the data in this format.
distribution_statement	char('Data may be re-used, provided that related metadata explaining the data has been reviewed by the user, and the data is appropriately acknowledged. Data, products and services from IMOS are provided \"as is\" without any warranty as to fitness for a particular purpose.')	Statement describing data distribution policy.
license	char('http://creativecommons.org/licenses/by/4.0/')	Reference for the license for the data
Comment	char('This NetCDF file has been created using the IMOS NetCDF Conventions v1.4.')	
Disclaimer	char('Data, products and services from IMOS are provided \"as is\" without any warranty as to fitness for a particular purpose.')	

4.2.3 Dimensions

Surface current vector maps produced by the IMOS Ocean Radar Facility are 1-hour averages of the sea surface current. They have two-dimensional coordinates of latitude, longitude coordinates, along with various measured parameters. All variables are defined on a regular latitude – longitude grid; the size of data is fixed. FV01 files include the following dimension: TIME; LATITUDE; LONGITUDE

Table 36. *Dimension*

Dimension	Definition
TIME	Temporal interval over which the data was averaged (UNLIMITED)
LATITUDE	Number of the unique latitude coordinate values
LONGITUDE	Number of the unique longitude coordinate values

4.2.4 Variables

Variables and attributes in FV01 netcdf data files for WERA surface currents are listed in Table 37. Table 38 contains the parameters included in the netcdf file, with Table 39 lists the quality control indicator and the flags in use for IMOS Ocean Radar Facility radial data.

Table 37. *Variables and attributes for the RT FV00 WERA vector maps*

Variable	Attributes	Definition

TIME	double TIME;
	standard_name = "time";
	long_name = "time";
	units = "days since 1950-01-01 00:00:00 UTC";
	calendar = "gregorian";
	axis = "T";
	valid_min = 0.0;
	valid_max = 90000.0;
		Time at which <PARAM> measurements were made. Values are recorded as days since 12 am of 1st January 1950.

LONGITUDE	double LONGITUDE
	standard_name = "longitude";
	long_name = "longitude";
	units = "degrees_east";
	axis = "X";
	valid_min = -180.0;
	valid_max = 180.0;
	reference_datum = "geographical coordinates, WGS84 datum";	

LATITUDE	double LATITUDE
	standard_name = "latitude";
	long_name = "latitude";
	units = "degrees_north";
	axis = "Y";
	valid_min = -90.0;
	valid_max = 90.0;
	reference_datum = "geographical coordinates, WGS84 datum";	

<PARAM>	float <PARAM>(LATITUDE,LONGITUDE); <PARAM>_FillValue =<X> <PARAM>long_name = <X>; <PARAM>units = <X> <PARAM>valid_min = <X> <PARAM>valid_max = <X>; <PARAM>cell_method = <X>; <PARAM>ancillary_variables = <X>; <PARAM>coordinates;	<PARAM> contains the values of a parameter listed in reference table 5. <X>: this field is specified in the reference table 11. The quality_control_indicator values are as listed in Table 6.
<PARAM_quality_control>	byte <PARAM_quality_control>(POSITION); <PARAM_quality_control>long_name;	Quality flag applied on the <PARAM> values as result of the RT quality checks.

	<PARAM_quality_control>quality_control_set = <X>; <PARAM_quality_control>quality_control_conventions<X>;; <PARAM_quality_control>_FillValue = <X>; <PARAM_quality_control>valid_min = <X>; <PARAM_quality_control>valid_max = <X>; <PARAM_quality_control>flag_values = <X>; <PARAM_quality_control>flag_meanings = <X>; <PARAM_quality_control>coordinates;	Information on flag meanings is found in Table 12.

Table 38 contains the parameters included in the netcdf file, with Table 39 lists the quality control indicator and the flags in use for IMOS Ocean Radar Facility radial data.

Table 38. *List of parameters included in the netcdf files*

Code	**standard_name**	**long_name (for non-CF)**	**_FillValue**	**valid_min**	**valid_max**	**coordinates**	**Ancillary_variables**	**units**
GDOP		Radar beam intersection angles	999999	0	180.0	TIME, LATITUDE, LONGITUDE		degrees
UCUR	eastward_sea_water_velocity	Mean of sea water velocity U component values in 1 hour, after rejection of obvious bad data (see abstract).	999999	-10	10	TIME, LATITUDE, LONGITUDE	UCUR_quality_control	m s-1
VCUR	northward_sea_water_velocity	Mean of sea water velocity V component values in 1 hour, after rejection of obvious bad data (see abstract).	999999	-10	10	TIME, LATITUDE, LONGITUDE	VCUR_quality_control	m s-1
UCUR_sd		Standard deviation of sea water velocity U component values in 1 hour, after rejection of obvious bad data (see abstract).	999999	-10	10	TIME, LATITUDE, LONGITUDE	UCUR_quality_control	m s-1
VCUR_sd		Standard deviation of sea water velocity V component values in 1 hour, after	999999	-10	10	TIME, LATITUDE, LONGITUDE	VCUR_quality_control	m s-1

		rejection of obvious bad data (see abstract).						
NOBS1		Number of observations of sea water velocity in 1 hour from station 1, after rejection of obvious bad data (see abstract).	-99B			TIME, LATITUDE, LONGITUDE		1
NOBS2		Number of observations of sea water velocity in 1 hour from station 2, after rejection of obvious bad data (see abstract).	-99B			TIME, LATITUDE, LONGITUDE		1

Table 39. *Quality control indicator and the flags in use for FV01 DM IMOS Ocean Radar Facility WERA vector current maps*

Flag value	**Meaning**	**Description**
0	No QC performed	The level at which all data enter the working archive. They have not yet been quality controlled
1	Good data	Top quality data in which no malfunctions have been identified and all real features have been verified during the quality control process.
2	Probably good data	Good data in which some features (probably real) are present but these are unconfirmed. Code 2 data are also data in which minor malfunctions may be present but these errors are small and/or can be successfully corrected without seriously affecting the overall quality of the data.
3	Bad data that are potentially correctable	Suspect data in which unusual, and probably erroneous features are observed.
4	Bad data	Obviously erroneous values are observed.
5	Value changed	Altered by a QC centre, with original values (before the change) preserved in the history record of the data.
6	Not used	Reserved for future use.
7	Not used	Reserved for future use.
8	Interpolated value	Indicates that data values are interpolated.
9	Missing value	Indicates that the element is missing.

4.3 File format for DM SeaSonde radial data

At the time of writing (November 2019) the file format in use for the FV01 SeaSonde radial data is the updated netcdf-4 file format compliant with the IMOS-1.4 and CF-1.6 conventions as agreed with AODN. A description of the global attributes, dimensions, variables is given below.

4.3.1 File naming convention

The naming conventions for RT netcdf files from IMOS Ocean Radar Facility SeaSonde HF radar systems follow the IMOS convention for RT FV00 products (also described in [4]), as detailed below (Table 40):

IMOS_ACORN_<data-code>_<date> _ <platform-code> _FV <file-version> _<product-type>.nc

An example for the RT FV01 radial current for Red Head radar station is given below (Table 40):

IMOS_ IMOS_ACORN_RV_20191021T220000Z_RHED_FV01_radial.nc

Table 40*. Elements of file-naming convention*

Part of filename	Description
data-code	RV: radial velocity
Date	Start date and time of the measurements in UTC. Date format is: yyyymmddTHHMMSSZ where T is the delimiter between date and time, and Z indicates that time is in UTC. Example: 20191021T220000Z is 21th October 2019, 10:00PM
platform-code	A four-letter code for the SeaSonde HFR stations: GHED: Green Head station (WA) LANC: Lancelin station (WA) DONG: Dongara – Port Denison (WA) RHED: Red Head (NSW) SEAL: Seal Rocks Lighthouse (NSW)
file-version	Value representing the version of the file. This value is preceded by two characters: ‘FV’. 00: Level 0 – raw data. Raw data is defined as data processed with the acquisition software provided by the manufacturer, and data products that have undergone RT quality control procedures. Data are available in physical units. Level 0 data is suitable for public access. Metadata exists for the data. 01: Level 1 – quality controlled data. Quality controlled data have passed offline, delayed mode quality control procedures. Data are in physical units using standard SI metric units. Metadata exists for the data.
product-type	This code gives information about the product included in the dataset. Example: radial, for maps of sea surface current component towards or away from the radar receiver

4.3.2 Global attributes

A detailed description of the global attributes for DM FV01 SeaSonde radial data files is provided in Table 41.

Table 41. IMOS Ocean Radar Facility *netcdf files global attributes for RT radial currents*

Name	Example	Definition
Project	char('Integrated Marine Observing System (IMOS)');	The scientific project that produced the data
Conventions	char(‘CF-1.6,IMOS-1.4’);	Format convention used by the dataset
institution	char(‘IMOS Ocean Radar Facility’);	Name of the institute or facility where the original data was produced.
title	char([‘Newcastle (NSW), Red Head (NSW), Radial, 2019-10-21 22:00:00Z’]);	Short description of the dataset indicating the radar station that collect the data, the

		type of product and the acquisition date.
Instrument	char('CODAR Ocean Sensors/SeaSonde')	Type of instrument used to collect the data
platform_code	char('RHED');	Four-letter code for the HFR site
site_code	char('NEWC")	Four-letter code for the HFR node
date_created	char('2019-11-18T18:16:16Z');	Date and time at which the file was created. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2019-11-18T18:16:16Z : November 18th 2019 06:16:16PM
abstract	char('The IMOS Ocean Radar Facility (formerly known as ACORN) is producing NetCDF files containing quality controlled radial current maps at 180 min time intervals. A set of Matlab tools is adopted to read data files, perform quality controls on radial current components, and convert the files into netcdf format. Each radial current value has a quality control flag. Quality control tests include Signal-to-Noise Ratio (SNR) thresholding on the Doppler velocity data at each (Range, Bearing) pair. A threshold of 6dB is used for the SNR value of the Doppler lines at the monopole, and to the SNR of the Doppler lines at the two orthogonal directive loops. Doppler lines that do not satisfy the SNR criteria are discarded. Doppler lines that do satisfy the SNR criteria are then averaged to form the final radial velocity data. A regional radial speed threshold is then applied. More information on the data processing is available through the document: Quality Control procedures for ACORN radars Manual Version 2.1. Integrated Marine Observing System. DOI: 10.26198/5c89b59a931cb (http://dx.doi.org/10.26198/5c89b59a931cb). Data produced by the Australian Coastal Ocean Radar Network, Integrated Marine Observing System.'));	A paragraph describing the dataset: type of data contained, how it was created, who collected it, what instruments were used, etc.
source	char('Terrestrial HF radar');	Method of production of the original data.
keywords	char('Oceans');	A comma separated list of key words and phrases.
standard_name_vocabulary	Char('NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table 27')	Reference for CF standard names
netcdf_version	Char('4.3.3.1')	NetCDF file version
naming_authority	char('IMOS');	Naming authority will always be IMOS.
file_version	char('Level 1 - Quality Controlled data')	Version of data processing
file_version_quality_control	char('Data in this file has been through the quality control procedure as described in the document: Quality Control procedures for IMOS Ocean Radar Facility Manual Version 2.1. Integrated Marine Observing System. DOI: 10.26198/5c89b59a931cb (http://dx.doi.org/10.26198/5c89b59a931cb). Every data point in this file has an associated quality flag.');	Version of the quality control applied to the data
geospatial_lat_min	double(-33.6176294);	Southernmost latitude (positive north)

		from which dataset was obtained; a value between -90 and 90 degrees.
geospatial_lat_max	double(-32.5022499);	Northernmost latitude (positive north) from which dataset was obtained; a value between -90 and 90 degrees.
geospatial_lat_units	char('degrees_north')	Units used for geospatial_lat_min/max attributes.
geospatial_lon_min	double(151.3832652);	Westernmost longitude (positive east) from which dataset was obtained; a value between -180 and 180 degrees.
geospatial_lon_max	double(152.5994931);	Easternmost longitude (positive east) from which dataset was obtained; a value between -180 and 180 degrees.
geospatial_lon_units	char('degrees_east')	Units used for geospatial_lon_min/max attributes.
geospatial_vertical_min	double(0.0);	Minimum depth of measurements, in metres.
geospatial_vertical_max	double(0.0);	Maximum depth of measurements, in metres.
geospatial_vertical_units	char('meter')	Units used for geospatial_vertical_min/max attributes.
Positive	char('up')	Direction of vertical coordinates
reference_datum	char('sea surface')	Reference origin for the vertical coordinate
time_coverage_start	char('2019-10-21T22:00:00Z')	Start date and time in UTC, for which data in the dataset was collected. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2019-11-18T18:16:16Z : November 18th 2019 06:16:16PM
time_coverage_end	char('2019-10-21T22:00:00Z'')	End date and time in UTC, for which data in the dataset was collected. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2019-11-18T18:16:16Z : November 18th 2019 06:16:16PM
local_time_zone	double(10)	Local time zone (UTC+)
data_center	char(' Australian Ocean Data Network (AODN)')	Data center in charge of management and distribution of the data resource.
data_centre_email	char('info@aodn.org.au')	Data centre contact email address.
author	char('Simone Cosoli')	Name of person responsible for the creation of the dataset.
author_email	char('simone.cosoli@uwa.edu.au')	Email address for the data creator
institution_references	char('http://imos.org.au/facilities/oceanradar/')	Reference to the data provider and producer.
principal_investigator	char('Cosoli, Simone')	Name of principal investigator in charge of the radar unit.
principal_investigator_email	char('simone.cosoli@uwa.edu.au')	Principal investigator's email address.
Citation	char('Citation to be used in publications should follow the format: "IMOS.[year-of-data-download],[Title],[Data access URL],accessed [date-of access]".')	Citation used for usage of this data.
acknowledgement	char('Any users of IMOS data are required to clearly acknowledge the source of the material in the format: "Data was sourced from the Integrated Marine Observing System (IMOS) - IMOS is a national collaborative research infrastructure,	Any users (including re-packers) of IMOS data are required to acknowledge the source of the data in this format.

	supported by Australian Government.'")	
distribution_statement	char('Data may be re-used, provided that related metadata explaining the data has been reviewed by the user, and the data is appropriately acknowledged. Data, products and services from IMOS are provided \"as is\" without any warranty as to fitness for a particular purpose.')	Statement describing data distribution policy.
license	char('http://creativecommons.org/licenses/by/4.0/')	Reference for the license for the data
disclaimer	char(' Data, products and services from IMOS are provided "as is" without any warranty as to fitness for a particular purpose.')	Statement describing data fitness policy

4.3.3 Dimensions

IMOS Ocean Radar Facility radial data are snapshots of the radial component of the sea surface current. They have one-dimensional coordinates of latitude, longitude coordinates, along with various measured parameters. All variables are sparse, and the size of data varies mostly on external interference or hardware problems. FV00 files include the following dimension: TIME; POSITION; DATE; SEASONDE_RADS_TIME; SEASONDE_RCVR_TIME[4]; SEASONDE_HEADER_SIZE

Table 42 *Dimension*

Dimension	Definition
TIME	Number of time steps over which data was sampled (UNLIMITED)
POSITION	Number of grid points in which data has been collected. The dimension may change but it is always present in the file.
DATE	
SEASONDE_RADS_TIME	Number of time steps over which radial diagnostic data are sampled
SEASONDE_RCVR_TIME	Number of time steps over which receiver diagnostic data are sampled
SEASONDE_HEADER_SIZE	Dimension (byte) of the header in the raw file before extraction of variables and before conversion to physical units

4.3.4 Variables

Variables and attributes in FV01 netcdf data files for SeaSonde surface radial velocity mas are listed in Table 43. Table 44 contains the parameters included in the netcdf file, with Table 45 lists the quality control indicator and the flags in use for the DM FV01 SeaSonde IMOS Ocean Radar Facility radial data.

Table 43. *Variables and attributes for the DM FV01 SeaSonde radial data*

Variable	Attributes	Definition

TIME	double TIME;
	standard_name = "time";
	long_name = "time";
	units = "days since 1950-01-01 00:00:00 UTC";
	calendar = "gregorian";
	axis = "T";
	valid_min = 0.0;
	valid_max = 90000.0;
		Time at which <PARAM> measurements were made. Values are recorded as days since 12 am of 1st January 1950.

[4]Receiver diagnostics are available for RT FV00 data processed at the stations, for DM FV01 data if they are reprocessed at the station with a receiver available, or if RT radial metrics are available in which case the QC procedure will import all available metadata and write them to the QC'd radial maps. They are not available on the other side if FV01 data are reprocessed in full offline mode from low- or intermediate-level data (range series or cross spectra data) on a dedicated reprocessing machine.

POSITION	int POSITION
	long_name = "Grid position index";
	units = "1";
	valid_min = 1;
	valid_max = 5704;
		Adimensional variable that contains the position in the measurement grid

seasonde_CTF_Header	char seasonde_CTF_Header_GHED
	long_name = "CODAR Radial header";
	comment = "Original CODAR CTF header is stored in variable data. CTF header fields are also stored as variable attributes..";
	easonde_Version = "1.00";
	seasonde_File_Type = "LLUV";
	seasonde_Data_Type = "Radial";
	seasonde_File_Version = "rdls";
	seasonde_File_Label = "RadialMap";
	seasonde_LLUV_Version = "1.14";
	seasonde_LLUV_Date = "2010-07-18";
	seasonde_UUID = "98030FE6-8A8D-4BE0-B2BC-87B84FC19A2D";
	seasonde_Manufacturer = "CODAR Ocean Sensors. SeaSonde";
	seasonde_Site_Code = "GHED";
	seasonde_Date = "2017-09-22T11:00:00Z";
	seasonde_Time_Zone_Id = "UTC";
	seasonde_Time_Zone = 0; // int
	seasonde_Time_Zone_units = "min";
	seasonde_Time_Zone_Daylight = "No";
	seasonde_Duration = "PT1H19M58S";
	seasonde_Origin_Longitude = 114.9667167; // double
	seasonde_Origin_Longitude_units = "degree_east";
	seasonde_Origin_Latitude = -30.0732167; // double
	seasonde_Origin_Latitude_units = "degree_north";
	seasonde_Rx_Longitude = 114.9667167; // double
	seasonde_Rx_Longitude_units = "degree_east";
	seasonde_Rx_Latitude = -30.0732167; // double
	seasonde_Rx_Latitude_units = "degree_north";
	seasonde_Spheroid_Name = "WGS84";
	seasonde_Spheroid_Radius = 6378137.0; // double
	seasonde_Spheroid_Radius_units = "m";
	seasonde_Spheroid_Flattening = 0.0033528106647475143; // double
	sseasonde_Project_Method = "CGEO";
	seasonde_Project_Version = "1.57";
	seasonde_Project_Date = "2009-03-10";
	seasonde_LLUV_Trust = "[ll,xy,rb,uv,vd]";
	seasonde_Range_Blanking = 1.0f; // float
	seasonde_Range_Blanking_units = "seasonde_Range_Resolution";
	seasonde_Range_Limit = 30.0f; // float
	seasonde_Range_Limit_units = "seasonde_Range_Resolution";
	seasonde_Range_Resolution = 5828.9f; // float
	seasonde_Range_Resolution_units = "m";
	seasonde_Rx_Boresight = 286.0f; // float
	seasonde_Rx_Boresight_units = "degree_true";	

	seasonde_Reference_Angle = 0.0f; // float
	seasonde_Reference_Angle_units = "degree_true";
	seasonde_Angular_Resolution = 2.0f; // float
	seasonde_Angular_Resolution_units = "arc_degree";
	seasonde_Spatial_Resolution = 5.0f; // float
	seasonde_Spatial_Resolution_units = "arc_degree";
	seasonde_Ideal = "No";
	seasonde_Cal_Date = "2017-02-15T01:47:03";
	seasonde_Cal_Resolution = 1.0f; // float
	seasonde_Cal_Resolution_units = "arc_degree";
	seasonde_Cal_Smooth = NaNf; // float
	seasonde_Cal_Smooth_units = "arc_degree";
	seasonde_Cal_UUID = "F1A7DE88-DBCF-49BA-835D-617F4CB65B0A";
	seasonde_Frequency = 4463000.0f; // float
	seasonde_Frequency_units = "Hz";
	seasonde_Doppler_Resolution = 0.001953125f; // float
	seasonde_Doppler_Resolution_units = "Hz";
	seasonde_First_Order_Method = "[Default]";
	seasonde_Bragg_Smooth_Width = 1; // int
	seasonde_Current_Speed_Max = 1.5f; // float
	seasonde_Current_Speed_Max_units = "m s-1";
	seasonde_Second_Order = "No";
	seasonde_Bragg_Envelope_Ratio_Min = 151.36f; // float
	seasonde_Bragg_Envelope_Dip_Ratio_Max = 100.0f; // float
	seasonde_Bragg_Envelope_SN_Ratio_Min = 4.0f; // float
	seasonde_Cal_Amplitude = 0.45f, 0.58f; // float
	seasonde_Cal_Phase = 87.3f, 109.0f; // float
	seasonde_Cal_Phase_units = "arc_degree";
	seasonde_Cal_Amplitude_Dynamic = 0.26f, 0.43f; // float
	seasonde_Cal_Phase_Dynamic = 88.7f, 104.67f; // float
	seasonde_Cal_Phase_Dynamic_units = "arc_degree";
	seasonde_Music_Parameters = 40.0f, 20.0f, 2.0f; // float
	seasonde_Radial_N_Merge = 5; // int
	seasonde_Radial_N_Merge_Min = 2; // int
	seasonde_First_Order_Source = "Standard";
	seasonde_Radial_Merge_Method = "Averaged";
	seasonde_Radial_Region_Mask = "Pattern";
	seasonde_Chirp_Duration = 1.0f; // float
	seasonde_Chirp_Duration_units = "s";
	seasonde_Bandwidth = 25733.912f; // float
	seasonde_Bandwidth_units = "Hz";	

	seasonde_Chirp_Direction = "Down";
	seasonde_N_Ranges = 127; // int
	seasonde_N_Samples = 512; // int
	seasonde_Processed_Date = "2017-09-22T11:48:18Z";
	seasonde_Processing_Tool = "RadialMerger 10.7.1, SpectraToRadial 10.9.1, RadialSlider 11.2.2, RadialArchiver 11.2.8, AnalyzeSpectra 10.7.6";	

LONGITUDE	double LONGITUDE(POSITION)
	_FillValue = 9.969209968386869E36;
	standard_name = "longitude";
	long_name = "Longitude";
	reference_datum = "World Geodetic System 1984";
	units = "degrees_east";
	axis = "X";
	valid_min = -180.0;
	valid_max = 180.0;	

LATITUDE	double LATITUDE(POSITION)
	_FillValue = 9.969209968386869E36;
	standard_name = "latitude";
	long_name = "Latitude";
	reference_datum = "World Geodetic System 1984";
	units = "degrees_north";
	axis = "Y";
	valid_min = -90.0;
	valid_max = 90.0;	

<PARAM>	float <PARAM>(POSITION); <PARAM>_FillValue =<X> <PARAM>long_name = <X>; <PARAM>units = <X> <PARAM>valid_min = <X> <PARAM>valid_max = <X>; <PARAM>ancillary_variables = <X> <PARAM>coordinates;	<PARAM> contains the values of a parameter listed in reference table 5. <X>: this field is specified in the reference table 5. The quality_control_indicator values are as listed in Table 6.
<PARAM_quality_control>	byte <PARAM_quality_control>(POSITION); <PARAM_quality_control>long_name; <PARAM_quality_control>quality_control_set = <X>; <PARAM_quality_control>quality_control_conventions<X>;; <PARAM_quality_control>_FillValue = <X>; <PARAM_quality_control>valid_min = <X>; <PARAM_quality_control>valid_max = <X>; <PARAM_quality_control>flag_values = <X>; <PARAM_quality_control>flag_meanings = <X>; <PARAM_quality_control>coordinates;	Quality flag applied on the <PARAM> values as result of the RT quality checks. Information on flag meanings is found in Table 6.

Table 44 contains the parameters included in the netcdf file, with Table 45 lists the quality control indicator and the flags in use for IMOS Ocean Radar Facility radial data.

***Table 44**. List of parameters included in the netcdf files*

Code	standard_name	long_name (for non-CF)	_FillValue	valid_min	valid_max	coordinates	Ancillary _variables	units
ssr_Surface_		Magnitude	9.96921E36			TIME,	ssr_Surface_	m s-1

Radial_Sea_Water_Speed		of surface sea water current radial component				LATITUDE, LONGITUDE	Radial_Sea_Water_Speed_quality_control	
ssr_Surface_Radial_Direction_Of_Sea_Water_Velocity		Direction from receive antenna to grid position	-1	0	360	TIME, LATITUDE, LONGITUDE	ssr_Surface_Radial_Direction_Of_Sea_Water_Velocity_quality_control	arc_degree
seasonde_LLUV_VFLG		Vector indicator flag	-32767S			LATITUDE, LONGITUDE		1
seasonde_LLUV_ESPC		Standard deviation of current speed over the scatter patch	9.96921E36			LATITUDE, LONGITUDE		m s-1
seasonde_LLUV_ETMP		Standard deviation of current speed during coverage period	9.96921E36			LATITUDE, LONGITUDE		ms-1
seasonde_LLUV_MAXV		Maximum current speed found during coverage time	9.96921E36			LATITUDE, LONGITUDE		ms-1
seasonde_LLUV_MINV		Minimum current speed found during coverage time	9.96921E36			LATITUDE, LONGITUDE		ms-1
seasonde_LLUV_ERSC		Number of radials at the same range and bearing that went into the spatial value	-127			LATITUDE, LONGITUDE		1
seasonde_LLUV_ERTC		Number of radials at the same range and bearing that went into the temporal value	-127			LATITUDE, LONGITUDE		1
seasonde_LLUV_SPRC		Range cell number	-127			LATITUDE, LONGITUDE		1
seasonde_rads_TIME		Seconds around cardinal hour at which radial diagnostics are calculated	-2147483647					S

seasonde_rads_AMP1		Calculated antenna amplitude correction for loop 1 to monopole	9.96921E36					V^-2
seasonde_rads_AMP2		Calculated antenna amplitude correction for loop 2 to monopole	9.96921E36					V^-2
seasonde_rads_PH13		Calculated antenna phase correction for loop 1 to monopole	9.96921E36					arc_degree
seasonde_rads_PH23		Calculated antenna phase correction for loop 2 to monopole	9.96921E36					arc_degree
seasonde_rads_CPH1		Used antenna phase correction for loop 1 to monopole	9.96921E36					arc_degree
seasonde_rads_CPH2		Used antenna phase correction for loop 2 to monopole	9.96921E36					arc_degree
seasonde_rads_SNF1		Power spectrum noise floor of loop 1	9.96921E36					Dbm
seasonde_rads_SNF2		Power spectrum noise floor of loop 2	9.96921E36					Dbm
seasonde_rads_SNF3		Power spectrum noise floor of monopole	9.96921E36					Dbm
seasonde_rads_SSN2		Power spectrum signal to noise ratio of loop 2	9.96921E36					decibel
seasonde_rads_SSN3		Power spectrum signal to noise ratio of monpole	9.96921E36					decibel
seasonde_rads_DGRC		Range cell which had the highest signal to noise ratio for	-127					1

		monopole						
seasonde_rads_DOPV		Number of doppler cells which were processed into radials	-32767					1
seasonde_rads_DDAP		Percentage of doppler cells that had dual angle MUSIC solutions	-127					Percent
seasonde_rads_RADV		Number of radial solutions found at different bearings and ranges	-32767					1
seasonde_rads_RAPR		Average number of radial solutions per range cell	-32767					1
seasonde_rads_RARC		Number of range cells processed	-32767					1
seasonde_rads_RADR		Maximum range calculated by where the number of radials drops to below 20% of the average number of radial solutions per range	9.96921E36					M
seasonde_rads_RMCV		Maximum current speed	9.96921E36					ms-1
seasonde_rads_RACV		Average absolute current speed	9.96921E36					ms-1
seasonde_rads_RABA		Average current velocity bearing	9.96921E36					degrees_true
seasonde_rads_RTYP		Type of radial being processed	-127					1
seasonde_rads_STYP		Type of cross spectra being processed	-127					1
seasonde_rads_DATE		ISO8601 compatible date and time string						1

seasonde_rcvr_TIME		Seconds around cardinal hour at which receiver diagnostics are calculated	-2147483647					S
seasonde_rcvr_RTMP		Receiver front panel board temperature	-127					degrees_celsius
seasonde_rcvr_MTMP		Receiver AWGIII model temperature	-127					degrees_celsius
seasonde_rcvr_XTRP		Hexadecimal code for transmit watch tripped settings	-127					1
seasonde_rcvr_RUNT		Receiver run time since it was last powered or the AWG module restarted	-2147483647					S
seasonde_rcvr_SP24		External supply voltage for DC powered receivers	9.96921E36					V
seasonde_rcvr_SP05		+5VDC supply voltage on the receiver front panel board	9.96921E36					V
seasonde_rcvr_SN05		-5VDC supply voltage on the receiver front panel board	9.96921E36					V
seasonde_rcvr_SP12		+12VDC supply voltage on the receiver front panel board	9.96921E36					V
seasonde_rcvr_XPHT		Temperature on the transmitter front panel board	-127					degrees_Celsius
seasonde_rcvr_XAHT		Temperature on the transmitter amplifier	-127					degrees_Celsius
seasonde_rcvr_XAFW		Measured forward power inside	-32767					W

		the transmitter						
seasonde_rcvr_XARW		Measured reflected power inside the transmitter	-32767					W
seasonde_rcvr_XP28		+28VDC supply voltage on the transmitter front panel board	9.96921E36					V
seasonde_rcvr_XP05		+5VDC supply voltage on the transmitter front panel board	9.96921E36					V
seasonde_rcvr_GRMD		GPS receive mode	-127					1
seasonde_rcvr_GDMD		GPS discipline mode	-127					1
seasonde_rcvr_GSLK		GPS satellite lock	-127					1
seasonde_rcvr_GSUL		GPS satellite lock	-127					1
seasonde_rcvr_PLLL		Number of times the receiver PLL was found to lose lock to the GPS timing	-32767					1
seasonde_rcvr_HTMP		Receiver front panel high accuracy temperature	9.96921E36					degree_Celsius
seasonde_rcvr_HUMI		Receiver front panel high accuracy humidity	-127					Percent
seasonde_rcvr_RBIA		Receiver DC powered current draw	9.96921E36					A
seasonde_rcvr_EXTA		Receiver external signal input A logic high level count	-32767					1
seasonde_rcvr_EXTB		Receiver external signal input B logic high level count	-32767					1
seasonde_rcvr_CRUN		Computer run time	9.96921E36f					min

Table 45. *Quality control indicator and the flags in use for FV01 DM IMOS Ocean Radar Facility SeaSonde radial data*

Flag value	**Meaning**	**Description**
0	No QC performed	The level at which all data enter the working archive. They have not yet been quality controlled
1	Good data	Top quality data in which no malfunctions have been identified and all real features have been verified during the quality control process.
2	Probably good data	Good data in which some features (probably real) are present but these are unconfirmed. Code 2 data are also data in which minor malfunctions may be present but these errors are small and/or can be successfully corrected without seriously affecting the overall quality of the data.
3	Bad data that are potentially correctable	Suspect data in which unusual, and probably erroneous features are observed.
4	Bad data	Obviously erroneous values are observed.
5	Value changed	Altered by a QC centre, with original values (before the change) preserved in the history record of the data.
6	Not used	Reserved for future use.
7	Not used	Reserved for future use.
8	Interpolated value	Indicates that data values are interpolated.
9	Missing value	Indicates that the element is missing.

4.4 File format for DM SeaSonde vector data

DM FV01 SeaSonde vector data file format is netcdf-4 file compliant with the IMOS-1.4 and CF-1.6 conventions. A detailed description of the file format, the variable, the metadata is given in the following Section.

4.4.1 File naming convention

The naming conventions for DM netcdf files for surface currents from IMOS Ocean Radar Facility SeaSonde HF radar systems follow the IMOS convention for DM FV01 products (also described in [4]), as detailed below (Table 46):

IMOS_ACORN_<data-code>_<date> _ <node-code> _FV <file-version> _<product-type>.nc

An example for the DM FV01 vector current map for the Turquoise Coast (TURQ) region is given below:

IMOS_ACORN_V_20170630T230000Z_TURQ_FV01_1-hour-avg.nc

Table 46. *Elements of file-naming convention*

Part of filename	Description
data-code	V: 2D surface current velocity map
Date	Start date and time of the measurements in UTC. Date format is: yyyymmddTHHMMSSZ where T is the delimiter between date and time, and Z indicates that time is in UTC. Example: 20170926T160000Z is 26th September 2017, 16:30
node-code	A four-letter code for the regional deployment: TURQ: Turquoise coast (WA) BONC: Bonney Coast (SA) NEWC: Newcastle (NSW)
file-version	Value representing the version of the file. This value is preceded by two characters: ‘FV’. 00: Level 0 – raw data. Raw data is defined as data processed with the acquisition software provided by the manufacturer, and data products that have undergone RT quality control procedures. Data are available in physical units. Level 0 data is suitable for public access. Metadata exists for the data. 01: Level 1 – quality controlled data. Quality controlled data have passed offline, delayed mode quality control procedures. Data are in physical units using standard SI metric units. Metadata exists for the data.
product-type	This code gives information about the product included in the dataset. Example: 1-hour-avg, for surface current maps

4.4.2 Global attributes

The following attributes are included in the DM F01 vector current files.

***Table 47**. Global attributes for DM surface currents in use at the IMOS Ocean Radar Facility*

Name	Example	Definition
Project	char('Integrated Marine Observing System (IMOS)');	The scientific project that produced the data
Conventions	char('CF-1.6,IMOS-1.4');	Format convention used by the dataset
institution	char('IMOS Ocean Radar Facility');	Name of the institute or facility where the original data was produced.
Title	char([IMOS Ocean Radar Facility Turqoise Coast (TURQ), one hour averaged current RT-QC data, 2017-09-26T16:00:00Z]);	Short description of the dataset indicating the radar station that collect the data, the type of product and the acquisition date.
Instrument	char('CODAR Ocean Sensors/SeaSonde')	Type of instrument used to colect the data
site_code	char('TURQ, Turqoise Coast')	HF radar node
ssr_Stations	char('Lancelin (LANC), Green Head (GHED)')	Four-letter code for the HFR node
date_created	char('2017-07-31T05:56:54Z');	Date and time at which the file was created. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 20170926T160000Z is 26th September 2017, 16:30
abstract	The IMOS Ocean Radar Facility (formerly I ACORN) is producing NetCDF files c vector current maps at 1 hour time interval. produced from radial currents in the T Coast (WA), which represent the surface s current component along the radial directic receiver antenna. Radials are calculated shift of the Bragg peaks in a power spectru are mapped onto specific angles th Direction-Finding algorithm and are conve current vector components using an un least-squares fit. Radials and vector n computed using the standard software pro the ocean radar manifacturer, CODAR Sensors (COS). Radials are extracted f Doppler spectra using the calibrated antenn Thresholds for radial SNR and velocities a 6dB, and 150 cm s-1. Vectors are produce grid point using an unweighted least-squ Radial velocities from the two sites falling search radius R=20 km around each grid used in the computation. At least two radial are required in computation of the components. QC procedures apply intersection angle (GDOP>=30 & GDOP<= U, V current components are then further using 4 different statistical methods: deviation from the median (MAD); statisti velocity distributions; statistics of the dis of the 1st derivative; statistics of the distrib the high-frequency components. Data are based on the results of the statistical tests: 4 or more tests fail; 3, if two tests fail; 2, if fails; 1, no test fails. The final product is on a regular geographic grid. More inforn the data processing is available thro document: Quality Control procedures fo Ocean Radar Facility Manual Version 2.0. Integrated Marine Observing System. DOI: 10.26198/5c89b59a931cb	A paragraph describing the dataset: type of data contained, how it was created, who collected it, what instruments were used, etc.

	(http://dx.doi.org/10.26198/5c89b59a931cb)	
source	char('Terrestrial HF radar');	Method of production of the original data.
keywords	char('Oceans');	A comma separated list of key words and phrases.
standard_name_vocabulary	Char('NetCDF Climate and Forecast (CF) Metadata Convention Standard Name Table 27')	Reference for CF standard names
netcdf_version	Char('4.3.3.1')	NetCDF file version
naming_authority	char('IMOS');	Naming authority will always be IMOS.
file_version	char('Level 1 - Quality Controlled data')	Version of data processing
file_version_quality_control	char('Data in this file has been through the quality control procedure as described in the document: Quality Control procedures for IMOS Ocean Radar Facility Manual Version 2.0. Integrated Marine Observing System. DOI: 10.26198/5c89b59a931cb (http://dx.doi.org/10.26198/5c89b59a931cb). Every data point in this file has an associated quality flag.');	Version of the quality control applied to the data
geospatial_lat_min	double(-32.5151159);	Southernmost latitude (positive north) from which dataset was obtained; a value between -90 and 90 degrees.
geospatial_lat_max	double(-29.3070009);	Northernmost latitude (positive north) from which dataset was obtained; a value between -90 and 90 degrees.
geospatial_lat_units	char('Degrees_north')	Units used for geospatial_lat_min/max attributes.
geospatial_lon_min	double(112.1237434);	Westernmost longitude (positive east) from which dataset was obtained; a value between -180 and 180 degrees.
geospatial_lon_max	double(115.8266081);	Easternmost longitude (positive east) from which dataset was obtained; a value between -180 and 180 degrees.
geospatial_lon_units	char('degrees_east')	Units used for geospatial_lon_min/max attributes.
geospatial_vertical_min	double(0.0);	Minimum depth of measurements, in metres.
geospatial_vertical_max	double(0.0);	Maximum depth of measurements, in metres.
geospatial_vertical_units	char('m)	Units used for geospatial_vertical_min/max attributes.
time_coverage_start	char('2017-06-30T23:00:00Z')	Start date and time in UTC, for which data in the dataset was collected. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2017-09-11T06:05:00Z : September 11 2017 06:05:00AM
time_coverage_end	char('2017-06-30T23:00:00Z')	End date and time in UTC, for which data in the dataset was collected. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 2017-09-11T06:05:00Z : September 11 2017 06:05:00AM
local_time_zone	double(8)	Local time zone (UTC+)

data_center	char(' Australian Ocean Data Network (AODN)')	Data center in charge of management and distribution of the data resource.
data_centre_email	char('info@aodn.org.au')	Data centre contact email address.
author	char('Cosoli, Simone')	Name of person responsible for the creation of the dataset.
author_email	char('simone.cosoli@uwa.edu.au')	Email address for the data creator
institution_references	char('http://imos.org.au/facilities/oceanradar/')	Reference to the data provider and producer.
principal_investigator	char('Cosoli, Simone')	Name of principal investigator in charge of the radar
Citation	char(' The citation in a list of references is: IMOS, [year-of-data-download], [Title], [data-access-URL], accessed [date-of-access]'')	Citation used for usage of this data.
acknowledgement	char('Any users (including re-packagers) of IMOS data are required to clearly acknowledge the source of the material in this format: \"Data was sourced from the Integrated Marine Observing System (IMOS) - IMOS is a national collaborative research infrastructure, supported by Australian Government."')	Any users (including re-packers) of IMOS data are required to acknowledge the source of the data in this format.
distribution_statement	char('Data may be re-used, provided that related metadata explaining the data has been reviewed by the user, and the data is appropriately acknowledged. Data, products and services from IMOS are provided \"as is\" without any warranty as to fitness for a particular purpose.')	Statement describing data distribution policy.
license	char('http://creativecommons.org/licenses/by/4.0/')	Reference for the license for the data
Comment	char('This NetCDF file has been created using the IMOS NetCDF Conventions v1.4.')	
Disclaimer	char('Data, products and services from IMOS are provided \"as is\" without any warranty as to fitness for a particular purpose.')	

4.4.3 Dimensions

SeaSonde radar vector currents are 1-hour averages of the sea surface current. They have two-dimensional coordinates of I, J indexes instead of longitude latitude, along with various measured parameters. All variables are defined on a regular latitude – longitude grid; the size of data is fixed. FV01 files include the following dimension (Table 48): TIME; I, J.

Table 48. *Dimensions*

Dimension	Definition
TIME	Temporal interval over which the data was averaged (UNLIMITED)
I	Row indexes for the grid coordinated along the x-axis
J	Row indexes for the grid coordinated along the y-axis

4.4.4 Variables

Variables and attributes in FV01 netcdf data files for SeaSonde surface currents are listed in Table 49. Table 50 contains the parameters included in the netcdf file, with Table 51 lists the quality control indicator and the flags in use for the IMOS Ocean Radar Facility DM SeaSonde current data.

Table 49. *Variables and attributes for the DM FV01 SeaSonde vector maps*

Variable	Attributes	Definition

TIME	double TIME;
	standard_name = "time";
	long_name = "time";
	units = "days since 1950-01-01 00:00:00 UTC";
	calendar = "gregorian";
	axis = "T";
	valid_min = 0.0;
	valid_max = 90000.0;
		Time at which <PARAM> measurements were made. Values are recorded as days since 12 am of 1st January 1950.

I	int(I); long_name = "row index (top most value is 1)"; units = "1";	Starting point for the vector grid definition along the X axis
J	int(J); long_name = "column index (left most value is 1)"; units = "1";	Starting point for the vector grid definition along the Y axis

LONGITUDE	double LONGITUDE
	standard_name = "longitude";
	long_name = "longitude";
	units = "degrees_east";
	axis = "X";
	valid_min = -180.0;
	valid_max = 180.0;
	reference_datum = "geographical coordinates, WGS84 datum";	

LATITUDE	double LATITUDE
	standard_name = "latitude";
	long_name = "latitude";
	units = "degrees_north";
	axis = "Y";
	valid_min = -90.0;
	valid_max = 90.0;
	reference_datum = "geographical coordinates, WGS84 datum";	

<PARAM>	float <PARAM>(LATITUDE,LONGITUDE); <PARAM>_FillValue =<X> <PARAM>long_name = <X>; <PARAM>units = <X> <PARAM>valid_min = <X> <PARAM>valid_max = <X>; <PARAM>cell_method = <X>; <PARAM>ancillary_variables = <X>; <PARAM>coordinates;	<PARAM> contains the values of a parameter listed in reference table 5. <X>: this field is specified in the reference table 11. The quality_control_indicator values are as listed in Table 6.
<PARAM_quality_control>	byte <PARAM_quality_control>(POSITION); <PARAM_quality_control>long_name; <PARAM_quality_control>quality_control_set = <X>; <PARAM_quality_control>quality_control_conventions<X>;; <PARAM_quality_control>_FillValue = <X>; <PARAM_quality_control>valid_min = <X>;	Quality flag applied on the <PARAM> values as result of the RT quality checks. Information on flag meanings is found in Table 12.

	<PARAM_quality_control>valid_max = <X>; <PARAM_quality_control>flag_values = <X>; <PARAM_quality_control>flag_meanings = <X>; <PARAM_quality_control>coordinates;	

Table 50 contains the parameters included in the netcdf file, with Table 51 lists the quality control indicator and the flags in use for the IMOS Ocean Radar Facility SeaSonde current data.

***Table 50**. List of parameters included in the netcdf files*

Code	standard_name	long_name (for non-CF)	_FillValue	valid_min	valid_max	coordinates	Ancillary_variables	units
GDOP		Radar beam intersection angles	999999	0	180.0	TIME, LATITUDE, LONGITUDE		degrees
UCUR	eastward_sea_water_velocity	Mean of sea water velocity U component values in 1 hour, after rejection of obvious bad data (see abstract).	999999	-10	10	TIME, LATITUDE, LONGITUDE	UCUR_quality_control	m s-1
VCUR	northward_sea_water_velocity	Mean of sea water velocity V component values in 1 hour, after rejection of obvious bad data (see abstract).	999999	-10	10	TIME, LATITUDE, LONGITUDE	VCUR_quality_control	m s-1
UCUR_sd		Standard deviation of sea water velocity U component values in 1 hour, after rejection of obvious bad data (see abstract).	999999	-10	10	TIME, LATITUDE, LONGITUDE	UCUR_quality_control	m s-1
VCUR_sd		Standard deviation of sea water velocity V component values in 1 hour, after rejection of obvious bad data (see abstract).	999999	-10	10	TIME, LATITUDE, LONGITUDE	VCUR_quality_control	m s-1
NOBS1		Number of observations of sea water	-99B			TIME, LATITUDE, LONGITUD		1

		velocity in 1 hour from station 1, after rejection of obvious bad data (see abstract).				E		
NOBS2		Number of observations of sea water velocity in 1 hour from station 2, after rejection of obvious bad data (see abstract).	-99B			TIME, LATITUDE, LONGITUDE		1

Table 51. *Quality control indicator and the flags in use for FV00 RT IMOS Ocean Radar Facility WERA vector current maps*

Flag value	**Meaning**	**Description**
0	No QC performed	The level at which all data enter the working archive. They have not yet been quality controlled
1	Good data	Top quality data in which no malfunctions have been identified and all real features have been verified during the quality control process.
2	Probably good data	Good data in which some features (probably real) are present but these are unconfirmed. Code 2 data are also data in which minor malfunctions may be present but these errors are small and/or can be successfully corrected without seriously affecting the overall quality of the data.
3	Bad data that are potentially correctable	Suspect data in which unusual, and probably erroneous features are observed.
4	Bad data	Obviously erroneous values are observed.
5	Value changed	Altered by a QC centre, with original values (before the change) preserved in the history record of the data.
6	Not used	Reserved for future use.
7	Not used	Reserved for future use.
8	Interpolated value	Indicates that data values are interpolated.
9	Missing value	Indicates that the element is missing.

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