IMOS Integrated Marine Observing System

Ocean Radar Facility

Quality Control procedures for IMOS Ocean Radar

Manual version 2.1

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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
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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

Citation

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1 Introduction

This document is the IMOS Ocean Radar Facility quality-control and data user's manual. The Ocean Radar Facility is a component of Australia's Integrated Marine Observing System (IMOS). The document contains the description of the data stream, the data products, the data formats and the data quality control procedures for real-time (RT) and delayed-mode (DM) data produced by the Facility.

1.1 The IMOS Ocean Radar program

HF Radar (HFR) systems are a cost-effective solution to augment the existing in-situ measurements at unprecedented spatial and temporal resolutions. Data can be used to resolve time scales that range from diurnal variations (including near-inertial oscillations), sub-mesoscale to mesoscale variability, mesoscale to basin scale, and seasonal to inter-annual variability. They can be used to monitor a variety of processes, including upwelling, open ocean–shelf interaction and dynamics of return flows closer to the coast, sediment transport, and have a great potential for tsunami detection and early-warning systems. Thorough assimilation of real-time data into regional circulation models, they can provide estimates of surface flows which for example, aid in improved trajectory modelling for search and rescue or oil spill response.

The Ocean Radar Facility includes the two main types of ocean surface radars that are being used around the world. They are the Phased Array genre (WERA), manufactured in Germany, and the Direction Finding genre (SeaSonde or CODAR), manufactured in California (US). WERA systems consist of separate transmit and receive antenna arrays. They are arranged in two separate arrays with rectangular shape (transmitter array), and a linear or curvilinear array of receive antennas composed of 12 o 16 elements. SeaSonde systems are compact in their design and, depending on the work frequency, they can combine the transmit and receive elements in one single element. The SeaSonde radars in use to the Facility, however, require two separate elements for the receive and transmit antennas. A minimum separation of at least 2 radar wavelengths is required between the transmit and the receiver.
WERA HFR systems are deployed in the Rottnest Shelf region (WA), South Australia Gulfs region (SA), and Coffs Harbour (NSW). SeaSonde HFR systems are deployed on the Turquoise Coast (WA).

The primary use of both genres is the collection of sea surface currents on predefined grids. Two radar stations are required to produce surface current maps in an area of common overlap; radars in fact only resolve the radial component of the ocean current advancing or receding from the radar receivers. Radial currents for SeaSonde HFR systems are sampled on a polar coordinate grid, in which range resolution is dictated by the transmit bandwidth and the angular resolution is controlled by software. Typical values for angular resolution is 5˚. For these systems, the determination of the direction-of-arrival (DOA) of the radial velocity is the major source of uncertainty, and is controlled by the accuracy of the calibration as well as by the correct choice of the first order limits for the Bragg peaks. Radial currents for the WERA HFR systems are mapped onto a predefined rectangular grid. Accuracy in radial current measurements is controlled by several factors, including the presence of antenna sidelobes, noise and interferences. Accurate calibration is required also for these systems to improve measurement quality.

For both WERA and SeaSonde radars, surface current maps are derived on a regular grid. A least-square approach is used for SeaSonde systems: radial observations within a given search radius R around each grid point for each contributing sites are used in the mapping process. The critical factors in this approach is the geometry of the intersecting radar beams, and the relative contribution of radial velocities from each contributing stations. A similar inversion method is used for WERA radars; the geometry of the intersecting radar beams is a critical factor for WERA systems also, however there is always a 1:1 contribution for the two radar stations since the radar stations share the same sampling grid.

Additional data products are available for the beam-forming genre, which include sea state parameters (significant wave height, wave period, wave direction) and maps of wind direction at sea surface. As the case of surface currents, sea state parameters and wind direction maps require an area of common overlap between the radars. They also require longer integration times than currents in order to improve the reliability in the estimates of the second-order Bragg regions (wave parameters), and may also require spatial averaging between surrounding grid cells to reduce variance.

The IMOS Ocean Radar Facility uses a combination of proprietary software and custom software for the different products. Proprietary software is used to map radial velocity and surface current vectors in real-time (RT) and delayed-mode (DM) from the SeaSonde systems. A combination of proprietary and custom software is used for the RT and DM radial velocities and currents for WERA systems. Wind direction maps and wave parameters are available in DM mode only using a customized version of the SeaView software.

The purpose of the present manual is to document the real-time (RT) and delayed-mode (DM) quality-control (QC) procedures implemented for the IMOS Ocean Radar products. RT- and DM- QC tests described here are based on the so-called Level-0 to Level-3 products as defined within the QARTOD documentation:
- Level 0: applied at a Doppler spectra level;
- Level 1: applied to the radial velocity level;
- Level 2: applied to the surface current level;
- Level 3: applies to the derived products.

All tests have been developed and implemented in agreement with, or represent an improvement to, the existing RT- and DM- QC procedures in use within the HFR community. The IMOS Ocean Radar Facility implements Level 1 and Level 2 QC tests; efforts are done to extend QC tests to Level 0 products, in attempt to minimize the need of further processing and optimize the data products. It is assumed that the SeaSonde systems are calibrated with the proper antenna pattern measurements, and the proper phase calibrations and updated antenna locations are in use for the WERA systems.

The manual also describes the file formats and standards in use at the IMOS Ocean Radar Facility (netcdf-4 file format with IMOS1.4 and CF-1.6 conventions). The data formats are based on the NetCDF format because:
- it is the standard accepted data format by the HFR user community;
- It is a self-describing format for which tools are widely available;
- It is a reliable and efficient format for data exchange.

The document is organized 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;
- Quality control procedures for DM FV01 WERA waves and wind direction maps;
- File format for DM FV01 WERA radials and currents;
- File format for DM FV01 SeaSonde radials and currents;
- File format for DM FV01 WERA waves and wind direction maps;

2 Quality Control (QC) tests and procedures

2.1 Real-time Quality Control tests for WERA radials

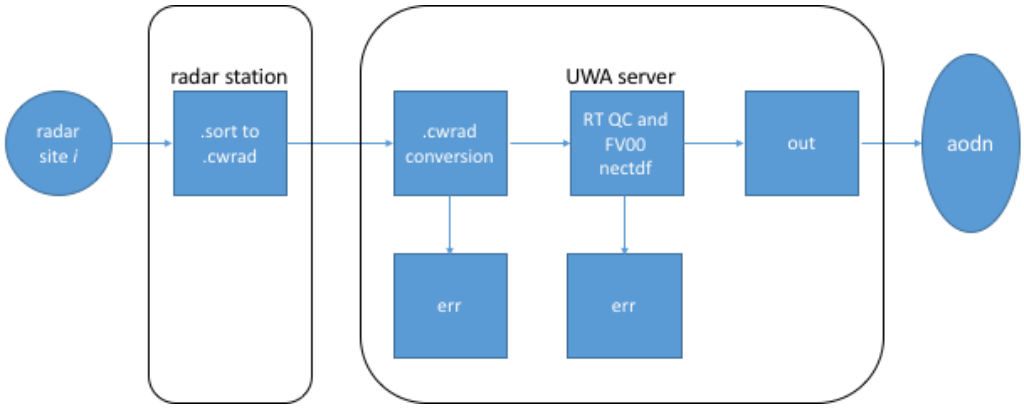


Figure 1*. The IMOS Ocean Radar Facility processing flow for real-time (FV00) data stream for WERA radial currents*

The processing stream for the RT radial currents for the WERA systems is summarized in Figure 1. During normal operations, at the WERA radar sites range time series measurements are collected with a 5-minutes integration every 10 minutes. Once the acquisition has completed, processing scripts are called to produce radial surface currents. The script acorn.process_SORT.sh is used to process range time series files (.SORT) to generate .spec files from which radial surface current files (.crad) and wave spectrum files (.wrad) are made. The .crad file is then merged with radial wave height data and the most recent mean RF pre-scan data.

Since September 2017, the raw, merged (.cwrad) files are processed, quality-controlled, and converted into netCDF-4 format at the UWA server.
The first step in the QC procedure is the conversion of the raw file. The binary file formats of merged .crad, .wrad, and unmerged .crad files all follow a similar convention (Figure 2). They start with a block-size indicator, followed by the data-block, and then a block-size cyclic redundancy check (CRC). The block-size indicator and CRC is always a 4 byte Integer. The majority of the data are in 4 byte chunks of type Integer or Float. There is a header of type Char and an information block which can be of mixed type. The block-size indicator gives the total size of the data-block. The block-size CRC is used to confirm the integrity of the data-block. Its value should be the identical to the block-size indicator before the data-block. Once the file is converted, the QC tests are run and the netcdf file is created.

If any of the steps between the file conversions, the QC or the netcdf creation fail, the incoming data file is redirected to an *error* directory for latter troubleshooting. If all the steps in the processing chain are passed successfully, the raw file is moved to the *processed* directory, QC flags are generated and saved to the updated netcdf file format in the *out* folder, and a copy of the file is moved to the *queued* directory where a LaunchAgent process triggers data upload to the AODN thredds server. Once uploaded successfully, the file is then removed automatically from the *queued* directory. If data upload fails, the sftp process is stopped and run upon upload of a newer file in the *queued* directory.

The following automatic RT QC tests are applied at UWA for the WERA radial currents:
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

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 based on long-terms statistics of the radial velocity, or using available records from other instruments in the region [1].

Figure 2*. Structure of the merged 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 aims at ensuring that the measured signal is sufficiently above a minimum noise level [1]. The IMOS Ocean Radar Facility defines the minimum SNR threshold on radial velocity based on quantitative comparisons with independent measurements, such as subsurface current measurements from moorings, or near-surface velocity measurements derived from drifters within the radar coverage area. Thresholds are determined based on the optimization of the root-mean-square difference, the correlation coefficient and the regression parameters of a best fit model between radar and independent data set, as a function of data loss. An example of optimization process for FRE radar station is provided in Figure 3.

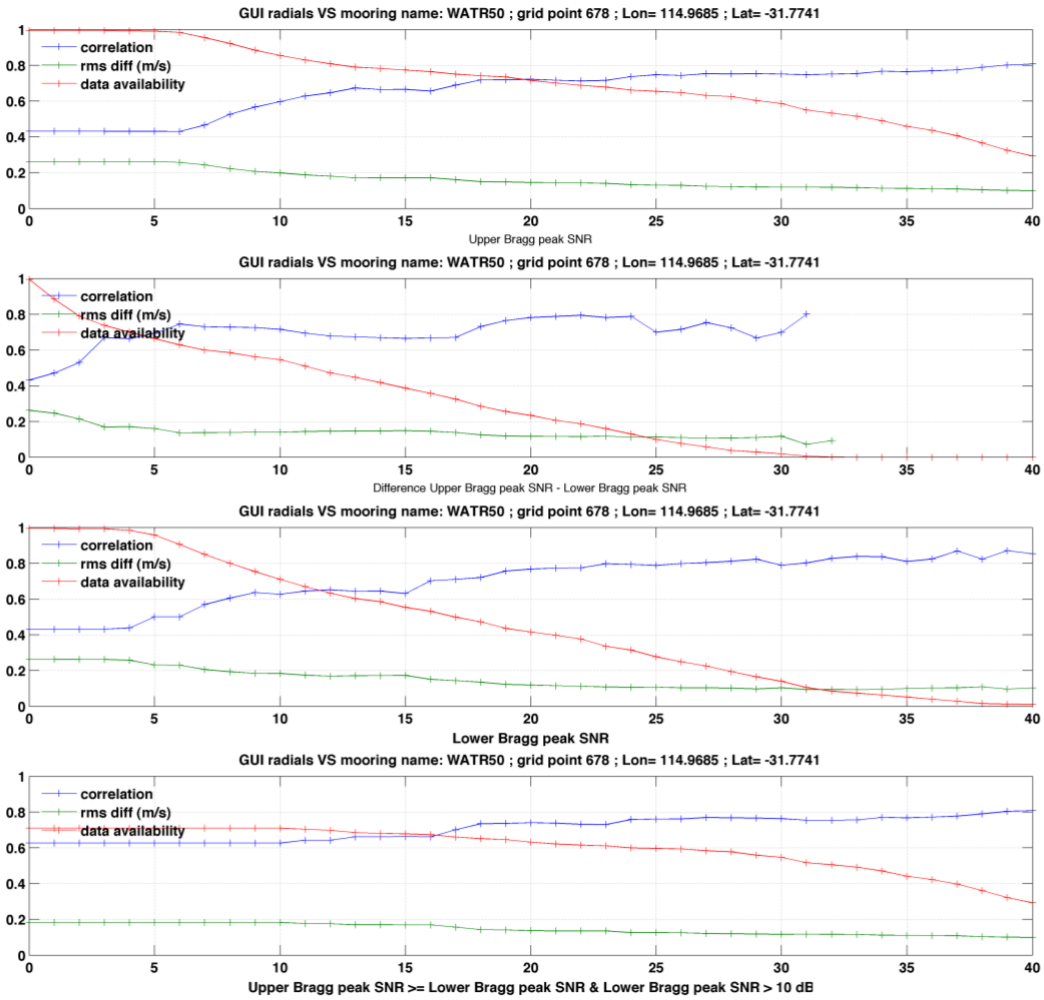


Figure 3. Example of the optimization procedure for the minimum SNR threshold value for the IMOS WERA radar systems. Quantitative comparisons are performed between subsurface velocity data and radar radial currents for the radar grid point closest to the mooring location. Correlation coefficients, rms differences and percent data availability are calculated for different SNR threshold values. The optimal SNR threshold is found when statistically significant changes in correlation coefficient and rms differences occur, while the data availability does not fall below 90%.

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 aims at identifying and flagging suspect radial velocities based on the spatial distribution of the corresponding SNR values along each radar beam. The IMOS Ocean Radar Facility implements the following approaches to identify and flag the suspect data points [1]:

1, a polynomial function is fit to SNR, and statistics of the differences are derived. Data is flagged and removed if exceeding the acceptable error threshold. A new iteration is run, error statistics updated and new data points flagged. The iteration terminates for that specific radar beam when no additional data is flagged. The procedure terminates when all directions are examined.

2, a 2D surface function is fit to SNR, and statistics of the differences are derived. Data is flagged and removed if exceeding the acceptable error threshold. A new iteration is run, error statistics updated and new data points flagged. The iteration terminates when no additional data is flagged. The procedure terminates when all directions are examined.

This procedure is particularly suited for the removal of bias in the radial velocity data that are caused by a contamination of the first-order Bragg region by the 50Hz signal.

The 50Hz signal interference arises from a variety of sources, either internal or external to the WERA hardware (noisy fans, noisy power line, poor grounding or poor electric insulation). It manifests as a peculiar feature in the Doppler spectra and usually occurs at multiples of the 50Hz frequency associated with the 220VAC power line; at a sampling rate of 2Hz, this signal is visible for instance at range cell (RC) 25 and harmonics. This is impacting in particular WERA systems in the Coffs Harbour (NSW). An example of contaminated Doppler spectra along the boresight direction for Red Rock (NSW) site is provided in Figure 4, while Figure 5 document the effects on radial velocity and SNR maps.

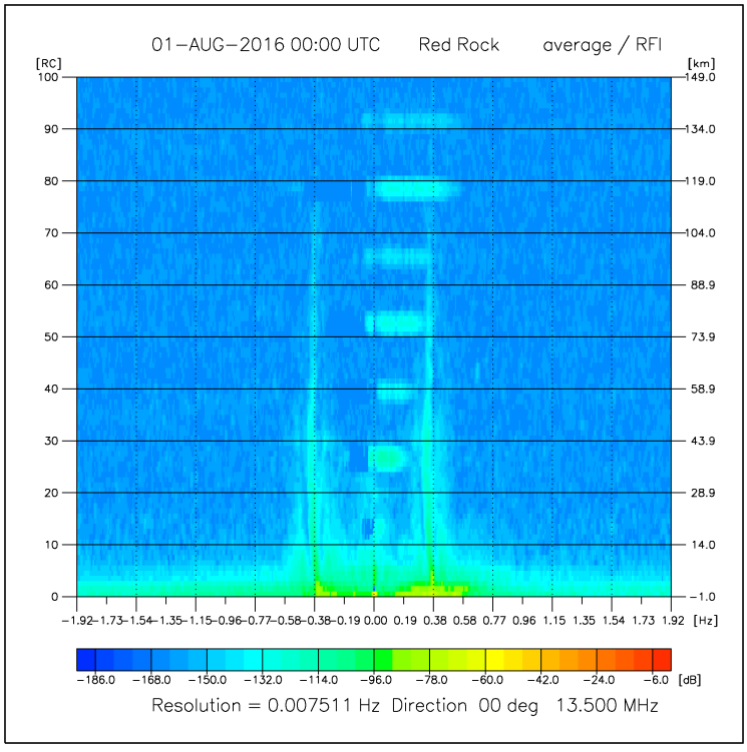


Figure 4*. Example of beam-formed Doppler spectra along the radar receive boresight angle for Red Rock (rrk) station in Coffs Harbour, New South Wales.*

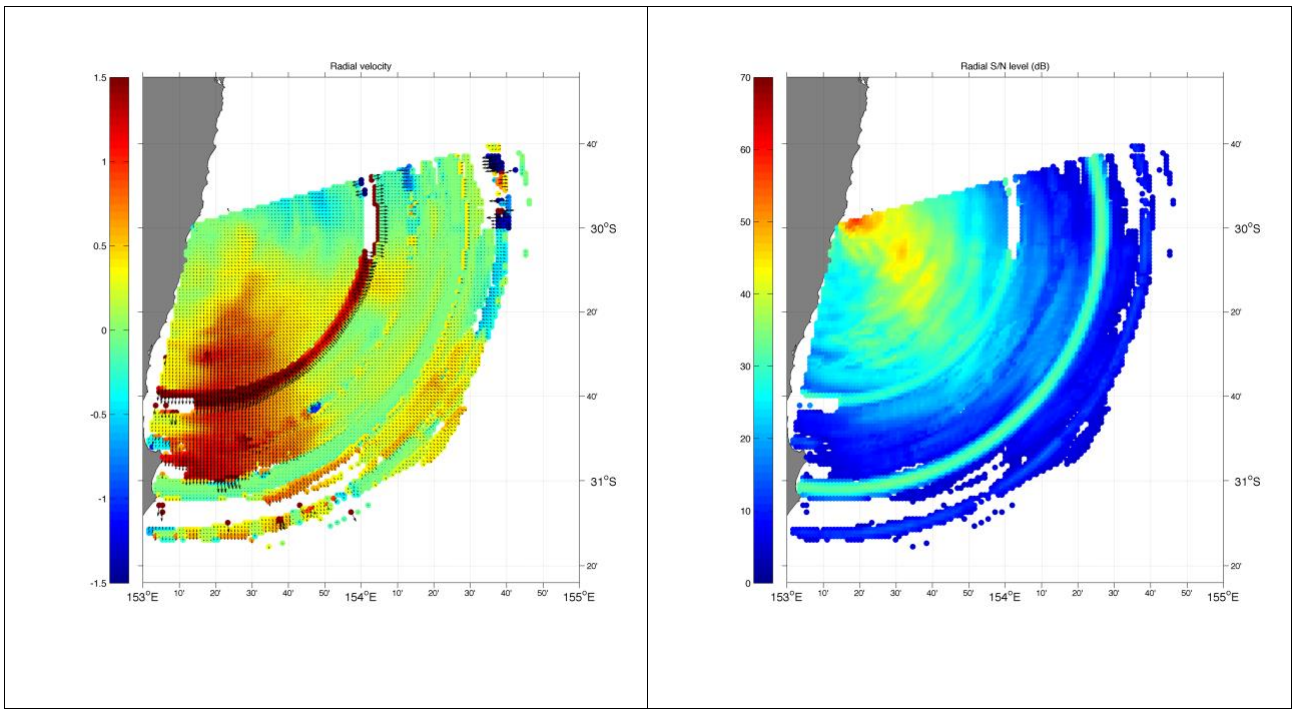


Figure 5a. *Radial current map and corresponding distribution of SNR.*

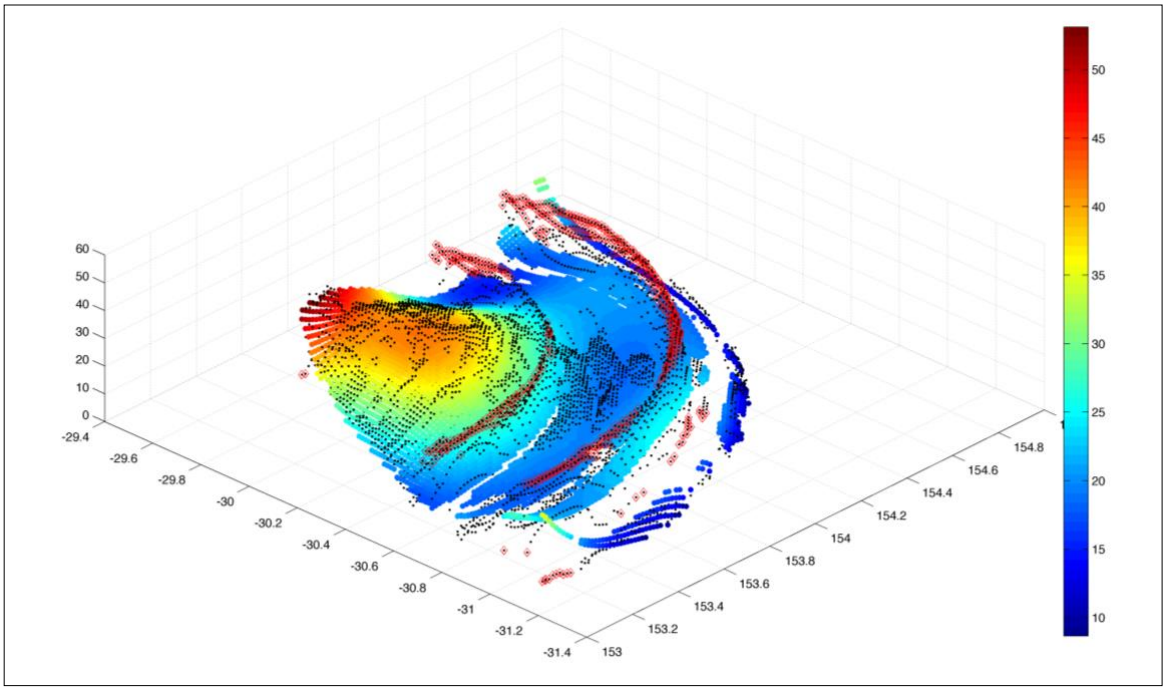


Figure 5b. *Example of 2D fit to SNR map for the radial map shown in Figure 5a. Anomalous data detected at the 1st iteration is flagged as red marks.*

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 error associated with a radial current velocity is not unrealistically high.

2.2 Real-time Quality Control tests for WERA vector maps

At the time of writing (March 2019), generation of RT FV00 vector current maps for the WERA systems is handled by UWA. The procedure uses the RT FV00 radials (Section 2.1), to generate a 1-hour averaged product with U and V components of the current on a predefined Cartesian grid. RT QC flags associated with the RT FV00 radials [1] are applied before the vector mapping process; the following additional tests are performing during the vector mapping stage to ensure the best data quality for surface currents.

The following automatic RT QC tests are applied at UWA for surface currents:
Test 2-5 (Section 2.1);
Test 6, Number of observations [2];
Test 7, 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 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 aims at reducing the errors introduced during the vector mapping process by poor orthogonality constraints in the radar beam intersection angles.
Poor geometric constraints between radials yields a total vector with too much uncertainty to be valid. The IMOS Ocean Radar Facility define as GDOP the intersection angle between the radar-look angles of the two radar stations, and constrains angles in the range [30˚, 150˚] - see Figure 6 [3].

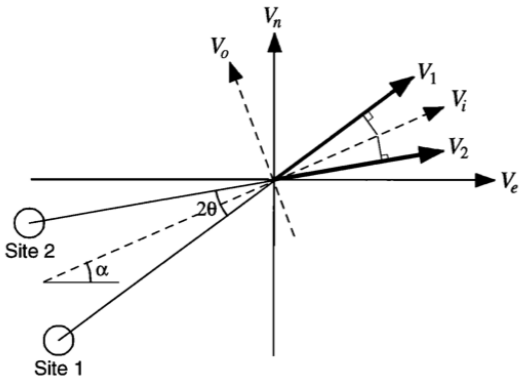


Figure 6*. Definition of the radar beam intersecting geometry adopted by the Ocean Radar Facility in the definition of the GDOP angular constraints for surface currents*

Rather than using the formulation proposed in [3], IOOS defines the GDOP as the trace of the covariance matrix in attempt to generalize the application of this QC test to radar nodes with more than two contributing sites. As such, GDOP is a scalar representing the contribution of the radial (bearing) geometry to uncertainty in velocity at a given grid point rather than being a range of angles. Higher GDOP values indicate larger covariances associated with the least squares fit used in obtaining the solution.

Starting from January 2018, the generation of RT FV00 vector current maps for the WERA systems takes place at the UWA server. The proposed procedure uses the RT QC FV00 radials, and passes only the radial velocities with QC flag < 4. The IMOS Ocean Radar Facility then applies the GDOP threshold, and applies additional QC flags based on the number of observations (NOBSMIN) for each stations, rather than removing the entire sequence of observations when radial data is missing.

In addition to Test 6, 7, and 9, the IMOS Ocean Radar Facility implements the following automatic RT QC for surface currents:
Test 8a, Number of observations;

Test 8a – 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		

Examples of the RT QC FV00 vectors created with the two different approaches are given in Figure 7 for 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. The approach in use at the IMOS Ocean Radar Facility has the clear advantage of improving the effects of the 50Hz artefacts presented in Figures 4-7 at COF WERA node, thus limiting the need of post processing and delayed mode QC tests. It also has the clear advantage of improving the spatial coverage without the need of spatial and – or temporal interpolation.

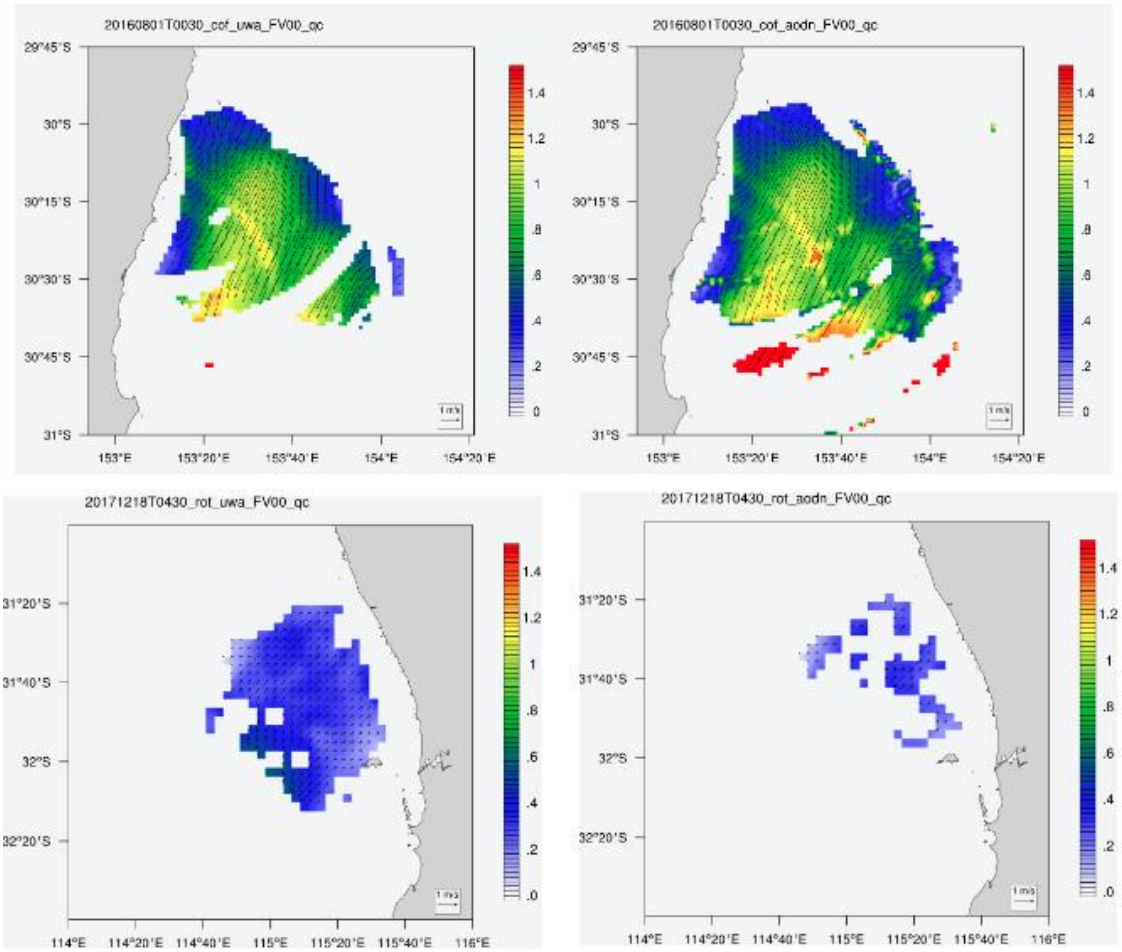


Figure 7*. Examples of the RT QC FV00 vectors created with the two vector mapping approaches currently in use at UWA (left panels), compared to same vector maps with RT procedures previously in use in use at AODN. Examples refer to COF (NSW) and ROT (WA) WERA radar systems. Left panels refer to RT FV00 created with the modified approach in use at UWA; right panels refer to RT FV00 created with the modified approach in use at AODN.*

2.3 Real-time Quality Control tests for SeaSonde radials

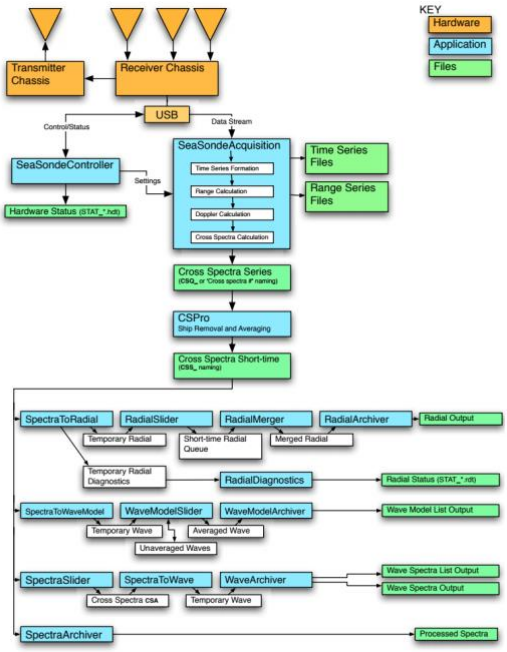
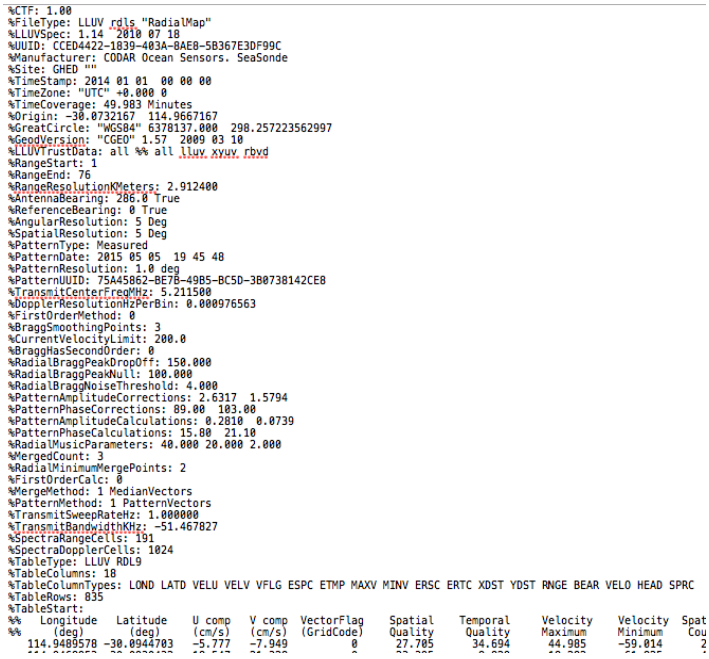


Figure 8. *The IMOS Ocean Radar Facility processing flow for real-time (FV00) data stream for SeaSonde radial currents*

The processing stream for the RT radial currents for the SeaSonde systems is summarised in Figure 8. During normal operation at the SeaSonde radar sites, voltage time series at the antenna are continuously collected and converted to range-gated data file. Every 5 minutes, a cross spectra file is generated and merged by the CSPro proprietary software into 15-minutes averaged Doppler spectra. CSPro performs a set of quality-control tests and removes the interference and the ship-echo signatures before the merging. The application SpectraToRadial is used to extract a temporary, short-term output radial file in ascii format after the spectral averaging. Every hour, the application RadialMerger collects the sequence of short-term radials and merges them into the final hourly file with radial currents in a polar coordinate system and quality statistics for each point, including number of merged segments, temporal and spatial standard deviation, and maximum - minimum values for the distributions of the merged radial currents.

The standard file format in use for the SeaSonde radials is the Codar CTL format - a tabular-format text file with Roman ASCII encoding. Each text line may end with '\r' (return, char 13) or '\n' (newline, char 10) or '\r\n' or '\n\r'. The maximum line length is 4096 characters, not counting the one or two end- of-line characters '\r\n'. The file consists of a header storing the file version, radar location and processing options and parameters, transmit frequency and bandwidth, number and type of columns (Figure 9); a table data with grid coordinates, radial velocity, radial quality statistics; additional tables in the footer of the file contain diagnostics of the radial and diagnostic status.



```
%CTF: 1.00
%FileType: LLUV rdls "RadialMap"
%LLUVSpec: 1.14 "2010 07 18"
%UUID: CCED4422-1B39-403A-BAE8-5B367E3DF99C
%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: 15.00  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*

Since June 2016, the Facility manages the RT conversion from standard proprietary .lluv format to the updated netcdf file format. No RT QC is applied to the radial at this stage, as the proprietary software in use to the Facility is not capable of properly handling the QC flags.

2.4 Real-time Quality Control tests for SeaSonde vector maps

The IMOS Ocean Radar Facility uses the proprietary software contained in the licensed (SeaSondeCombine) to derive hourly vector on a latitude-longitude grid. The radar stations push RT radials from the stations to the corresponding incoming directory, e.g. for the Turquoise coast (WA) node: */Users/lanc/in* for Lancelin; and, */Users/ghed/in*, for Green Head. A LaunchAgent monitors the incoming directories and launches a *rsync* process to copy the directory content to the processing folders as soon as a new file lands in the incoming directory.
For each SeaSonde node, the process *AnalyzeCurrents* runs on the background and checks for pairs of radial currents from each stations; when available, the application creates a vector map on a predefined grid. A different LaunchAgent monitors the output paths for the vector maps and calls the RT QC and the netcdf conversion procedures every time a new vector map is created.
Similarly to the radial files, the standard file format in use for the SeaSonde vectors is the Codar CTL format - a tabular-format text file with Roman ASCII encoding. Each text line may end with '\r' (return, char 13) or '\n' (newline, char 10) or '\r\n' or '\n\r'. The maximum line length is 4096 characters, not counting the one or two end- of-line characters '\r\n'. Each line in the table describes a single current vector. The main component of the vector is the Lon, Lat, U,V data. Additional information is included, such as x - y coordinates, range, bearing, velocity, and direction data as redundant reference information about the vector that helps to provide diagnostics when examining the data.
A least-squares method is then used for the computation of the vector components at each grid point, using radial information from the two stations within a prescribed search radius R.

The following QC checks for the RT vectors are currently performed before the creation of the netcdf file:
Test 9, maximum velocity threshold;
Test 10, number of observations;
Test 11, radial balance test;
Test 12, Geometry of the intersecting radar beam (GDOP test)

Test 9, 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 10, number of observations

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

Test 11, 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 10, 11 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].

Test 12, 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	Minimum number of radial velocities per site above a minimum value	If GDOPMIN=<GDOP=<GDOPMAX, flag = 1;
Example: GDOPMIN = 30˚; GDOPMAX = 150˚		

2.5 Delayed-time Quality Control tests for WERA radial maps

The delayed-mode (DM) Quality-Control (QC) for the WERA radial velocity maps consists of both time-domain and space-domain tests. Time domain-based test are applied to time series of radial velocity at each grid point in the radar domain. The following tests are implemented:

Test 13, statistics of the radial velocity distribution;
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 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.

Table 1. Aggregated QC flags for DM QC tests on WERA radial velocity time series

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

In addition to tests 13 – 16, the following QC tests are applied in the space domain:
Test 2 – Radial velocity threshold
Test 3 – Signal-to-Noise Ratio (SNR)
Test 4 – Spatial distribution of the Signal-to-Noise Ratio (SNR) (1D and 2D case)
A description of QC tests 2-4 is provided in 2.1 and will not be repeated here.

Results of QC tests 2 – 5 are flagged as follows:

Table 2 Aggregated QC flags for DM QC tests on WERA radial velocity time series

Flags	Condition	Flag meaning
Fail = 4	QC test failed	Bad data
Pass = 1	QC test passed	Good data

It is assumed that:
a, radial currents measured at each grid point are independent and uncorrelated from the surrounding grid cells;
b, radial velocity is continuous in time;
c, radial velocity time series follow a gaussian-type distribution.
Time instant where radial measurements are not available are filled with NaN-valued maps; these empty maps are then removed during the conversion step 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;

Anomalous values are identified from the 99% confidence limits of the distribution of velocity components under the assumption of Gaussian-type distributions; values exceeding these thresholds are flagged as spikes. The critical point in this procedure is the assumption of Gaussian distribution for the radial velocities, which needs most likely more a more detailed investigation or a better tuning. The procedure however seems to identify and flag anomalous data in a relatively robust way and it is also adopted at the Taiwan Ocean Radar Network (TORI) under 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 QC test is based on the first difference of the radial current time series at each point. The 1st difference operator ensures that data are normally-distributed and as such 95% (99%) confidence limits of the distribution can be used to identify anomalous values in the data set. In analogy with the procedure adopted for vector components, the distributions of the 1st order difference is estimated along with the corresponding upper - lower confidence limits. 1st differenced data exceeding these bounds are identified and data in the 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 test is based on statistics of the high-frequency components of the radial velocity series at each grid point and it is based on the assumption that noise and spikes are found in the high-frequency component of the velocity time series. A low-pass filter signal is fit to the radial currents and removed from the time series to extract the high-frequency portion. Then, tests are carried out on the distribution of the high-frequency part: assuming a Gaussian-type distribution, the 95% (99%) confidence limits are derived and data exceeding these limits are flagged as spike. The low-pass signal is defined as a Savitzky-Golay filter: a generalized moving average with filter coefficients determined by an unweighted linear least-squares regression and a polynomial model of specified degree (default is 2). To avoid artefacts from gaps and missing data in the time series, this test is performed only when at least 50% of the data is available.

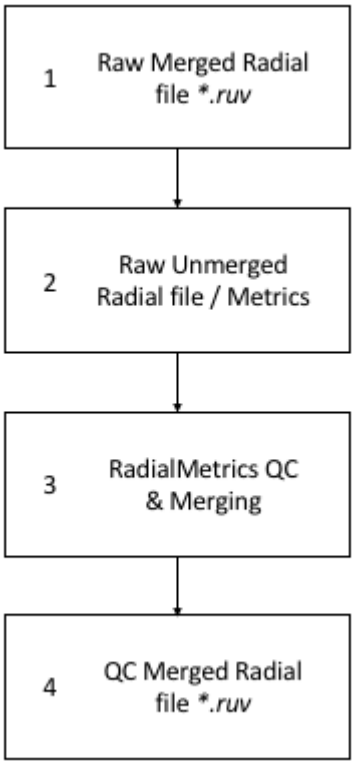
2.6 Delayed-time Quality Control tests for SeaSonde radial maps

At the time of writing (November 2019), the delayed-mode (DM) Quality-Control (QC) for the SeaSonde radial velocity maps is implemented and performed routinely as part of the standard Ocean Radar processing chain. The same procedure is being ported for RT operations and will not be repeated in the relevant Section of this document. The procedure acts at a level of each Doppler velocity that contributes to the radial velocity map at each (range, bearing pair). It is based on the following assumption and software prerequisites:

- the assumption is that SNR is a valid proxy for data quality, and in particular the SNR values of the individual Doppler lines in the Doppler spectra from the three orthogonal receive channels.

- it relies on the RadialMetrics output available from the manufacturer software (from SeaSondeRadialSuiteR7 and following releases) to access the individual Doppler lines within the first order region, their SNR values and additional useful metrics such as: the MUSIC metrics for single- and dual- angle solutions; the MUSIC angular width of the dominant peaks; the SNR values of the Doppler lines.

The processing scheme is described below (also displayed in Figure 10) and is constituted of a series of sequential steps that:



1, identify and extract the sequence of radial metric files / short-term radial maps; this information is easily retrieved from the footer of the radial file

2, identify the Doppler lines for every radial current in the file; once the sequence of short-term radial velocity files and the corresponding radial metrics files are identified, they are concatenated to create a unique data structure with the relevant information. Loops over radar range cells and angular bearings are used to identify the Doppler velocity lines that contribute to the final radial velocity map output over the radar coverage

3, filter the data based on SNR threshold values and maximum Doppler velocity; threshold values of 6dB are applied to SNR of individual Doppler velocities at each receive channel (SNR_i, i=1:3), so to remove weakly-constrained data; final threshold on the maximum Doppler velocity is applied after SNR filtering.

4, compute an average radial current within the radar coverage. Currently, two options are available: a, unweighted average; b, weighted-average in which weights applied to the Doppler lines are defined by the snr values of Doppler velocities that passed the QC tests. Averages are performed within 5˚ from around each radial bearing.

5, write a *.ruv radial file fully compatible with the SeaSonde proprietary software, with updated information on the number of data rows

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

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. The standard processing scheme for SeaSonde radars is based on the collection of sea-echo signals that originate from the reflection of a frequency- modulated interrupted continuous waveform (FMICW) signal transmitted in the 4 (5) -MHz-frequency band. Complex-valued voltage time series at the three antenna elements are collected every 512 s or 1024 s; at a 1-Hz sampling rate, they correspond to a sampling interval of 8 min, 32 s (or, 17 min, 3 s). The signal at the three antennas is range gated and fast Fourier transformed to obtain raw spectra at the three antennas; then, raw spectra are cross multiplied to generate auto- and cross-spectra, and ensemble averaged at blocks of three consecutive datasets to produce the so-called short-term cross-spectra. Directional information of the radial currents is derived from the analysis of the ensemble-averaged short-term cross-spectra. SeaSonde radars uses a DF algorithm known as MUSIC to derive the direction of arrival of 2(N - 1) signals for each

Doppler line, with N being the number of antenna elements (N = 3) and the multiplying factor being related to the fact that Doppler spectra from either advancing or receding waves are processed independently. The inversion of the short-term cross-spectra produces a temporary output known as the short-term radial map (i.e., the short-term radial), and a corresponding radial metric output with the signal processing output as detailed earlier[1]. Every hour, a sequence of up to five or seven consecutive short-term maps collected around the cardinal hour is merged to produce a surface current map containing the surface current for each radar station over the radar footprint.

The radial file metadata store detailed information on the sequence of short-term radials that have contributed to the final radial velocity maps. Through the SeaSonde RadialMetrics suite, details such as the signal power level, the noise level, the single- or dual-angle solutions are available for each Doppler line that was inverted to radial velocity maps. It is as such relatively straightforward to match the short-term radial velocity map with the corresponding radial metric output and proceed through steps 1-5 as described above.

In standard delayed-mode operation, the following limits are enforced:

1, maximum radial speed (150 cm/s);

2, minimum signal-to-noise ratio at loop 1 (min_snr1, 6 dB);

3, minimum signal-to-noise ratio at loop 2 (min_snr2, 6 dB);

4, minimum signal-to-noise ratio at loop 3 (min_snr3, 6 dB);

5, maximum threshold on Doppler speed (max_DopVel; 100 cm/s).

Threshold values used here have been specifically tuned for the Australian Ocean Radar SeaSonde systems through comparisons with independent data within the HFR coverage and will not necessarily apply to other installations elsewhere. Results of comparisons with mooring data show that all comparison metrics (correlation, root-mean-square differences, angular offset) are optimised and improve significantly with the proposed quality-control method. Examples of radial maps before and after the QC filtering are provided below, along with evidences of lower directional errors. Data refer to the SeaSonde system deployed at Lancelin (WA; site code: LANC).

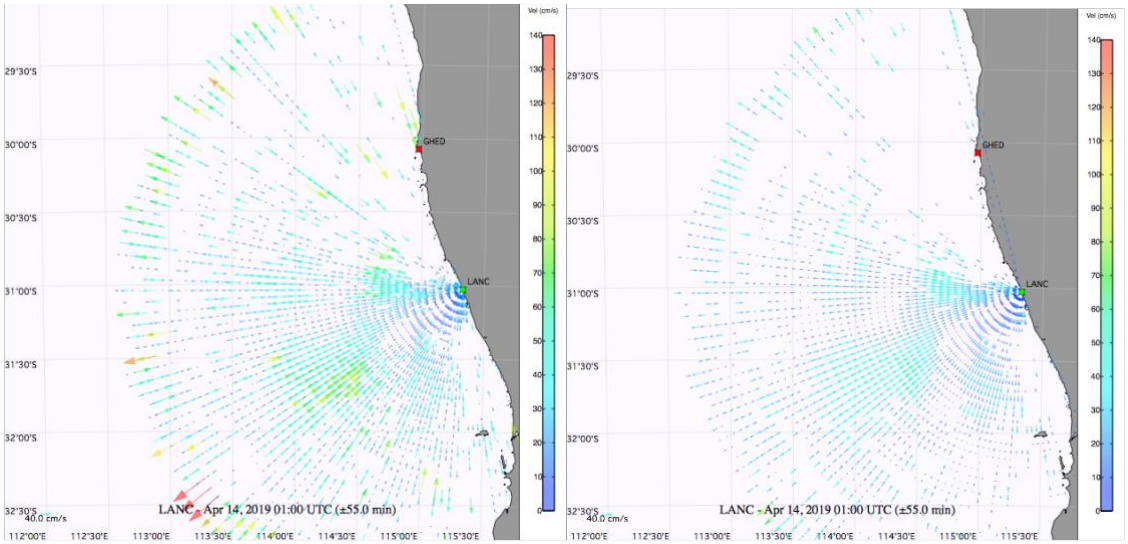


Figure 11. *Example of the DM QC FV01 applied to LANC radials data. Left panel refers to RT FV00 without quality control; right panel refers to DM FV01 with quality control.*

1 Note that in standard operation mode neither the RadialMetrics output nor the short-term radials are provided. Output must be activated either through the proprietary SeaSondeRadialSetup application or by editing the AnalysisOptions.txt file in the RadialConfigs folder.

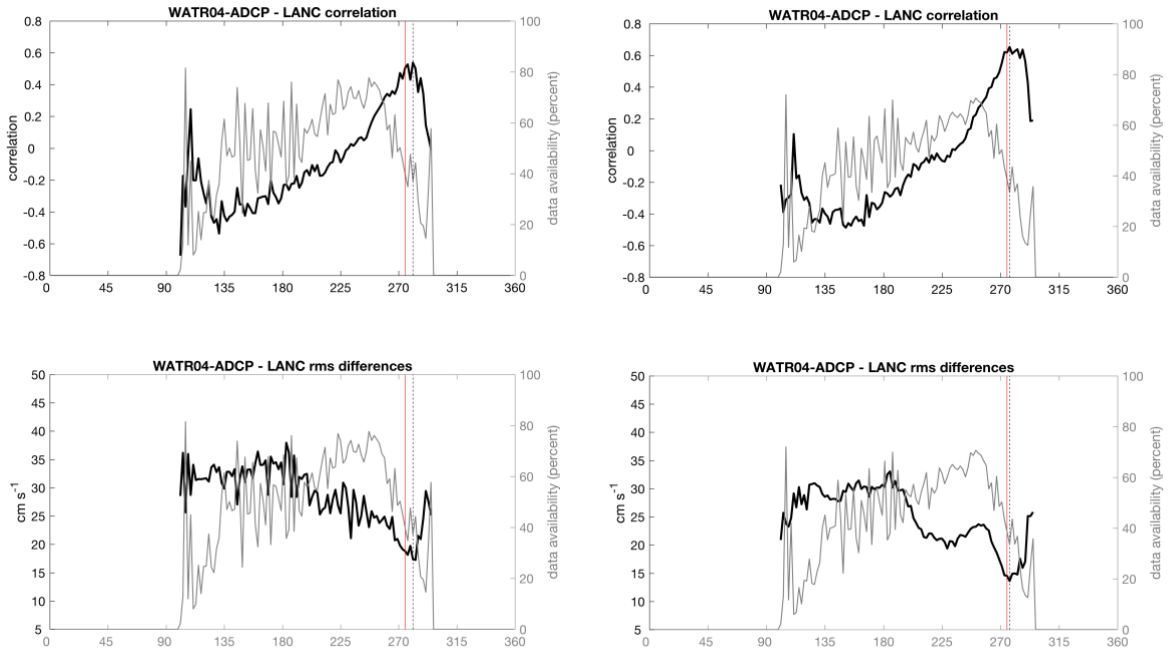


Figure 12*. Example of the effects of DM QC FV01 applied to LANC radials on bearing errors. Left panel refers to RT FV00 without quality control; right panel refers to DM FV01 with quality control. Statistically significant improvement in correlation magnitude and rms differences can be observed when 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 17, 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 18, 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;

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

The delayed-mode (DM) Quality-Control (QC) for vector maps are platform-independent and apply both to WERA and SeaSonde vector maps. They consist of the following time-domain tests and apply separately to the two horizontal current components (UCUR and VCUR):

Test 11, number of observations[2];
Test 12, radial balance test;
Test 13, statistics of the distribution;
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 are complementary and redundant and are capable of handling the majority of the anomalous observations. They are performed separately on the two horizontal components of surface current velocity independently (UCUR – VCUR). The values of the QC tests performed on the two velocity components are the merged into a single flag: if an observation is flagged as "Fail = 4" for UCUR (VCUR) it will be flagged accordingly for VCUR (UCUR), as an erroneous value in one of the components may bias current magnitude and current direction.
Results of the QC tests are then aggregated into a single IODE-compliant QC flag value as follows based on the number of QC tests that are 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 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

A description of QC tests 11-16 is provided in previous sections and will not be repeated here.

It is assumed that:
a, vector velocity components measured at each grid point are independent and uncorrelated from the surrounding grid cells;
b, vector velocity is continuous in time;
c, vector velocity components follow a Gaussian-type distribution.
Time instant where vector measurements are not available are filled with NaN-valued maps; these empty maps are then removed during the conversion step to netCDF files.

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

2.8 Delayed-Mode (DM) for WERA waves and wind parameters

The IMOS Ocean Radar Facility is providing wind and wave (metocean) parameters in delayed-mode (DM) only and for the WERA radar stations at the ROT (Rottnest Shelf, WA), SAG (South Australia Gulfs, SA), and COF (Coffs Harbour, NSW) radar nodes. Parameters are derived using programs developed for the Facility at UWA along with the proprietary Seaview Sensing software.
Wind parameters are extracted from the 1st-order Bragg peaks in a Doppler spectrum by fitting a wave/wind model to the relative peak amplitudes of the two first-order Bragg peak components. Only the strongest Doppler peaks are retained in this inversion procedure.
The normalized second order sidebands of the backscatter Doppler spectrum are used to extract the ocean wave directional spectrum via a non-linear integral equation. The numerical inversion of the first-kind Fredholm integral equation through an iterative inversion algorithm provides estimates of the directional frequency spectrum. Each directional frequency spectrum can be used to provide the dual-radar wave parameters such as significant wave height, period and direction. The model is used to linearize the Barrick-Weber equations and initialize the inversion of these equations: the inversion produces the full directional spectrum of ocean waves on a grid that is uniform in direction, and in square root of wavenumber. The summary wave statistics (significant wave height, mean period, peak period, mean wave direction and peak wave direction) are derived from the full directional wave spectra using standard techniques.

QC procedures for wave and wind can be divided into two categories:
a, Configuration parameters applied during the data processing procedures; these values are set within configuration files on the reprocessing system;
b, Thresholding parameters applied to the data in post-processing mode; these thresholds are applied from within MySQL databases and allow restrictions to be applied to the data.

The following QC tests are implemented for the wind parameters:
Test 19, data excision;
Test 20, Signal-to-Noise Ratio (SNR) of the 1st order Bragg peaks;
Test 21, peak separation

Test 19, data excision

Flags	Condition	Codable Instructions
Fail = 4	Doppler lines in the Doppler spectrum are outside the accepted distance from the theoretical position	Coded within the SeaView software
Pass = 1	Doppler lines in the Doppler spectrum are within the accepted distance from the theoretical position	Coded within the SeaView software
Tolerance = 4%		

Test 20, Signal-to-Noise Ratio (SNR) of the 1st order Bragg peaks

Flags	Condition	Codable Instructions
Fail = 4	SNR of the Doppler below a minimum predefined threshold value	Coded within the SeaView software
Pass = 1	SNR of the Doppler above a minimum predefined threshold value	Coded within the SeaView software
SNR_MIN=10dB		

Test 21, peak separation;

Flags	Condition	Codable Instructions
Fail = 4	Maximum divergence from theoretical Bragg peak separation in Doppler spectrum above a predefined threshold	Coded within the SeaView software
Pass = 1	Maximum divergence from theoretical Bragg peak separation in Doppler spectrum below a predefined threshold	Coded within the SeaView software
peak_separation=10%		

In addition to QC tests 18 – 20, the following QC tests are specifically implemented for the wave parameters:
Test 22, minimum depth;
Test 23, Minimum signal-to-noise level for inner second order sideband of Doppler spectrum;
Test 24, Minimum signal-to-noise level for outer second order sideband of Doppler spectrum;
Test 25, Minimum ratio of first order peak to second order order outer peak in Doppler spectrum

Test 22, minimum depth;

Flags	Condition	Codable Instructions
Fail = 4	Water depth at grid point below a predefined threshold	Coded within the SeaView software
Pass = 1	Water depth at grid point above a predefined threshold	Coded within the SeaView software
Minimum depth = 5 m		

Test 23, Minimum signal-to-noise level for inner second order sideband of Doppler spectrum (SNRimin);

Flags	Condition	Codable Instructions
Fail = 4	SNRimin below a predefined threshold	Coded within the SeaView software
Pass = 1	SNRimin above a predefined threshold	Coded within the SeaView software
SNRimin = 15dB		

Test 24, Minimum signal-to-noise level for outer second order sideband of Doppler spectrum (SNRomin);

Flags	Condition	Codable Instructions
Fail = 4	SNRomin below a predefined threshold	Coded within the SeaView software
Pass = 1	SNRomin above a predefined threshold	Coded within the SeaView software
SNRomin = 15dB		

Test 25, Minimum ratio of first order peak to second order order outer peak in Doppler spectrum (SNR1SNR2omin);

Flags	Condition	Codable Instructions
Fail = 4	SNR1SNR2omin below a predefined threshold	Coded within the SeaView software
Pass = 1	SNR1SNR2omin above a predefined threshold	Coded within the SeaView software
SNR1SNR2omin = 3dB		

3. File format for RT products

3.1 File format for RT WERA radial data

At the time of writing (March 2019) the file format in use for the FV00 WERA radial data complies with the IMOS-1.4 and CF-1.6 conventions. This revised version aims at solving compatibility issues between the netcdf-3 FV00 radial data file format (a JCU legacy product adherent to IMOS-1.2 and CF-1.4 conventions) with the new conventions and metadata in use to AODN. A description of the new UWA FV00 netcdf-4 file format, compliant with the IMOS-1.4 and CF-1.6 conventions, is provided in detail below.

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_20170911T060500Z_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: 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

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,2017-09-13 02:55:00Z']);	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('2017-09-11T06:47:50Z');	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 in real-time. 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 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 IMOS Ocean Radar Manual Version 2.0. 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 IMOS Ocean Radar 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(-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(‘2017-09-11T06:05:00Z’)	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(‘2017-09-11T06:05:00Z’)	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
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 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, 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
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(16)	Number of receive elements
ssr_Rx_Longitude	double(115.7458339, 115.7458736, 115.745918, 115.7459616, 115.7460018, 115.7460335, 115.7460871, 115.7461331, 115.74618, 115.7462278, 115.7462737, 115.7463283, 115.7463717, 115.7464181, 115.7464627, 115.7465069)	Longitudes of the receive array elements
ssr_Rx_Longitude_units	char(‘degree_east’);	Units for Longitude
ssr_Rx_Latitude	double(-32.0334373, -32.0333013, -32.0331558, -32.0330163, -32.0328722, -32.0327263, -32.0325994, -32.0324569, -32.0323177, -32.0321771, -32.0320408, -32.0319074, -32.0317612, -32.0316254, -32.0314839, -32.0313382)	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(-75.0)	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(33309.4)	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;
	valid_max = 5704;
		Adimensional variable that contains the position in the measurement grid

FREQUENCY	double FREQUENCY;
	long_name = "Frequency";
	units = "Hz";
	valid_min = 8800347.0;
	valid_max = 9799653.0;
		Array of frequency steps between a minimum and maximum range used for the spectrum scan

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> contains the values of a parameter listed in reference table 5. <X>: this field is specified in the reference table 5.

	<PARAM>valid_max = <X>; <PARAM>ancillary_variables = <X> <PARAM>coordinates;	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 8 contains the parameters included in the netcdf file, with Table 9 lists 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
ssr_Bragg_Power_L		Height of the left Bragg	-1	0	10e6	TIME, LATITUDE,	ssr_Bragg_Power_L_qual	1

		peak in power spectrum				LONGITUDE	ity_control	
ssr_Bragg_Power_R		Height of the right Bragg peak in power spectrum	-1	0	10e6	TIME, LATITUDE, LONGITUDE	ssr_Bragg_Power_R_quality_control	1
ssr_Surface_Radial_Wave_Significant_Heigh		Sea surface dominant wave height calculated by integrating the radial wave spectrum derived from a sea surface radar Bragg's spectrum	-1	0	100	TIME, LATITUDE, LONGITUDE	ssr_Surface_Radial_Wave_Significant_Heigh_quality_control	m
ssr_Surface_Radial_Wave_Dominant_Period		Sea surface dominant wave period calculated from the peak in the radial wave spectrum derived from a sea surface radar Bragg\'s spectrum	-1	0	100	TIME, LATITUDE, LONGITUDE	ssr_Surface_Radial_Wave_Dominant_Period_quality_control	s

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_20170922T083000Z_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: 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 non QC data, 2017-09-22T08:30:00Z']);	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('2017-09-22T09:00:06Z');	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 (formerly known as ACORN) 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. The IMOS Ocean Radar Facility 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. The IMOS Ocean Radar Facility 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	A paragraph describing the dataset: type of data contained, how it was created, who collected it, what instruments were used, etc.

	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 IMOS Ocean Radar Facility Manual Version 2.0. Integrated Marine Observing System. DOI: 10.26198/5c89b59a931cb (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('4.1.1')	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 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('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('Cosli, 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 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 lists the quality control indicator and the flags in use for ACORN radar radial data.

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;	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 14 contains the parameters included in the netcdf file, with Table 15 lists 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	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 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

At the time of writing (November 2019) the file format in use for the FV00 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.

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 colect 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 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(-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 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, 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

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_LL		Standard	9.96921E36			LATITUDE,		ms-1

UV_ETMP		deviation of current speed during coverage period				LONGITUDE		
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	9.96921E36					arc_degree

		correction for loop 2 to monopole						
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_ra		Average	-32767					1

ds_RAPR		number of radial solutions per range cell						
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	-127					1

		settings						
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 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_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 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 26th September 2017, 16:30
abstract	char('The IMOS Ocean Radar Facility (known as ACORN) is producing NetC containing vector current maps at 1 h interval for time instant 2017-09-26 16:0 the region extending between L (112.124,115.827) and Latitude:(-32.515, The final product is produced on a geographic grid. They are produced fro currents in the Turquoise Coast (WA represent the surface sea water current co along the radial direction from a receiver Radials are calculated from the shift of t peaks in a power spectrum. They are map specific angles through a Direction algorithm and are converted into curren components using an unweighted least-sq Radials and vector maps are computed u standard software provided by the oce manifacturer, CODAR Ocean Sensors Radials are extracted from the Doppler spec the calibrated antenna pattern. Thresholds SNR and velocities are set to 6dB, and 15(Vectors are produced at each grid point unweighted least-squares fit. Radial velocit the two sites falling within a search radius around each grid point are used in the com At least two radials per site are req computation of the velocity compone procedures apply first to intersectio (GDOP>=30 & GDOP<=150); a threshol cm s-1 is applied on current velocity. t current components are then flagged base number of radial velocities from each contribute to the velocity vector. Quality f to 4 if NOBS1==1 or NOBS2==1; it is s NOBS1/NOBS2>=10 or NOBS2/NOBS1<= set to 2 if (NOBS1/NOBS2> NOBS2/NOBS1<10), or if (NOBS2/NOBS NOBS1/NOBS2<10). The final product is on a regular geographic grid. More inform	A paragraph describing the dataset: type of data contained, how it was created, who collected it, what instruments were used, etc.

	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 (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('4.1.3')	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 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('2017-09-26T16:00:00Z')	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 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.')	

3.4.3 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. FV00 files include the following dimension (Table 24): TIME; I, J.

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

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 lists 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>;	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 26 contains the parameters included in the netcdf file, with Table 27 lists 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	-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 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 22nd 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 ove 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 netc 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 dist 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 Ver 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[3]; 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.

[3]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 directio 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 dist 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 inform 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.

4.5 File format for DM WERA dual-radar wave data

Dual-radar wave data are produced at the UWA server in Delayed-Mode (DM) mode only using a modified version of the Seaview processing software. The binary files produced by the software are then used to produce csv (comma-separate) ascii file. A separate file is generated for each variable every hour. Wave parameters are then aggregated and converted into a 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.

4.5.1 File naming convention

The naming conventions for DM netcdf files for dual-radar wave data follow the IMOS convention for DM FV01 products (also described in [4]), as detailed below (Table 52):

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

An example for the DM FV01 dual-radar wave data for the South Australia Gulfs (SAG) region is given below:

IMOS_ACORN_W_20110918T043000Z_SAG_FV01_wavep.nc

***Table 52**. Elements of file-naming convention*

Part of filename	Description
data-code	W: dual-radar wave parameters
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: 20110918T043000Z is 18th September 2017, 04:30
node-code	A three-letter code for the regional deployment: ROT: Rottnest Shelf (WA) SAG: South Australia Gulfs (SA) COF: Coffs Harbour (NSW) CBG: Capricorn Bunker Group (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: wavep, for dual-radar wave parameters

4.5.2 Global attributes

The following attributes are included in the DM FV01 dual-radar wave data.

***Table 53**. IMOS Ocean Radar Facility netcdf files global attributes for DM FV01 dual-radar wave data*

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 Gulfs (SAG), one hour averaged wave QC data, 2011-09-	Short description of the dataset indicating the radar station that collect the data, the type of product and the acquisition date.

	18T04:30:00Z]);	
Instrument	char('WERA Oceanographic HF Radar/Helzel Messtechnik, GmbH using modified Seaview Sensing Ltd software')	Type of instrument used to colect the data
site_code	char('SAG, South Australian Gulf')	HF radar node
ssr_Stations	char('Cape Wiles (CWI), Cape Spencer (CSP)')	Three-letter code for the HFR node
date_created	char('2017-10-13T07:28:53Z');	Date and time at which the file was created. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 20170926T160000Z is 26th September 2017, 16:30
abstract	char('The IMOS Ocean Radar Facility (known as ACORN) is producing NetCDF wave data for each site every hour. T obtained using modified software sup Seaview Sensing Ltd which applies the described in Wyatt et al, A relaxation me integral inversion applied to HF radar mea of the ocean wave directional s International Journal of Remote Sensing, 1095, 1990; Green and Wyatt, Row-action of the Barrick-Weber equations, Jou Atmospheric and Oceanic Technology, 23, 2006 . This file contains wave parameters been extracted from the measured directio spectra. Directions are all towards which th propagating. Each value has a correspondin control flag where a value of 1 means that have passed all the standard Seaview Ser procedures and an additional threshold val for the inversion residual. More informatio data processing is available through the d Quality Control procedures for IMOS Oce Facility Manual Version 2.0. 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 29')	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/10.26198/5c89b59a931c b). 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('2011-09-18T04:30:00Z')	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('2011-09-18T04:30:00Z')	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 of IMOS data are required to clearly acknowledge the source of the material derived from IMOS in the format: \"Data was sourced from the Integrated Marine Observing System (IMOS) - IMOS is a national collaborative research infrastructure, supported by Australian Government.\" If relevant, also credit other organizations involved in collection of this particular data stream (as listed in \'credit\' in the metadata record).')	Any users (including re-packers) of IMOS data are required to acknowledge the source of the data in this format.
license	char('http://creativecommons.org/licenses/	Reference for the license for the data

	by/4.0/')	
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.')	

4.5.3 Dimensions

Dual-radar wave products generated by the IMOS Ocean Radar Facility WERA systems are 1-hour averages of sea state. 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 54. *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

4.5.4 Variables

Variables and attributes in FV01 netcdf data files for WERA dual-radar wave parameters are listed in Table 55. Table 56 contains the parameters included in the netcdf file, with Table 57 lists the quality control indicator and the flags in use for WERA dual-radar wave data.

Table 55. *Variables and attributes for the WERA dual-radar wave data*

Variable	Attributes	Definition

TIME	double TIME;
	standard_name = "time";
	long_name = "time";
	units = "days since 1950-01-01 00:00:00 UTC";
	axis = "T";
	valid_min = 0.0; // double
	valid_max = 999999.0; // double
	calendar = "gregorian";
	comment = "Given time lies at the middle of the 1 hour averaging period.";
	local_time_zone = 9.5; // double
		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 56 contains the parameters included in the netcdf file, with Table 57 lists the quality control indicator and the flags in use for IMOS Ocean Radar Facility radial data.

Table 56*. List of parameters included in the netcdf files for WERA dual-radar wave data*

Code	**standard_name**	**long_name (for non-CF)**	**_FillValue**	**valid_min**	**valid_max**	**coordinates**	**Ancillary _variables**	**units**
VDIRT	sea_surface_wave_to_direction	Direction towards which the wave is propagating	999999	0	180.0	TIME, LATITUDE, LONGITUDE	VDIRT_quality_control	degree
VAVH	sea_surface_wave_significant_height	sea_surface_wave_significant_height	999999	0	100	TIME, LATITUDE, LONGITUDE	VAVH_quality_control	m
WPPE	sea_surface_wave_period_at_variance_spectral_density_maximum	sea_surface_wave_period_at_variance_spectral_density_maximum	999999	0	100	TIME, LATITUDE, LONGITUDE	WPPE_quality_control	s
WPDIT		sea_surface_wave_to_direction_at_variance_spectral_density_maximum	999999	0	3600	TIME, LATITUDE, LONGITUDE	WPDIT_quality_control	degree
WPFM	sea_surface_wave_mean_period_from_variance_spectral_density_first_frequency_mome	First moment period	999999	0	100	TIME, LATITUDE, LONGITUDE	WPFM_quality_control	s

	nt							
WPSM	sea_surface_wave_mean_period_from_variance_spectral_density_second_frequency_moment	Second moment period	999999	0	100	TIME, LATITUDE, LONGITUDE	WPSM_quality_control	s

Table 57. *Quality control indicator and the flags in use for WERA dual-radar wave 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.
10	uncertain_phenomenon	

4.6 File format for DM WERA dual-radar wind data

Dual-radar wind data are produced at the UWA server in Delayed-Mode (DM) mode only using a modified version of the Seaview processing software. The binary files produced by the software are then used to produce csv (comma-separate) ascii file. A separate file is generated for each variable every hour. Wind parameters are then aggregated and converted into a 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.

4.6.1 File naming convention

The naming conventions for DM netcdf files for dual-radar wind data follow the IMOS convention for DM FV01 products (also described in [4]), as detailed below (Table 58):

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

An example for the DM FV01 dual-radar wind data for the South Australia Gulfs (SAG) region is given below:

IMOS_ACORN_MW_20161231T233000Z_SAG_FV01_windp.nc

***Table 58**. Elements of file-naming convention*

Part of filename	Description
data-code	MW: dual-radar wave parameters
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: 20161231T233000Z is 31st December 2017, 23:30
node-code	A three-letter code for the regional deployment: ROT: Rottnest Shelf (WA) SAG: South Australia Gulfs (SA) COF: Coffs Harbour (NSW) CBG: Capricorn Bunker Group (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: windp, for dual-radar wind parameters

4.6.2 Global attributes

The following attributes are included in the DM FV01 dual-radar wind data.

***Table 59**. netcdf files global attributes for DM FV01 dual-radar wind data produced by 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 South Australian Gulf (SAG), one hour averaged wind and short wave QC data, 2016-12-	Short description of the dataset indicating the radar station that collect the data, the type of product and the acquisition date.

	31T23:30:00Z]);	
Instrument	char('WERA Oceanographic HF Radar/Helzel Messtechnik, GmbH using modified Seaview Sensing Ltd software')	Type of instrument used to colect the data
site_code	char('SAG, South Australian Gulf')	HF radar node
ssr_Stations	char('Cape Wiles (CWI), Cape Spencer (CSP)')	Four-letter code for the HFR node
date_created	char('2017-07-03T16:32:06Z');	Date and time at which the file was created. Format: yyyy-mm-ddTHH:MM:SSZ' Example: 20170926T160000Z is 26th September 2017, 16:30
abstract	char('The IMOS Ocean Radar Facility (formerly known as ACORN) is producing NetCDF files with wind direction and short wave direction and spread data for each site every hour. These are obtained using modified software supplied by Seaview Sensing Ltd which applies the method described in Wyatt et al, 1996, Maximum Likelihood estimation of the directional distribution of 0.53Hz ocean waves, Journal of Atmospheric and Oceanic Technology, 14, 591-603, 1996. Directions are all towards which the wave is propagating or the wind is blowing. Each value has a corresponding quality control flag where a value of 2 means that the data have passed all the standard Seaview Sensing QC procedures. 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/10.26198/5c89b59a931cb));

		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('2016-12-31T23:30:00Z')	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('2016-12-31T23:30:00Z')	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 of IMOS data are required to clearly acknowledge the source of the material derived from IMOS in the format: \"Data was sourced from the Integrated Marine Observing System (IMOS) - IMOS is a national collaborative research infrastructure, supported by Australian Government.\" If relevant, also credit other organizations involved in collection of this particular data stream (as listed in \'credit\' in the metadata record).')	Any users (including re-packers) of IMOS data are required to acknowledge the source of the data in this format.

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.')	

4.6.3 Dimensions

WERA dual-radar wind products are 1-hour averages of sea state. 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 60. *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

4.6.4 Variables

Variables and attributes in FV01 netcdf data files for WERA dual-radar wind parameters are listed in Table 61. Table 62 contains the parameters included in the netcdf file, with Table 63 lists the quality control indicator and the flags in use for IMOS Ocean Radar Facility WERA dual-radar wind.

Table 61. *Variables and attributes for the WERA dual-radar wave data*

Variable	Attributes	Definition

TIME	double TIME;
	standard_name = "time";
	long_name = "time";
	units = "days since 1950-01-01 00:00:00 UTC";
	axis = "T";
	valid_min = 0.0; // double
	valid_max = 999999.0; // double
	calendar = "gregorian";
	comment = "Given time lies at the middle of the 1 hour averaging period.";
	local_time_zone = 9.5; // double
		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 62 contains the parameters included in the netcdf file, with Table 63 lists the quality control indicator and the flags in use for the IMOS Ocean Radar Facility dual-radar wind data.

Table 62*. List of parameters included in the netcdf files for WERA dual-radar wave data*

Code	**standard_name**	**long_name (for non-CF)**	**_FillValue**	**valid_min**	**valid_max**	**coordinates**	**Ancillary _variables**	**units**
WDIR	wind_to_direction	Direction towards which the wind is blowing based on short wave direction	999999	0	360.0	TIME, LATITUDE, LONGITUDE	WDIR_quality_control	degree
WWAV	sea_surface_wind_wave_to_direction	Direction towards which the wind swell is propagating based on short wave direction	999999	0	3600	TIME, LATITUDE, LONGITUDE	WWAV_quality_control	degree
WWDS		Short wave directional spreading using Donelan model	999999	0	100	TIME, LATITUDE, LONGITUDE	WPPE_quality_control	s

Table 63. *Quality control indicator and the flags in use for WERA dual-radar wind 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.
10	uncertain_phenomenon	

References

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