WMO CF-Extensions

2022-03-24

10 March 2021, version 0.1

# DEFINITIONS

**CF Conventions**: The Climate and Forecast Conventions for netCDF (CF Conventions; e.g. Eaton et al., 2020) define a minimum set of metadata required to ensure that conforming netCDF files meet a basic level of self-description and interoperability. The required (minimal) set of metadata ensures that all variables in a dataset have “an associated description of what it represents, including physical units if appropriate, and that each value can be located in space (relative to earth-based coordinates) and time”. Additional metadata are defined by the CF Conventions but are only recommended where they may not be needed or appropriate for all datasets.

**WMO-CF Extensions**: The WMO-CF extensions build on the CF Conventions to provide the framework for standardizing semantics and metadata, further reducing the effort involved in specifying data products and increasing interoperability. The WMO-CF:

1. Define additional metadata requirements or recommendations that are not defined by the CF Conventions;
2. Specify the set of optional CF Conventions metadata that this extension requires, making those optional metadata mandatory.

**WMO-CF Profiles**: The WMO-CF profiles implement the WMO-CF extensions for different data types by, inter alia: defining the standardized metadata and semantics; specifying the names of dimension and coordinate variables; and specifying the ordering of dimensions. The WMO-CF Profiles reduce the degrees of freedom available when creating netCDF files, increasing the standardization of data from different publishers for the same type of data.

# FM System of Numbering WMO-CF Extensions and Profiles

Each WMO-CF profile or extension bears a number (X), preceded by the letters FM. This number is followed by the year (Y) and month (m) of operational implementation in the form FM X-Y-M. Furthermore, an indicator term is used to designate the WMO-CF profile colloquially and is therefore called a “code name”.

## FM SYSTEM OF WMO-CF PROFILES

|  |  |
| --- | --- |
| **FM 301-XX**  WMO-CF Radial | Reports from operational weather radar |
| **FM 302-XX**  WMO-CF Marine Trajectory | Profile for the representation of meteorological / oceanographic observations along a trajectory within the ocean (or other body of water) or at / near the ocean surface.  Example observing platforms include, inter alia: crewed vessels making observations at the sea surface along a track; autonomous surface vehicles making similar measurements; and oceanographic gliders making measurements along a track. |

## REPRESENTATION OF INFORMATION IN THE WMO-CF PROFILES AND EXTENSION

1. NetCDF version and features
   1. WMO-CF files should be encoded in version 4 of the NetCDF format.
   2. String data should be encoded using the string atomic data type.
2. Representation of information in the WMO-CF NetCDF Extension and WMO-CF profiles.
   1. Data shall conform with version 1.8 or higher of the netCDF conventions for CF (Climate and Forecast) metadata (CF hereafter).The version shall be specified in the Conventions global attribute (see section 6).
   2. Data shall conform with version 1.3 or higher of the Attribute Convention for Data Discovery (ACDD) conventions. The version shall be specified in the Conventions global attribute (see section 6).
   3. Data shall also conform with the regulations and the WMO-CF extensions defined within this document.
   4. Data conforming with the WMO-CF extensions shall be identified by the use of the label WMO-CF n.n in the Conventions global attribute (see section 6) where n.n is the version number.
   5. Data shared on the WIS shall conform with one of the WMO-CF profiles defined within this document.
   6. Creators of WMO-CF files shall ensure that they validate against the specified CF conventions and the WMO-CF extensions.
   7. Attributes defined as part of the WMO-CF extension shall use the wmo\_\_ namespace (double underscore).
   8. Any attribute using the wmo\_\_ namespace but not defined as part of the WMO-CF extension shall be invalid.
3. Dimensions and Coordinate Variables
   1. Dimension names shall be specified within the WMO-CF Profiles defined below.
   2. The order of the dimensions within a variable shall be specified within the WMO-CF Profiles.
   3. The coordinate variable names shall be defined within the WMO-CF Profiles.
   4. The standard\_name attribute shall be used for all coordinate variables.
   5. The units attribute shall be used for all coordinate variables.
   6. The axis attribute shall be used to indicate the spatiotemporal coordinates (X, Y, Z, T) when present.
   7. Time coordinate variables (T) shall include the calendar attribute.
4. Station identifiers
   1. Each station included in a data file shall be identifiable via:
      1. A WIGOS Station Identifier (WSI), or
      2. A traditional WMO Identifier (e.g. 5-digit or 7-digit code), if no WIGOS Station Identifier has been assigned, or
      3. An alternative station identifier, if no WIGOS Station Identifier or traditional WMO Identifier has been assigned. For example, ship ITU callsign.
   2. The WIGOS Station Identifier shall be stored as a string using the standard notation:
      1. <WIGOS station identifier series>-<issuer of identifier>-<issue number>-<local identifier>
   3. The form of the traditional WMO Identifier to be used shall be specified within the WMO-CF profile definitions below.
   4. The form of the alternative station identifier, if required, shall be specified within the WMO-CF profile definitions below.
   5. Data files containing data from a single station shall store the WIGOS Station Identifier and traditional WMO identifier using the wmo\_\_wsi and wmo\_\_id global attributes respectively.
   6. Data files containing data from multiple stations shall store station identifiers according to the WMO-CF profile definitions below.
5. General regulations for variables and variable attributes
   1. A distinction is made between those variables that contain observed, measured or simulated data (hereafter data variables) and those containing metadata or ancillary information (ancillary data).
   2. Data variables
      1. Table 1 below lists the variable attributes that are defined for observed data and for use with the WMO-CF extensions.
      2. Attributes marked mandatory (M) shall be included for all variables.
      3. Attributes marked conditional (C) shall be included when the conditions described below are met.
      4. Attributes marked optional (O) are optional.
      5. Additional attributes may be defined as part of the WMO-CF Profiles listed in this volume.
      6. Other attributes not defined, either in the general regulations or in the profiles, may be used but have no meaning within the context of the WMO-CF Extensions.
      7. The standard\_name attribute shall be used when there is an existing definition in the CF conventions.
      8. The long\_name attribute should be used to describe the content of the variable.
      9. The wmo\_\_parameter\_uri and wmo\_\_parameter\_name attributes shall be used to unambiguously identify the observed/measured parameter being reported.
      10. The wmo\_\_parameter\_uri shall point to an entry in a codes registry authorized for use within the profile of the data product. The use of codes.wmo.int is authorized for all profiles; individual WMO-CF profiles may additionally define their own list of authorized registries.
      11. The units attribute shall be reported for all variables that represent dimensional quantities.
      12. When reported, the units shall be selected from those in WMO Common Code Table C-6 and represented using a string recognisable by the UDUnits package.
      13. If a variable is packed into an integer value the scale\_factor and add\_offset shall be used as defined in the NetCDF User Guide and in the CF Conventions.
      14. Variables that contain missing data shall include the \_FillValue attribute and use this to indicate the default fill value and value of missing data.
      15. Variables that contain missing data shall also include the valid\_range attribute to indicate the range of valid values expected.
      16. The valid\_range attribute shall indicate the full range of values that are valid and not just the range of values reported in the file.
      17. For observed variables where metadata or other information is available in an ancillary variable the link shall be made using the ancillary\_variables attribute.
      18. Where there is a requirement for metadata to be reported this shall be included in the profile definitions below.
   3. Ancillary data
      1. Ancillary variables contain metadata or information about one or more observed variables.
      2. Ancillary variables shall be referenced from the associated data variables with CF ancillary\_variables attributes as described in CF Section 3.4 “Ancillary Variables”.
      3. Where the ancillary variable has a physical meaning, for example observation height above a reference surface, then the rules for observed data shall also apply.
      4. For efficiency the ancillary data may be encoded using either flags or masks following the CF conventions, see example 1.
      5. When ancillary data are encoded the flag\_meanings and either flag\_values or flag\_masks shall be included in the file following the CF conventions.
      6. Where a code list or controlled vocabulary is specified in the WMO-CF profile definition then only values from that code list shall be valid for the flag\_meanings.
      7. The relevant code list or controlled vocabulary shall be indicated via the wmo\_\_parameter\_name and wmo\_\_parameter\_uri attribute, see example 1.
      8. Attributes containing Boolean values shall be encoded as either the string ‘true’ or ‘false’.
      9. No meaning or default value should be inferred by the absence of an ancillary variable.
      10. No meaning shall be inferred by data set to the missing value.
6. Global attributes
   1. Table 2 lists the global attributes defined for use with WMO CF-1.0. This includes attributes defined in other conventions, such as the Attribute Convention for Data Discovery 1-3 (ACDD 1-3) and the CF conventions, and the netCDF user guide (NUG).
   2. Attributes marked mandatory (M) shall be included for all variables.
   3. Attributes marked conditional (C) shall be included when the conditions described below are met.
   4. Attributes marked optional (O) are optional.
   5. Additional attributes may be defined as part of the WMO-CF Profiles listed in this volume.
   6. Other attributes not defined in the general regulations, the profiles or the CF conventions may be used but have no meaning within the context of the WMO-CF Extensions.
   7. The Conventions attribute shall be used to indicate the conventions followed by a dataset. Where multiple conventions are followed these shall be comma separated.
   8. The featureType attribute shall be used for files containing discrete sampling geometries to indicate the type of geometry.
   9. The standard\_name\_vocabulary attribute shall be used to indicate the version of the standard\_name table used.
   10. The following global attributes are defined as part of the WMO-CF extension and shall be included:
       1. wmo\_\_cf\_profile. The wmo\_\_cf\_profile attribute shall indicate the specific profile included within a file and shall reference one of the profiles defined within this volume.
       2. wmo\_\_originating\_centre. The wmo\_\_originating\_centre attribute shall be used to identify the originator of the files. Valid values are defined in Common Code Table C-11. Where data originate from outside of the WMO system the wmo\_\_originating\_centre attribute may be omitted.
       3. wmo\_\_originating\_sub\_centre. The wmo\_\_originating\_sub\_centre attribute shall be used to identify the originating sub centre where different from the originating centre. Valid values are defined in Common Code Table C-12. Where data originate from outside of the WMO system the wmo\_\_originating\_sub\_centre attribute may be omitted.
       4. wmo\_\_data\_category. The wmo\_\_data\_category attribute shall be included to identify the type of data contained within the file. Valid values are given in Common Code Table C-13.
       5. wmo\_\_update\_sequence\_number. The wmo\_\_update\_sequence\_number attribute shall be included and used to indicate whether the data are original or updated. The rules shall follow those defined for BUFR (zero for original messages and for messages containing only delayed reports; incremented for the other updates).
       6. wmo\_\_wsi. The wmo\_\_wsi attribute shall be used to indicate a WIGOS Station identifier of the observing station or platform to which the file relates. The wmo\_\_wsi attribute shall be omitted if the file contains data related to multiple stations, or if no WIGOS Station Identifier has been assigned.
       7. wmo\_\_id. The wmo\_\_id attribute shall be used to indicate the traditional WMO identifier of the observing station or platform to which the file relates. The wmo\_\_id attribute shall be omitted if the file contains data related to multiple stations.
7. Compression and chunking
   1. Compression, or chunking, may be used on variables within a NetCDF file.
   2. Data can furthermore be compressed or chunked using HDF filters. If this is the case however the data producer must use a method that has been agreed upon by ET-Data. In that case the filter in question would be described in this volume. The following minimum requirements shall apply:
      1. Decompression algorithm is open;
      2. Software implementing this is freely available;
      3. Filter number is registered with HDF Group to avoid name clashes.

## Tables

List of defined variable attributes for ancillary and data variables.

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute name | Description | Mandatory (M), Conditional (C) or Optional (O) | Source convention or standard |
| standard\_name | A standard name that references a description of a variable"s content in the standard name table | C - see regulations 3.d and 5.b.vii. See also profile definitions. | CF-1.8 |
| long\_name | A descriptive name that indicates a variable"s content. This name is not standardized. | O | NUG, CF-1.8 |
| wmo\_\_parameter\_uri | Link to external code registry to unambiguously identify the parameter or variable reported. This may be one from the codes.wmo.int registry or from another registry specified in the profile definitions. | M | WMO-CF 1.0 |
| wmo\_\_parameter\_name | Parameter name used to unambiguously identify the parameter or variable reported. Analogous to standard\_name. | M | WMO-CF 1.0 |
| \_FillValue | A value used to represent missing or undefined data. Allowed for auxiliary coordinate variables but not allowed for coordinate variables. | C - see regulation 5.b.xv | NUG, CF-1.8 |
| valid\_range | Smallest and largest valid values of a variable. | M | CF-1.8 |
| scale\_factor | If present for a variable, the data are to be multiplied by this factor after the data are read by an application. See also the add\_offset attribute. | O | NUG, CF-1.8 |
| add\_offset | If present for a variable, this number is to be added to the data after it is read by an application. If both scale\_factor and add\_offset attributes are present, the data are first scaled before the offset is added. | O | NUG, CF-1.8 |
| units | Units of a variable’s content. | C - see regulation 5.b.xii | NUG, CF-1.8 |
| coordinates | Identifies auxiliary coordinate variables, label variables, and alternate coordinate variables. | C - see profile definitions | CF-1.8 |
| ancillary\_variables | Identifies a variable that contains closely associated data, e.g., the measurement uncertainties of instrument data. | C - see regulation 5.b.xix | CF-1.8 |

List of defined global attributes.

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute name | Description | Mandatory (M), Conditional (C) or Optional (O) | Source convention or standard |
| Conventions | A comma-separated list of the conventions that are followed by the dataset. e.g. NUG, ACDD-1.3, CF-1.8, WMO CF-1.0 | M |  |
| date\_issued | The date on which this data (including all modifications) were formally issued (i.e., made available to a wider audience). Note that these apply just to the data, not the metadata. The ISO 8601:2004 extended date format shall be used. | M | ACDD-1.3 |
| date\_modified | The date on which the data was last modified. Note that this applies just to the data, not the metadata. The ISO 8601:2004 extended date format shall be used. | M | ACDD-1.3 |
| featureType | Specifies the type of discrete sampling geometry to which the data in the scope of this attribute belongs, and implies that all data variables in the scope of this attribute contain collections of features of that type. | C - see regulation 6.h, mandatory for discrete sampling geometries. | CF-1.8 |
| geospatial\_bounds | Describes the data’s 2D or 3D geospatial extent in OGC’s Well-Known Text (WKT) Geometry format (reference the OGC Simple Feature Access (SFA) specification). The meaning and order of values for each point’s coordinates depends on the coordinate reference system (CRS). The ACDD default is 2D geometry in the EPSG:4326 coordinate reference system. The default may be overridden with geospatial\_bounds\_crs and geospatial\_bounds\_vertical\_crs (see those attributes). EPSG:4326 coordinate values are latitude (decimal degrees\_north) and longitude (decimal degrees\_east), in that order. Longitude values in the default case are limited to the [-180, 180) range. Example: 'POLYGON 40.26 -111.29, 41.26 -111.29, 41.26 -110.29, 40.26 -110.29, 40.26 -111.2940.26 -111.29, 41.26 -111.29, 41.26 -110.29, 40.26 -110.29, 40.26 -111.29'. | C - see profile definitions | ACDD-1.3 |
| geospatial\_bounds\_crs | The coordinate reference system (CRS) of the point coordinates in the geospatial\_bounds attribute. This CRS may be 2-dimensional or 3-dimensional, but together with geospatial\_bounds\_vertical\_crs, if that attribute is supplied, must match the dimensionality, order, and meaning of point coordinate values in the geospatial\_bounds attribute. If geospatial\_bounds\_vertical\_crs is also present then this attribute must only specify a 2D CRS. EPSG CRSs are strongly recommended. If this attribute is not specified, the CRS is assumed to be EPSG:4326. Examples: 'EPSG:4979' (the 3D WGS84 CRS), 'EPSG:4047'. | C - see profile definitions | ACDD-1.3 |
| keywords | A comma-separated list of key words and/or phrases. Keywords may be common words or phrases, terms from a controlled vocabulary (GCMD is often used), or URIs for terms from a controlled vocabulary (see also "keywords\_vocabulary" attribute). | M | ACDD-1.3 |
| keywords\_vocabulary | If you are using a controlled vocabulary for the words/phrases in your "keywords" attribute, this is the unique name or identifier of the vocabulary from which keywords are taken. If more than one keyword vocabulary is used, each may be presented with a prefix and a following comma, so that keywords may optionally be prefixed with the controlled vocabulary key. Example: 'GCMD:GCMD Keywords, CF:NetCDF COARDS Climate and Forecast Standard Names'. | M | ACDD-1.3 |
| license | Options are: WMOEssential, WMOAdditional, WMOOther, NoLimitation | M | ACDD-1.3 |
| processing\_level | A textual description of the processing (or quality control) level of the data. | O | ACDD-1.3 |
| publisher\_email | The email address of the person (or other entity specified by the publisher\_type attribute) responsible for publishing the data file or product to users, with its current metadata and format. | M | ACDD-1.3 |
| publisher\_name | The name of the person (or other entity specified by the publisher\_type attribute) responsible for publishing the data file or product to users, with its current metadata and format. | M | ACDD-1.3 |
| publisher\_url | The URL of the person (or other entity specified by the publisher\_type attribute) responsible for publishing the data file or product to users, with its current metadata and format. | M | ACDD-1.3 |
| standard\_name\_vocabulary | The name and version of the controlled vocabulary from which variable standard names are taken. (Values for any standard\_name attribute must come from the CF Standard Names vocabulary for the data file or product to comply with CF.) Example: 'CF Standard Name Table v27'. | M | ACDD-1.3 |
| summary | A paragraph describing the dataset, analogous to an abstract for a paper. | O | ACDD-1.3 |
| time\_coverage\_duration | Describes the duration of the data set. The extended ISO 8601:2004 duration format shall be used. | M | ACDD-1.3 |
| time\_coverage\_end | Describes the time of the last data point in the data set. The extended ISO 8601:2004 date format shall be used. | M | ACDD-1.3 |
| time\_coverage\_resolution | Describes the targeted or typical time period between each value in the data set. The extended ISO 8601:2004 duration format shall be used. | C - see profile definition | ACDD-1.3 |
| time\_coverage\_start | Describes the time of the first data point in the data set. The extended 8601:2004 date format shall be used. | M | ACDD-1.3 |
| title | Short description of the file contents. | M | ACDD-1.3, NUG, CF-1.8 |
| wmo\_\_cf\_profile | The WMO CF profile used to represent the data contained within the file. | M | WMO CF-1.0, this volume |
| wmo\_\_data\_category | The type of data contained within the file according to Common Code Table C-13 | M | WMO CF-1.0, this volume |
| wmo\_\_originating\_centre | The originator of the data according to Common Code Table C-11. | C - see regulation 6.j.ii. | WMO CF-1.0, this volume |
| wmo\_\_originating\_sub\_centre | The originating sub centre for the data if different from the wmo\_\_originating\_centre. See common code table C-12 | C - see regulation 6.j.iii | WMO CF-1.0, this volume |
| wmo\_\_update\_sequence\_number | Indicator as to whether the data are original or updated. The rules shall follow those defined for BUFR in Volume I.2 (zero for original messages and for messages containing only delayed reports; incremented for other updates). | C - see regulation 6.j.v. | WMO CF-1.0, this volume |
| wmo\_\_id | The traditional WMO identifier for the observing station/platform. | C - see regulation 6.j.vi and 6.j.vii. | WMO CF-1.0, this volume |
| wmo\_\_wsi | The WIGOS Station Identifier (WSI) for the observing station/platform. | C - see regulation 6.j.vi and 6.j.vii. | WMO CF-1.0, this volume |

## Examples

**Example 1** Minimal example showing the use of flag values and flag meanings attribute to record the anemometer type.

int anemometer\_type( obs );  
 anemometer\_type:long\_name="type of anemometer";  
 anemometer\_type:flag\_values= 0, 1, 2, 3, 15;  
 anemometer\_type:flag\_meanings="Cup\_rotor Propeller\_rotor Sonic Wind\_observation\_through\_ambient\_noise Missing\_value";  
 anemometer\_type:wmo\_\_parameter\_name="Anemometer type";  
 anemometer\_type:wmo\_\_parameter\_uri="http://codes.wmo.int/bufr4/codeflag/\_0-02-169";

## References / links

* Brian Eaton, Jonathan Gregory, Bob Drach, Karl Taylor, Steve Hankin, Jon Blower, John Caron, Rich Signell, Phil Bentley, Greg Rappa, Heinke Höck, Alison Pamment, Martin Juckes, Martin Raspaud, Randy Horne, Timothy Whiteaker, David Blodgett, Charlie Zender, Daniel Lee, 2020: NetCDF Climate and Forecast (CF), Version 1.8. 183pp, available from <http://cfconventions.org/Data/cf-conventions/cf-conventions-1.8/cf-conventions.html>.
* <https://cfconventions.org/Data/cf-conventions/cf-conventions-1.8/cf-conventions.html>
* <https://www.unidata.ucar.edu/software/netcdf/docs/user_guide.html>
* <https://wiki.esipfed.org/Attribute_Convention_for_Data_Discovery_1-3>

# FM 301-XX WMO-CF RADIAL

## Regulations

1. Scope
   1. This profile is for the representation of weather radar and lidar data in the native instrument-centric polar coordinates. Such data is the primary output of the radar/lidar signal processor known as "Level 2" data. This is the lowest level output commonly available from operational instruments and is well suited to data exchange.
   2. The structure of this profile conforms to the WMO Information and Data Models for Radial Radar and Lidar Data. Effort has also been made to maximize compatibility with the CfRadial 2 format from which this profile has been derived
2. Overview
   1. Level 2 radar/lidar data may be conceptualized as a simple hierarchy of data objects where each object contains a collection of objects from the level below. These objects are:
      1. Volume – The top-level object for the profile. A Volume is a collection of logically associated sweeps. Typically, these sweeps will represent a continuous or near-continuous series of observations acquired by the instrument during a single cycle of the scan schedule.
      2. Sweep – Represents a subset of the data in the volume over which certain fundamental conditions remain constant. A common example is for a sweep to contain the data observed during a single 360-degree scan at a fixed elevation angle.
      3. Ray – Represents a collection of data along a single direction of pointing from the instrument.
      4. Range Bin – Represents a collection of data within a ray that are related to the same short window of range along the beam propagation path.
      5. Dataset – A measured or calculated quantity that is associated with a range bin. Each Dataset will typically represent one of the measured radar moments such as reflectivity or Doppler velocity, but may also be used to store derived information such as quality control metrics.
   2. Within a Sweep all Range Bins contain the same collection of Datasets, and all Rays contain the same collection of Range Bins. This allows the lower three levels of the hierarchy to be collapsed into a collection of 2D variables. Each variable stores a single Dataset, with dimensions for Ray and Range Bin.
   3. To facilitate the hierarchical nature of the data to be represented, NetCDF groups are used. The global scope is used to store the Volume object, a group is used for each Sweep object, and a variable within each Sweep group is used for each Dataset. Coordinate variables and ancillary variables within the Sweep groups provide metadata related to the Ray and Range Bin objects.
3. Global scope / root group
   1. The global scope of the profile contains data and metadata which are relevant to the entire volume.
   2. Attributes
      1. Table FM-301\_1 lists the global attributes that shall be included in addition to those defined under regulation 6.
      2. Table FM-301\_2 lists the mandatory values that shall be used for the global attributes where defined.
      3. Table FM-301\_3 lists additionally defined global attributes that are optional.
   3. Ancillary variables
      1. Table FM-301\_4 lists the global variables that shall be included in the global / root group.
      2. Table FM-301\_5 lists the global variables that should be included in the global / root group.
4. Sweep groups
   1. A sweep group contains all of the data and metadata related to Sweep object. This includes the dimensions and coordinates which define the basic geometry of the sweep (Rays and Range Bins), the measured radar/lidar quantities (Datasets), as well as many supporting ancillary variables. Each sweep group may also contain subgroups to cater for specialized metadata such as monitoring information.
   2. Sweep groups shall be named sweep\_<n> where <n> is the sweep number starting at 0 for the first sweep acquired during the volume and increasing sequentially in acquisition order.
   3. Dimensions
      1. The time dimension shall define the number of Rays in the sweep. It shall be used as the primary dimension for Dataset variables.
      2. The range dimension shall define the number of Range Bins in the sweep. It shall be used as the secondary dimension for Dataset variables.
      3. The frequency dimension shall define the number of operating frequencies. Where a single frequency is present this dimension shall have length 1.
      4. The prt dimension may define the number of pulse repetition times used in a pulsing scheme. This dimension is optional for fixed, staggered and dual PRT schemes but required for more complex schemes.
   4. Coordinate variables
      1. Table FM-301\_6 lists the coordinate variables that shall be used in the sweep groups.
   5. Ancillary variables
      1. Table FM-301\_7 lists the ancillary variables that shall be included in the sweep groups.
      2. Table FM-301\_8 lists the ancillary variables that may be included in the sweep groups.
   6. Dataset variables (observed and quality data)
      1. Dataset variables shall have dimensions (time, range).
      2. Dataset variables for well known radar moments shall be named according to Table FM-301\_9.
      3. The general regulations for variables (section 5) shall apply, including the regulations on mandatory and optional attributes.
      4. The coordinates attribute shall be set to "elevation azimuth range"
      5. Additional attributes for field / geophysical variables are defined in Table FM-301\_10.
   7. Monitoring subgroup
      1. If monitoring data is available, a monitoring subgroup will be included in each relevant sweep group, to store the monitoring variables.
      2. The group shall be named monitoring.
      3. Table FM-301\_11 lists the variables that may be included in this subgroup when present.
5. Radar parameters group
   1. The radar parameters group holds optional ancillary variables that are specific to the radar instrument.
   2. This group shall be located at the global scope and named radar\_parameters.
   3. Table FM-301\_12 lists the variables which may be included in this group.
   4. This group may be omitted from the file if no radar parameters are to be stored.
6. Lidar parameters group
   1. The lidar group holds optional ancillary variables that are specific to the lidar instrument.
   2. This group shall be located at the global scope and named lidar\_parameters.
   3. Table FM-301\_13 lists the variables which may be included in this group.
   4. This group may be omitted from the file if no lidar parameters are to be stored.
7. Radar calibration group
   1. The radar calibration group holds optional ancillary variables that are related to calibrations of the radar instrument. Several calibrations may be stored, typically one per pulse width.
   2. This group shall be located at the global scope and named radar\_calibration.
   3. Dimensions
      1. The calib dimension shall define the number of calibrations stored.
   4. Table FM-301\_14 lists the ancillary variables which may be included in this group.
   5. This group may be omitted from the file if no radar calibrations are to be stored.
8. Lidar calibration group
   1. The lidar calibration group holds optional ancillary variables that are related to calibrations of the lidar instrument.
   2. This group shall be located at the global scope and named lidar\_calibration.
   3. No ancillary variables have been defined for this group. It is reserved for future use.
   4. This group may be omitted from the file if no lidar calibration variables are to be stored.

## FM 301-XX Tables

Global attributes for the global scope / root group that shall be reported in addition to those defined in general regulation 6.

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Convention | Value or description |
| instrument\_name | string | CF/Radial | Name of radar or lidar |
| institution | String | CF | See CF Conventions Appendix A |
| references | String | CF | See CF Conventions Appendix A |
| source | String | CF | See CF Conventions Appendix A |
| history | String | CF | See CF Conventions Appendix A |
| comment | String | CF | See CF Conventions Appendix A |
| platform\_is\_mobile | string | Cf/Radial | "false" (mobile platforms are not supported by this profile) |

Mandatory values defined for the global attributes.

|  |  |  |
| --- | --- | --- |
| Attribute name | Type | Value |
| Conventions | string | "CF-1.8, WMO CF-1.0, ACDD-1.3" |
| wmo\_\_cf\_profile | string | "FM 301-XX" |

Global attributes defined for this profile that are conditional or optional.

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute name | Type | Convention | Value or description |
| site\_name | string | CF/Radial | Name of site where data were gathered |
| scan\_name | string | CF/Radial | Name of scan strategy used, if applicable |
| scan\_id | int | CF/Radial | Scan strategy id, if applicable. Assumed 0 if missing. |
| ray\_times\_increase | Boolean | CF/Radial | "true" or "false". Set to true if ray times increase monotonically throughout all of the sweeps in the volume. |
| simulated | Boolean | ODIM | "true" or "false". Set to true if data in this file are simulated. |

Metadata variables with global scope that shall be included in WMO-CF Radial files. Units and other attributes are defined in Table FM-301\_4b.

|  |  |  |  |
| --- | --- | --- | --- |
| variable path/name | Dimensions | Type | Comment |
| /volume\_number |  | int | Volume numbers are sequential, relative to some arbitrary start time, and may wrap. |
| /time\_coverage\_start |  | string | UTC time of first ray in file. |
| /time\_coverage\_end |  | string | UTC time of the last ray in the file. |
| /latitude |  | double | Latitude of instrument using WGS84. For a mobile platform this is the latitude of the instrument at the start of the volume |
| /longitude |  | double | Longitude of instrument using WGS84. For a mobile platform this is the longitude of the instrument at the start of the volume |
| /altitude |  | double | Altitude of instrument above mean sea level, using WGS84 and EGM2008 geoid corrections. For a scanning radar this is the center of rotation of the antenna. For a mobile platform this is the altitude at the start of the volum |
| /platform\_type |  | string | Type of platform upon which the radar system is mounted. Allowed values are listed in Table 15 |
| /instrument\_type |  | string | Type of instrument. Allowed values are listed in Table 15. |

Mandatory attributes for the global variables defined in Table FM-301\_4a.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path/name | Attribute | Type | Value |
| /time\_coverage\_\_start | units | string | "seconds since <reftime>" where <reftime> is an ISO8601 time string of the form YYYY-MM-DDThh:mm:ssZ |
|  | calendar | string | See CF Conventions Appendix A |
|  | standard\_name | string | "time" |
| /time\_coverage\_end | units | string | "seconds since <reftime>" where <reftime> is an ISO8601 time string of the form YYYY-MM-DDThh:mm:ssZ |
|  | calendar | string | See CF Conventions Appendix A |
|  | standard\_name | string | "time" |
| /latitude | units | string | "degrees\_north" |
|  | standard\_name | string | "latitude" |
| /longitude | units | string | "degrees\_east" |
|  | standard\_name | string | "longitude" |
| /altitude | units | string | "meters" |
|  | standard\_name | string | "height\_above\_reference\_elliposid" |

Metadata variables with global scope that are conditional or optional. Attributes are listed in Table FM-301\_5b.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path/name | Dimensions | Type | Comment |
| /altitude\_agl |  | double | Altitude of instrument above ground level. This is the center of rotation of the antenna |
| /primary\_axis |  | string | Principle axis of rotation. Allowed values are specified in Table 15. |
| /status\_str |  | string | General-purpose string for storing any information that is not included in other parts of the data structure. Any text-based encoding may be used including simple text, XML, JSON etc |

Attributes for those variables listed in Table FM-301\_5a.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path/name | Attribute | Type | Value |
| /altitude\_agl | units | string | "meters" |
|  | standard\_name | string | "height" |

Coordinate variables for the sweep groups. Attributes are defined in Table FM-301\_6b.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path/name | Dimensions | Type | Comment |
| /sweep\_<n>/time | (time) | double | Coordinate variable for the time dimension. Each value is the time at center of each ray |
| /sweep\_<n>/range | (range) | float | Coordinate variable for the range dimension. Each value is range along beam propagation path to the center of each range bin |
| /sweep\_<n>/frequency | (frequency) | float | List of operating frequencies in Hertz. In most cases only a single frequency is used. |

Mandatory attributes for the sweep group coordinate variables.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path/name | attribute | kind | value |
| /sweep\_<n>/time | units | string | "seconds since <reftime>" where <reftime> is an ISO8601 time string of the form YYYY-MM-DDThh:mm:ssZ |
|  | calendar | string | See CF Conventions Appendix A |
|  | standard\_name | string | "time" |
| /sweep\_<n>/range | units | string | "meters" |
|  | standard\_name | string | "projection\_range\_coordinate" |
|  | long\_name | string | "range\_to\_measurement\_volume" |
|  | axis | string | "radial\_range\_coordinate" |
|  | spacing\_is\_constant | Boolean / string | "true" if range bins are evenly spaced |
|  | meters\_to\_center\_of\_first\_gate | float | Range to start of first gate in meters |
|  | meters\_between\_gates | float | Range between consecutive gates in meters. Required if spacing\_is\_constant is true |
| /frequency | units | string | "s -1" |
|  | standard\_name | string |  |

Mandatory metadata variables that shall be included in the sweep groups. Table FM-301\_7b lists the attributes for these variables where defined.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path/name | Dimensions | Kind | Comment |
| /sweep\_<n>/sweep\_number | (range) | int | The index of the sweep within the volume, 0-based. |
| /sweep\_<n>/sweep\_mode | none | string | Type of sweep that was performed. Allowed values are listed in Table 15 |
| /sweep\_<n>/follow\_mode | none | string | Target following mode used to control antenna pointing. Allowed value are listed in Table 15 |
| /sweep\_<n>/prt\_mode | none | string | Pulsing mode used for sweep. Standard allowed values are listed in Table 15. More complicated pulsing schemes may also be represented using a sequence of "H" and "V" characters. For example "HHVVH" |
| /sweep\_<n>/fixed\_angle | none | float | Target angle for the sweep. In most sweep modes this is the elevation angle, for RHI mode this is the azimuth angle |
| /sweep\_<n>/azimuth | (time) | float | Azimuth of the antenna relative to true north at the center of dwell for each ray of the sweep. |
| /sweep\_<n>/elevation | (time) | float | Elevation of the antenna relative to true north at the center of dwell for each ray of the sweep. |

Mandatory attributes defined for the sweep group metadata variables (Table FM-301\_7a).

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path / name | attribute | kind | value |
| /sweep\_<n>/fixed\_angle | units | string | "degrees" |
| /sweep\_<n>/azimuth | units | string | "degrees" |
|  | standard\_name | string | "sensor\_to\_target\_azimuth\_angle" |
|  | long\_name | string | "Azimuth angle from true north" |
|  | axis | string | "radial\_azimuth\_coordinate" |
| /sweep\_<n>/elevation | units | string | "degrees" |
|  | standard\_name | string | "sensor\_to\_target\_elevation\_angle" |
|  | long\_name | string | "Elevation angle from horizontal plane" |
|  | axis | string | "radial\_elevation\_coordinate" |

Optional / conditional metadata variables that may be reported in the sweep groups. Attributes are define in Table FM-301\_8b.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path / name | Dimensions | Kind | Comment |
| /sweep\_<n>/polarization\_mode | none | string | Polarization mode used during sweep. Allowed values are listed in Table 15 |
| /sweep\_<n>/polarization\_sequence | (prt) | string | Polarization sequence for each PRT that is used. Only applicable if prt\_mode is "hybrid". As an example, the form of it would be ['H','H','V','V','H'] for HHVVH pulsing |
| /sweep\_<n>/rays\_are\_indexed | none | Boolean / string | Indicates whether or not the ray angles (elevation in RHI sweep mode, azimuth in other modes) are indexed to a regular grid. |
| /sweep\_<n>/rays\_angle\_resolution | none | float | If rays\_are\_indexed is true, this is the resolution of the angular grid – i.e. the delta angle between successive ray |
| /sweep\_<n>/qc\_procedures | none | string | General-purpose string for storing any information that describes the QC procedures performed on this sweep. Any text-based encoding may be used including simple text, XML, JSON etc |
| /sweep\_<n>/target\_scan\_rate | none | float | Intended scan rate for this sweep. The actual scan rate is stored in scan\_rate. This variable is optional. Omit if not available. |
| /sweep\_<n>/scan\_rate | (time) | float | Actual antenna scan rate. Set to negative if counter- clockwise in azimuth or decreasing in elevation. Positive otherwise. |
| /sweep\_<n>/antenna\_transition | (time) | byte | 1 if antenna is in transition, i.e. between sweeps, 0 if not. If transition rays are not included in the file this varible may be omitted. |
| /sweep\_<n>/pulse\_width | (time) | float | Length of transmitted pulse. |
| /sweep\_<n>/calib\_index | (time) | int | Index for the radar calibration that applies to this pulse width. The value must match one of the calibration indexes listed by /radar\_calibration/calib\_index. |
| /sweep\_<n>/rx\_range\_resolution | (time) | float | Resolution of the raw receiver samples if different to `meters\_between\_gate`s. Raw data may be resampled before data storage. |
| /sweep\_<n>/prt | (time) | float | Pulse repetition time. For staggered prt, also see prt\_ratio. |
| /sweep\_<n>/prt\_ratio | (time) | float | Ratio of prt/prt2. For dual/staggered prt mode. |
| /sweep\_<n>/prt\_sequence | (time, prt) | foat | Sequence of prts used. Optional for fixed, staggered and dual, which can make use of prt and prt\_ratio. Required for more complicated pulsing schemes. |
| /sweep\_<n>/nyquist\_velocity | (time) | float | Unambiguous velocity. This is the effective Nyquist velocity after unfolding. See also the field-specific attributes fold\_limit\_lower and fold\_limit\_upper. |
| /sweep\_<n>/unambiguous\_range | (time) | float | Unambiguous range |
| /sweep\_<n>/n\_samples | (time) | int | Maximum number of samples used to compute moments. The actual number of samples used may vary from field to field. This value refers to the maximum number of samples used for any field. The Dataset attribute sampling\_ratio is the actual number of samples used for a given field, divided by n\_samples. It will generally be 1.0, the default. |

Attributes for the optional sweep group metadata variables defined in Table FM-301\_8a

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path / name | Attribute | Kind | Value |
| /sweep\_<n>/rays\_angle\_resolution | units | string | "degrees" |
| /sweep\_<n>/target\_scan\_rate | units | string | "degrees/s" |
| /sweep\_<n>/scan\_rate | units | string | "degrees/s" |
| /sweep\_<n>/pulse\_width | units | string | "seconds" |
| /sweep\_<n>/rx\_range\_resolution | units | string | "meters" |
| /sweep\_<n>/prt | units | string | "seconds" |
| /sweep\_<n>/prt\_sequence | units | string | "seconds" |
| /sweep\_<n>/nyquist\_velocity | units | string | "meters/s" |
| /sweep\_<n>/unambiguous\_range | units | string | "meters" |

Dataset variable names, standard\_name and long\_name attributes for well known radar moments.

|  |  |  |
| --- | --- | --- |
| Variable path / name | Quantity (standard\_name) | Description (long\_name) |
| /sweep\_<n>/DBZH | radar\_equivalent\_reflectivity\_factor\_h | Equivalent reflectivity factor H |
| /sweep\_<n>/DBZV | radar\_equivalent\_reflectivity\_factor\_v | Equivalent reflectivity factor V |
| /sweep\_<n>/ZH | radar\_linear\_equivalent\_reflectivity\_factor\_h | Linear equivalent reflectivity factor H |
| /sweep\_<n>/ZV | radar\_linear\_equivalent\_reflectivity\_factor\_v | Linear equivalent reflectivity factor V |
| /sweep\_<n>/DBTH | radar\_equivalent\_reflectivity\_factor\_h | Total power H (uncorrected reflectivity) |
| /sweep\_<n>/DBTV | radar\_equivalent\_reflectivity\_factor\_v | Total power V (uncorrected reflectivity) |
| /sweep\_<n>/TH | radar\_linear\_equivalent\_reflectivity\_factor\_h | Linear total power H (uncorrected reflectivity) |
| /sweep\_<n>/TV | radar\_linear\_equivalent\_reflectivity\_factor\_v | Linear total power V (uncorrected reflectivity) |
| /sweep\_<n>/VRADH | radial\_velocity\_of\_scatterers\_away\_from\_instrument\_h | Radial velocity of scatterers away from instrument H |
| /sweep\_<n>/VRADV | radial\_velocity\_of\_scatterers\_away\_from\_instrument\_v | Radial velocity of scatterers away from instrument V |
| /sweep\_<n>/WRADH | radar\_doppler\_spectrum\_width\_h | Doppler spectrum width H |
| /sweep\_<n>/WRADV | radar\_doppler\_spectrum\_width\_v | Doppler spectrum width V |
| /sweep\_<n>/ZDR | radar\_differential\_reflectivity\_hv | Log differential reflectivity H/V |
| /sweep\_<n>/LDR | radar\_linear\_depolarization\_ratio | Log-linear depolarization ratio HV |
| /sweep\_<n>/LDRH | radar\_linear\_depolarization\_ratio\_h | Log-linear depolarization ratio H |
| /sweep\_<n>/LDRV | radar\_linear\_depolarization\_ratio\_v | Log-linear depolarization ratio V |
| /sweep\_<n>/PHIDP | radar\_differential\_phase\_hv | Differential phase HV |
| /sweep\_<n>/KDP | radar\_specific\_differential\_phase\_hv | Specific differential phase HV |
| /sweep\_<n>/PHIHX | radar\_differential\_phase\_copolar\_h\_crosspolar\_v | Cross-polar differential phase |
| /sweep\_<n>/RHOHV | radar\_correlation\_coefficient\_hv | Correlation coefficient HV |
| /sweep\_<n>/RHOHX | radar\_correlation\_coefficient\_copolar\_h\_crosspolar\_v | Co-to-cross polar correlation coefficient H |
| /sweep\_<n>/RHOVX | radar\_correlation\_coefficient\_copolar\_v\_crosspolar\_h | Co-to-cross polar correlation coefficient V |
| /sweep\_<n>/DBM | radar\_received\_signal\_power | Log power |
| /sweep\_<n>/DBMHC | radar\_received\_signal\_power\_copolar\_h | Log power co-polar H |
| /sweep\_<n>/DBMHX | radar\_received\_signal\_power\_crosspolar\_h | Log power cross-polar H |
| /sweep\_<n>/DBMVC | radar\_received\_signal\_power\_copolar\_v | Log power co-polar V |
| /sweep\_<n>/DBMVX | radar\_received\_signal\_power\_crosspolar\_v | Log power cross-polar V |
| /sweep\_<n>/SNR | radar\_signal\_to\_noise\_ratio | Signal-to-noise ratio |
| /sweep\_<n>/SNRHC | radar\_signal\_to\_noise\_ratio\_copolar\_h | Signal-to-noise ratio co-polar H |
| /sweep\_<n>/SNRHX | radar\_signal\_to\_noise\_ratio\_crosspolar\_h | Signal-to-noise ratio cross-polar H |
| /sweep\_<n>/SNRVC | radar\_signal\_to\_noise\_ratio\_copolar\_v | Signal-to-noise ratio co-polar V |
| /sweep\_<n>/SNRVX | radar\_signal\_to\_noise\_ratio\_crosspolar\_v | Signal to noise ratio cross polar V |
| /sweep\_<n>/NCP | radar\_normalized\_coherent\_power | Normalized coherent power |
| /sweep\_<n>/NCPH | radar\_normalized\_coherent\_power\_h | Normalized coherent power co-polar H |
| /sweep\_<n>/NCPV | radar\_normalized\_coherent\_power\_v | Normalized coherent power co-polar V |
| /sweep\_<n>/RR | radar\_estimated\_precipitation\_rate | Rain rate |
| /sweep\_<n>/REC | radar\_scatterer\_classification | Radar echo classification |

List of optional / conditional attributes that may be reported for Dataset variables.

|  |  |  |  |
| --- | --- | --- | --- |
| Attribute name | Type | Convention | Value or description |
| \_Undetect | same as field data | ODIM | Indicates an area (range bin) that has been radiated but has not produced a valid echo |
| sampling\_ratio | float | CF/Radial | Number of samples for this field divided by n\_samples. |
| is\_discrete | Boolean / string | CF/Radial | "true" or "false". If "true", this indicates that the field takes on discrete values, rather than floating point values. For example, if a field is used to indicate the hydrometeor type, this would be a discrete field. |
| field\_folds | Boolean / string | CF/Radial | "true" or "false". Used to indicate that a field is limited between a min and max value, and that it folds between the two extremes. This typically applies to such fields as radial velocity and PhiDP |
| fold\_limit\_lower | float | CF/Radial | If field\_folds is "true", this indicates the lower limit at which the field folds. |
| fold\_limit\_upper | float | CF/Radial | If field\_folds is "true", this indicates the upper limit at which the field folds. |
| is\_quality\_field | Boolean / string | CF/Radial | Set to "true" if this Dataset stores a quality control field. |
| flag\_values | same as field data | CF | Array of flag values. These values have special meaning, as documented in flag\_meanings. |
| flag\_meanings | string | CF | Meaning of flag\_values or flag\_masks. |
| flag\_masks | same as field data | CF | Valid bit-wise masks used in a flag field that is comprised of bit-wise combinations of mask values. See flag\_meanings. |
| qualified\_variables | string | CF/Radial | Applicable if is\_quality\_field is "true". Array list of variables that this variable qualifies. Every field variable in this list should list this variable in its ancillary\_variable attribute. |
| ancillary\_variables | string | CF | Array list of variables to which this variable is related. In particular, this is intended to list the variables that contain quality information about this field. In that case, the quality field will list this field in its qualified\_variable attribute. |
| thresholding\_xml | string | CF/Radial | Thresholding details. Supplied if thresholding has been applied to the field. |
|  |  |  | This should be in self-descriptive XML. For example: |
|  |  |  | <thresholding field="DBZ"> |
|  |  |  | <field\_used> |
|  |  |  | <name>NCP</name> |
|  |  |  | <min\_val>0.15</min\_val> |
|  |  |  | </field\_used> |
|  |  |  | <field\_used> |
|  |  |  | <name>SNR</name> |
|  |  |  | <min\_val>-3.0</min\_val> |
|  |  |  | </field\_used> |
|  |  |  | </thresholding> |

Optional / conditional variables that may be included in the monitoring subgroup when present. Attributes are defined in Table FM-301\_11b.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path / name | Dimensions | Kind | Comment |
| /sweep\_<n>/monitoring/radar\_measured\_transmit\_power\_h | (time) | float | Measured transmit power H polarization |
| /sweep\_<n>/monitoring/radar\_measured\_transmit\_power\_v | (time) | float | Measured transmit power V polarization |
| /sweep\_<n>/monitoring/radar\_measured\_sky\_noise | (time) | float | Noise measured at the receiver when connected to the antenna with no noise source connected. |
| /sweep\_<n>/monitoring/radar\_measured\_cold\_noise | (time) | float | Noise measured at the receiver when connected to the noise source, but it is not enabled. |
| /sweep\_<n>/monitoring/radar\_measured\_hot\_noise | (time) | float | Noise measured at the receiver when it is connected to the noise source and the noise source is on. |
| /sweep\_<n>/monitoring/phase\_difference\_transmit\_hv | (time) | float | Phase difference between transmitted horizontally and vertically-polarized signals as determined from the first valid range bins |
| /sweep\_<n>/monitoring/antenna\_pointing\_accuracy\_elev | (time) | float | Antenna-pointing accuracy in elevation |
| /sweep\_<n>/monitoring/antenna\_pointing\_accuracy\_az | (time) | float | Calibration offset for the horizontal channel |
| /sweep\_<n>/monitoring/calibration\_offset\_h | (time) | float | Calibration offset for the horizontal channel |
| /sweep\_<n>/monitoring/calibration\_offset\_v | (time) | float | Calibration offset for the vertical channel |
| /sweep\_<n>/monitoring/zdr\_offset | (time) | float | ZDR offset (bias) |

Attributes defined for those variables listed in Table FM-301\_11a.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path / name | Attribute | Kind | Value |
| /sweep\_<n>/monitoring/radar\_measured\_transmit\_power\_h | units | string | dBm |
| /sweep\_<n>/monitoring/radar\_measured\_transmit\_power\_v | units | string | dBm |
| /sweep\_<n>/monitoring/radar\_measured\_sky\_noise | units | string | dBm |
| /sweep\_<n>/monitoring/radar\_measured\_cold\_noise | units | string | dBm |
| /sweep\_<n>/monitoring/radar\_measured\_hot\_noise | units | string | dBm |
| /sweep\_<n>/monitoring/phase\_difference\_transmit\_hv | units | string | degrees |
| /sweep\_<n>/monitoring/antenna\_pointing\_accuracy\_elev | units | string | degrees |
| /sweep\_<n>/monitoring/antenna\_pointing\_accuracy\_az | units | string | degrees |
| /sweep\_<n>/monitoring/calibration\_offset\_h | units | string | dB |
| /sweep\_<n>/monitoring/calibration\_offset\_v | units | string | dB |
| /sweep\_<n>/monitoring/zdr\_offset | units | string | dB |

List of optional / conditional metadata variables that may be reported for the radar parameters group. Attributes are defined in Table FM-301\_12b.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path/name | Dimensions | Kind | Comment |
| /radar\_parameters/antenna\_gain\_h | none | float | Nominal antenna gain, H polarization |
| /radar\_parameters/antenna\_gain\_v | none | float | Nominal antenna gain, V polarization |
| /radar\_parameters/beam\_width\_h | none | float | Antenna beam width, H polarization |
| /radar\_parameters/beam\_width\_v | none | float | Antenna beam width, V polarization |
| /radar\_parameters/receiver\_bandwidth | none | float | Bandwidth of radar receiver |

Attributes defined for those variables listed in Table FM-301\_12a.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path / name | Attribute | Kind | Value |
| /radar\_parameters/antenna\_gain\_h | units | string | dBi |
| /radar\_parameters/antenna\_gain\_v | units | string | dBi |
| /radar\_parameters/beam\_width\_h | units | string | degrees |
| /radar\_parameters/beam\_width\_v | units | string | degrees |
| /radar\_parameters/receiver\_bandwidth | units | string | s-1 |

List of optional / conditional metadata variables that may be reported for the lidar parameters group. Attributes are defined in Table FM-301\_13b.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path/name | Dimensions | Kind | Comment |
| /lidar\_parameters/beam\_divergence | none | float | Transmit side |
| /lidar\_parameters/field\_of\_view | none | float | Receive side |
| /lidar\_parameters/aperture\_diameter | none | float |  |
| /lidar\_parameters/aperture\_efficency | none | float |  |
| /lidar\_parameters/peak\_power | none | float |  |
| /lidar\_parameters/pulse\_energy | none | float |  |

Attributes defined for those variables listed in Table FM-301\_13a.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path / name | Attribute | Kind | Value |
| /lidar\_parameters/beam\_divergence | units | string | milliradians |
| /lidar\_parameters/field\_of\_view | units | string | milliradians |
| /lidar\_parameters/aperture\_diameter | units | string | cm |
| /lidar\_parameters/aperture\_efficency | units | string | percent |
| /lidar\_parameters/peak\_power | units | string | watts |
| /lidar\_parameters/pulse\_energy | units | string | joules |

List of optional / conditional metadata variables that may be reported for the radar calibration group. Attributes are defined in Table FM-301\_14b.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path/name | Dimensions | Kind | Comment |
| /radar\_calibration/calib\_index | (calib) | byte | Calibration index for each ray |
| /radar\_calibration/time | (calib) | float | Time of calibration |
| /radar\_calibration/pulse\_width | (calib) | float | Pulse width for this calibration |
| /radar\_calibration/antenna\_gain\_h | (calib) | float | Derived antenna gain, H channel |
| /radar\_calibration/antenna\_gain\_v | (calib) | float | Derived antenna gain, V channel |
| /radar\_calibration/xmit\_power\_h | (calib) | float | Transmit powr H channel |
| /radar\_calibration/xmit\_power\_v | (calib) | float | Transmit power V channel |
| /radar\_calibration/two\_way\_waveguide\_loss\_h | (calib) | float | 2-way waveguide loss measurement plan to feed horn, H channel |
| /radar\_calibration/two\_way\_waveguide\_loss\_v | (calib) | float | 2-way waveguide loss measurement plane to feed horn, V channel |
| /radar\_calibration/two\_way\_radome\_loss\_h | (calib) | float | 2-way radome loss, H channel |
| /radar\_calibration/two\_way\_radome\_loss\_v | (calib) | float | 2-way radome loss, V channel |
| /radar\_calibration/receiver\_mismatch\_loss | (calib) | float | Receiver filter bandwidth mismatch loss |
| /radar\_calibration/receiver\_mismatch\_loss\_h | (calib) | float | Receiver filter bandwidth mismatch loss, H channel |
| /radar\_calibration/receiver\_mismatch\_loss\_v | (calib) | float | Receiver filter bandwidth mismatch loss, V channel |
| /radar\_calibration/radar\_constant\_h | (calib) | float | Radar constant, H channel |
| /radar\_calibration/radar\_constant\_v | (calib) | float | Radar constant, V channel |
| /radar\_calibration/probert\_jones\_correction | (calib) | float | Probert Jones antenna correction factor |
| /radar\_calibration/dielectric\_factor\_used | (calib) | float | The |K2| in the radar equation |
| /radar\_calibration/noise\_hc | (calib) | float | Measured noise level, H co-pol channel |
| /radar\_calibration/noise\_vc | (calib) | float | Measured noise level, V co-pol channel |
| /radar\_calibration/noise\_hx | (calib) | float | Measured noise level, H cross-pol channel |
| /radar\_calibration/noise\_vx | (calib) | float | Measured noise level, V cross-pol channel |
| /radar\_calibration/receiver\_gain\_hc | (calib) | float | Measured receiver gain, H co-pol channel |
| /radar\_calibration/receiver\_gain\_vc | (calib) | float | Measured receiver gain, V co-pol channel |
| /radar\_calibration/receiver\_gain\_hx | (calib) | float | Measured receiver gain, H cross-pol channel |
| /radar\_calibration/receiver\_gain\_vx | (calib) | float | Measured receiver gain, V cross-pol channel |
| /radar\_calibration/base\_1km\_hc | (calib) | float | Reflectivity at 1km for SNR=0dB noise corrected, H co-pol channel |
| /radar\_calibration/base\_1km\_vc | (calib) | float | Reflectivity at 1km for SNR=0dB noise corrected, V co-pol channel |
| /radar\_calibration/base\_1km\_hx | (calib) | float | Reflectivity at 1km for SNR=0dB noise corrected, H cross-pol channel |
| /radar\_calibration/base\_1km\_vx | (calib) | float | Reflectivity at 1km for SNR=0dB noise corrected, V cross-pol channel |
| /radar\_calibration/sun\_power\_hc | (calib) | float | Calibrated sun power, H co-pol channel |
| /radar\_calibration/sun\_power\_vc | (calib) | float | Calibrated sun power, V co-pol channel |
| /radar\_calibration/sun\_power\_hx | (calib) | float | Calibrated sun power, H cross-pol channel |
| /radar\_calibration/sun\_power\_vx | (calib) | float | Calibrated sun power, V cross-pol channel |
| /radar\_calibration/noise\_source\_power\_h | (calib) | float | Noise source power, H channel |
| /radar\_calibration/noise\_source\_power\_v | (calib) | float | Noise source power, V channel |
| /radar\_calibration/power\_measure\_loss\_h | (calib) | float | Power measurement loss in coax and connectors, H channel |
| /radar\_calibration/power\_measure\_loss\_v | (calib) | float | Power measurement loss in coax and connectors, V channel |
| /radar\_calibration/coupler\_forward\_loss\_h | (calib) | float | Coupler loss into waveguide, H channel |
| /radar\_calibration/coupler\_forward\_loss\_v | (calib) | float | Coupler loss into waveguide, V channel |
| /radar\_calibration/zdr\_correction | (calib) | float | corrected = measured + correction |
| /radar\_calibration/ldr\_correction\_h | (calib) | float | corrected = measured + correction |
| /radar\_calibration/ldr\_correction\_v | (calib) | float | corrected = measured + correction |
| /radar\_calibration/system\_phidp | (calib) | float | System PhiDP, as seen in drizzle close to radar |
| /radar\_calibration/test\_power\_h | (calib) | float | Calibration test power, H channel |
| /radar\_calibration/test\_power\_v | (calib) | float | Calibration test power, V channel |
| /radar\_calibration/receiver\_slope\_hc | (calib) | float | Computed receiver slope, ideally 1.0, H co-pol channel |
| /radar\_calibration/receiver\_slope\_vc | (calib) | float | Computed receiver slope, ideally 1.0, V co-pol channel |
| /radar\_calibration/receiver\_slope\_hx | (calib) | float | Computed receiver slope, ideally 1.0, H cross-pol channel |
| /radar\_calibration/receiver\_slope\_vx | (calib) | float | Computed receiver slope, ideally 1.0, V cross-pol channel |

Attributes defined for those variables listed in Table FM-301\_14a.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path / name | Attribute | Kind | Value |
| /radar\_calibration/time | units | string | "seconds since <reftime>" where <reftime> is an ISO8601 time string of the form YYYY-MM-DDThh:mm:ssZ |
| /radar\_calibration/pulse\_width | units | string | seconds |
| /radar\_calibration/antenna\_gain\_h | units | string | dB |
| /radar\_calibration/antenna\_gain\_v | units | string | dB |
| /radar\_calibration/xmit\_power\_h | units | string | dBm |
| /radar\_calibration/xmit\_power\_v | units | string | dBm |
| /radar\_calibration/two\_way\_waveguide\_loss\_h | units | string | dB |
| /radar\_calibration/two\_way\_waveguide\_loss\_v | units | string | dB |
| /radar\_calibration/two\_way\_radome\_loss\_h | units | string | dB |
| /radar\_calibration/two\_way\_radome\_loss\_v | units | string | dB |
| /radar\_calibration/receiver\_mismatch\_loss | units | string | dB |
| /radar\_calibration/receiver\_mismatch\_loss\_h | units | string | dB |
| /radar\_calibration/receiver\_mismatch\_loss\_v | units | string | dB |
| /radar\_calibration/radar\_constant\_h | units | string | m/mW dB units |
| /radar\_calibration/radar\_constant\_v | units | string | m/mW dB units |
| /radar\_calibration/probert\_jones\_correction | units | string | dB |
| /radar\_calibration/noise\_hc | units | string | dBm |
| /radar\_calibration/noise\_vc | units | string | dBm |
| /radar\_calibration/noise\_hx | units | string | dBm |
| /radar\_calibration/noise\_vx | units | string | dBm |
| /radar\_calibration/receiver\_gain\_hc | units | string | dB |
| /radar\_calibration/receiver\_gain\_vc | units | string | dB |
| /radar\_calibration/receiver\_gain\_hx | units | string | dB |
| /radar\_calibration/receiver\_gain\_vx | units | string | dB |
| /radar\_calibration/base\_1km\_hc | units | string | dBZ |
| /radar\_calibration/base\_1km\_vc | units | string | dBZ |
| /radar\_calibration/base\_1km\_hx | units | string | dBZ |
| /radar\_calibration/base\_1km\_vx | units | string | dBZ |
| /radar\_calibration/sun\_power\_hc | units | string | dBm |
| /radar\_calibration/sun\_power\_vc | units | string | dBm |
| /radar\_calibration/sun\_power\_hx | units | string | dBm |
| /radar\_calibration/sun\_power\_vx | units | string | dBm |
| /radar\_calibration/noise\_source\_power\_h | units | string | dBm |
| /radar\_calibration/noise\_source\_power\_v | units | string | dBm |
| /radar\_calibration/power\_measure\_loss\_h | units | string | dB |
| /radar\_calibration/power\_measure\_loss\_v | units | string | dB |
| /radar\_calibration/coupler\_forward\_loss\_h | units | string | dB |
| /radar\_calibration/coupler\_forward\_loss\_v | units | string | dB |
| /radar\_calibration/zdr\_correction | units | string | dB |
| /radar\_calibration/ldr\_correction\_h | units | string | dB |
| /radar\_calibration/ldr\_correction\_v | units | string | dB |
| /radar\_calibration/system\_phidp | units | string | degrees |
| /radar\_calibration/test\_power\_h | units | string | dBm |
| /radar\_calibration/test\_power\_v | units | string | dBm |

Allowed values for enumerated string variables.

|  |  |
| --- | --- |
| variable path / name | valid values |
| /platform\_type | fixed |
|  | vehicle |
|  | ship |
|  | aircraft |
|  | aircraft\_fore |
|  | aircraft\_aft |
|  | aircraft\_tail |
|  | aircraft\_belly |
|  | aircraft\_roof |
|  | aircraft\_nose |
|  | satellite\_orbit |
|  | satellite\_geostat |
| /instrument\_type | radar |
|  | lidar |
| /primary\_axis | axis\_z |
|  | axis\_y |
|  | axis\_x |
|  | axis\_z\_prime |
|  | axis\_y\_prime |
|  | axis\_x\_prime |
| /sweep\_<n>/sweep\_mode | sector |
|  | coplane |
|  | rhi |
|  | vertical\_pointing |
|  | idle |
|  | azimuth\_surveillance |
|  | elevation\_surveillance |
|  | sunscan |
|  | pointing |
|  | manual\_ppi |
|  | manual\_rhi |
|  | doppler\_beam\_swinging |
|  | complex\_trajectory |
|  | electronic\_steering |
| /sweep\_<n>/follow\_mode | none |
|  | sun |
|  | vehicle |
|  | aircraft |
|  | target |
|  | manual |
| /sweep\_<n>/prt\_mode | fixed |
|  | staggered |
|  | dual |
|  | hybrid |
| /sweep\_<n>/polarization\_mode | horizontal |
|  | vertical |
|  | hv\_alt |
|  | hv\_sim |
|  | circular |

# FM 302-XX WMO-CF MARINE TRAJECTORY

## Regulations

1. Scope
   1. This profile is intended for the reporting of meteorological and/or oceanographic observations along one or more trajectories, including both at or near the ocean surface and at depth, from a single platform. The trajectory may follow an undulating profile.
   2. A ragged array representation is used to allow multiple trajectories to be reported (e.g. see CF v1.8 conventions). This may be either a contiguous or indexed ragged array.
   3. Only data for a single platform shall be included in the file.
   4. Groups are not supported in this profile and groups other than the root group shall not be used.
2. Global scope / root group
   1. Global attributes
      1. The regulations defined in section 6 for global attributes shall apply.
      2. Table FM-302\_1 lists the values to be used for the indicate attributes.
   2. Station / platform identifier
      1. For platforms where a WIGOS station identifier has been assigned the identifier shall be included in the file using the wmo\\_\_wsi global attribute.
      2. For platforms without a WIGOS station identifier the traditional WMO identifier shall be reported using the wmo\\_\_id global attribute.
   3. Dimensions
      1. Files containing marine profile trajectory data shall have the following dimensions:
         1. obs, the obs dimension shall be used to indicate the total number of observations within the file.
         2. trajectory, the trajectory dimension shall be used to indicate the number of trajectories contained in the file and to index the observations to a trajectory. When there is a single trajectory in the file this shall have dimension 1.
   4. Coordinate Variables
      1. Table FM-302\_2 lists the coordinate variables that shall used with this profile.
      2. For platforms located at the sea surface the depth shall be given as zero.
      3. The observation locations relative to the sea surface shall then be given by the sensor installation height (/<measurand\_short\_name>\_<n>\_sensor\_installed\_height) variable. See 2.g.iv.
   5. Trajectory identification
      1. Table FM-302\_3 lists the variables that shall be used to identify the trajectory that an observation belongs to.
      2. trajectory provides the identifier for a trajectory.
      3. trajectory\_index provides the trajectory that an observation belongs to.
   6. Data variables
      1. The general regulations for data variables, including mandatory attributes, defined in regulation 5 shall apply.
      2. Only data variables with a valid standard\_name shall be included.
      3. Data variables shall have a single dimension obs.
      4. The NetCDF variable name shall be interpreted as the short name for the variable.
      5. Multiple variables sharing the same short name shall follow the following naming convention: <measurand\_short\_name>\_<n>, where <n> is incremented for each additional variable sharing the same short name. For example, salinity\_1 and salinity\_2 in the case of two salinity sensors on an observing platform.
      6. The trajectory\_index variable shall be used to indicate which trajectory an observation belongs to.
   7. Ancillary variables
      1. The naming of the ancillary variables shall take the form <measurand\_short\_name>\_<n>\_<ancillary\_variable>
      2. Table FM-302\_4 lists the mandatory ancillary variables that shall be reported for each observed / measured variable
      3. Table FM-302\_5 lists the conditional or optional ancillary variables defined for the observed / measured variables.
      4. The installed height of a sensor shall be included when the sensor is not at the same depth (or height) specified by the depth variable. In this case the sensor depth (or height) relative to the sea surface shall be given by the installed height added to the depth.

## FM 302-XX Tables

Values that shall be used for the indicated global attributes.

|  |  |  |
| --- | --- | --- |
| Attribute name | Type | Value |
| Conventions | string | "CF-1.8, WMO CF-1.0, ACDD-1.3" |
| wmo\_\_cf\_profile | string | "FM 302-XX" |
| featureType | string | "trajectory" |

Coordinate variables that shall be used in the marine trajectory profile. Attributes are given in Table FM-302\_2b.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path / name | Dimensions | Type | Comments |
| /lat | (obs) | float or double | Latitude of the observations |
| /lon | (obs) | float or double | Longitude of the observations |
| /depth | (obs) | float or double | Vertical position of the observing station or platform relative to sea level, for example glider depth. |
| /time | (obs) | float or double | Date and time of the observation |

Attributes define for the coordinate variables given in Table FM-302\_2a.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path / name | Attribute | Type | Value |
| /lat | standard\_name | string | latitude |
|  | units | string | degrees\_north |
|  | axis | string | Y |
| /lon | standard\_name | string | longitude |
|  | units | string | degrees\_east |
|  | axis | string | X |
| /depth | standard\_name | string | depth |
|  | units | string | meters |
|  | axis | string | Z |
|  | positive | string | down |
|  | long\_name | string | depth\_below\_sea\_level |
| /time | standard\_name | string | time |
|  | units | string | "seconds since <reftime>" where <reftime> is an ISO8601 time string of the form YYYY-MM-DDThh:mm:ssZ |
|  | axis | string | T |
|  | calendar | string | standard |

Variables defined to identify the trajectory an observation belongs to and that shall be included in marine trajectory files. Attributes are listed in Table FM-302\_3b.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path / name | Dimensions | Type | Comments |
| /trajectory | (trajectory) | string | Identifier for trajectory |
| /trajectory\_index | (obs) | int | Index of the trajectory an observation belongs to. |

Attributes define for the trajectory variables listed in Table FM-302\_3a.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path / name | Attribute | Type | Value |
| /trajectory | cf\_role | string | trajectory\_id |
| /trajectory\_index | long\_name | string | Index of the trajectory that this observation belongs to |
|  | instance\_dimension | string | trajectory |

Ancillary variables defined and that shall be reported for each measured / observed variable. Attributes are given in Table FM-302\_4b. <prefix> has been used to represent <measurand\_short\_name>\_<n>.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path / name | Dimensions | Type | Comments |
| /<prefix>\_sensor | (trajectory) | string | Name of sensor |
| /<prefix>\_sensor\_make | (trajectory) | string | Manufacturer of sensor |
| /<prefix>\_sensor\_model | (trajectory) | string | Model of sensor |
| /<prefix>\_sensor\_serial\_number | (trajectory) | string | Sensor serial number |
| /<prefix>\_sensor\_calibration\_date | (trajectory) | float | Last calibration data of sensor |

Attributes for the ancillary variables defined in Table FM-302\_4a .<prefix> has been used to represent <measurand\_short\_name>\_<n>.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path / name | Attribute | Type | Value |
| /<prefix>\_sensor\_calibration\_date | standard\_name | string | time |
|  | units | string | "seconds since <reftime>" where <reftime> is an ISO8601 time string of the form YYYY-MM-DDThh:mm:ssZ |
|  | axis | string | T |
|  | calendar | string | standard |

Conditional / optional ancillary variables defined and that should be reported for each measured / observed variable when the described conditions are met. Attributes are given in Table FM-302\_5b. <prefix> has been used to represent <measurand\_short\_name>\_<n>.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path / name | Dimensions | Type | Comments |
| /<prefix>\_sensor\_installed\_height | (trajectory) | float | Value to be added to sensor\_depth to get vertical position of sensor relative to sea surface. |
| </prefix>\_sensor\_measurement\_method | (trajectory) | string | The method used by the sensor to measure the parameter, e.g. capacitive humidity sensor. |

Attributes for the ancillary variables defined in Table FM-302\_5a. <prefix> has been used to represent <measurand\_short\_name>\_<n>.

|  |  |  |  |
| --- | --- | --- | --- |
| Variable path / name | Attribute | Type | Value |
| /<prefix>\_sensor\_installed\_height | units | string | meters |
| </prefix>\_sensor\_measurement\_method | wmo\_\_parameter\_name | string |  |
|  | wmo\_\_parameter\_uri | string |  |