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| **World Meteorological Organization**  **Commission for Instruments and Methods of Observations**  **Inter-Programme Expert Team on Operational Weather Radars** Seoul, Republic of Korea, 14–17 May 2018 | **CIMO/IPET-OWR-2/Doc. 5.1(7)** |
| Submitted by: Mr Mark Curtis  2018-05-02  **Version 1** |

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Standard Weather Radar Data Representation

### SUMMARY

This document provides information on the proposed standard for representation of weather radar data. The creation of this standard is the first action of Task 4 (Weather radar data exchange) in the IPET-OWR work plan. As part of this action three documents have been produced: an information model, a data model, and a file format specification. A forth document, guidance material on use of the exchange format, is under development as the third action of Task 4. The status of each document is outlined and outstanding issues requiring resolution are identified.

### REFERENCES:

1. [WMO Information Model for Radial Radar and Lidar Data, Version 1.3](https://my.alfresco.com/share/s/P20UfemUTMGbyxxkMERyzw)
2. [WMO Data Model for Radial Radar and Lidar Data, Version 1.0](https://my.alfresco.com/share/s/x05jRLn0TwmzcSm2eIAX2A)
3. [CfRadial Data File Format, Version 2.0 (2018-04-30 draft)](https://my.alfresco.com/share/s/socaU3bgQ2qneCr-OPKd2g)
4. [Proposal for radar/lidar specific additions to the standard names table of the NetCDF Climate and Forecast (CF) Metadata Conventions](https://my.alfresco.com/share/s/TIndKULIQ8y5lom3t38aGA)
5. [CfRadial Data File Format, Version 1.3](https://ral.ucar.edu/projects/titan/docs/radial_formats/CfRadialDoc.pdf)
6. [EUMETNET OPERA weather radar information model for implementation with the HDF5 file format, Version 2.2](http://eumetnet.eu/wp-content/uploads/2017/01/OPERA_hdf_description_2014.pdf)

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# 1. BACKGROUND INFORMATION

An important step in supporting the international exchange of weather radar data is the development of a standardized data representation. This work began under the WMO Task Team on Weather Radar Data Exchange (TT-WRDE) with the development of a draft Information Model that identified the data and metadata which is useful for international exchange. The work has been continued by IPET-OWR with the finalization of the Information Model and the creation of a Data Model and File Format.

The term 'weather radar data' encompasses a large range of datasets produced at different levels of processing within the weather radar system. Four basic levels are identified:

* Level 0: Electronic signals passed among the components of the instrument hardware.
* Level 1: Time-series or 'I/Q' (in-phase and quadrature) data which are produced by the instrument's signal processor.
* Level 2: Data derived from Level 1 which is organized in native polar coordinates by rays, bins and quantities. Examples include reflectivity and Doppler velocity.
* Level 3: Higher order products derived from Level 2 and typically not in the native polar coordinates. Examples include vertical profiles, Cartesian grids, and vector products.

Of these levels, only Level 2 (polar data) is addressed by the standardized data representation that has been developed. A standard representation of Level 1 data may be useful; however international exchange of Level 1 data is not considered relevant at this time. Level 3 data is considered too far removed from the raw observations for many purposes, and many Level 3 products already have standardized representations.

The standardized representation has been developed as three separate documents; an Information Model (IM), a Data Model (DM), and a File Format. This arrangement cleanly separates the abstract model of the radar data itself (IM), from the access usage patterns (DM), and the concrete storage model of the implementing file format.

A fourth document is also under development which provides guidance to WMO members on the use of the standardized representation for the purpose of international data exchange.

## Information Model (Task 4, Deliverable 1a)

The Information Model (IM) specifies how weather radar data should be represented at the conceptual level. It specifies the various data types and structures that comprise the radar data in the native polar coordinate space. Metadata associated with each fundamental data type is identified, along with appropriate units and minimum required numerical precision.

The data types specified by the IM form a simple hierarchy with the top level object being a volume which represents a collection of logically associated radar data. For example, a volume may comprise of all Level 2 data produced during a single cycle of the radar schedule. Each volume contains a collection of sweeps, and a sweep is made up of several datasets that share a common geometry based on the number of rays and range bins used. Each of the volume, sweep, dataset, ray and bin object types has a set of associated metadata.

A sweep object is not limited to the representation of a traditional horizontally swept scan at a fixed elevation angle (PPI). Instead, a sweep may represent any continuously swept arc of observations for which certain conditions (e.g. transmit frequency, ray geometry) remain constant. This allows the IM to support traditional scan products used operationally such as PPIs and RHIs as well as more exotic scanning strategies that may be useful in the research context.

Two types of datasets are defined by the IM. These are scalar datasets and spectrum datasets. The scalar dataset type is used to represent the most common Level 2 quantities such as reflectivity and Doppler velocity. The spectrum dataset type is used to represent a vector of values at each range bin such as the power spectrum for the co-polar horizontal signal.

The IM document is now complete. A review of the document has been undertaken to ensure that all metadata widely relevant for international exchange purposes has been included.

## Data Model (Task 4, Deliverable 1b)

The Data Model (DM) elaborates on the IM to address the issue of how users should view and interact with the various objects. This includes detail such as the encoding of individual types (IEEE-754 floating point values, UTF-8 strings etc.), quantization and packing of datasets for efficient storage, and standard names for common dataset quantities.

All of the requirements specified by the DM relate to the user's interaction with the data. This is typically achieved through an Application Programming Interface (API). Provided that the DM requirements are met, file formats have complete freedom with regard to the physical representation of the data. For example, a file format may internally compress datasets to reduce the file size. Such a format is still conforming to the DM provided that the dataset can be accessed by the user through an API in the DM specified encoding. In this way, the DM can be considered as requirements on a data interface API.

Further to the user requirements the DM clarifies several freedoms that are available to implementing files formats. These explicitly allow optimizations which may be important for achieving an appropriate balance of complexity, efficiency and performance in the format. Storage efficiency and runtime performance are important considerations for operational weather radar data applications.

The DM document is now complete. All quantities identified by the IM are assigned canonical names which are based on the labels used by ODIM\_H5.

## File Format Representation (Task 4, Deliverable 1c)

The activities of TT-WRDE identified two open file formats for weather radar data representation with large international user bases. These are the OPERA Data Information Model for HDF5 (ODIM\_H5) and the CfRadial extensions to the NetCDF Climate and Forecast (CF) Metadata Conventions. ODIM\_H5 has significant operational use within Europe and Australia, while CfRadial supports research within North America, Europe and elsewhere.

An analysis of the two formats revealed that they have complementary strengths and weaknesses. ODIM\_H5 is hierarchically structured allowing data to be stored in a simple and flexible layout, however its approach to metadata is poorly standardized and only partially self-describing. CfRadial on the other hand excels at the consistent representation of metadata and is fully self-describing, which is an important feature for research and climate applications. CfRadial lacks hierarchal structure however since all data is stored in flat arrays. This makes it unsuitable or difficult to use for many operational applications.

The decision was made to converge the two standards to exploit the strengths of each in a new file format. CfRadial was used as the basis of the new standard since it was considered less effort to add the necessary structure to CfRadial than it was to standardize the approach to metadata within ODIM\_H5. Retaining the link to CF also allows the format to benefit from the established governance and practices related to adoption of new data and metadata types.

During the intra-session period since IPET-OWR-1 the new CfRadial 2.0 standard has been produced with input from both IPET-OWR members and the original CfRadial authors. The described file format is consistent with the IM and DM. This format is now functionally complete and is undergoing revision based on feedback from CfRadial 1.0 users and the larger CF community.

CF maintains a list of standard names for well-known quantities that includes their descriptions and canonical units (<http://cfconventions.org/standard-names.html>). It is important that the radar/lidar centric quantities identified in CfRadial 2.0 are also reflected in the CF standard names table. A proposal to add these standard names has been created and will be submitted to the CF Standard Names Committee for consideration.

In addition to the standard quantity names, CF also defines a list of standard grid mappings to support data on non-geodetic grids. These grid mappings primarily support Cartesian map projections (e.g. Mercator), however also provide some instrument centric projections (e.g. geostationary satellites). A proposal to add a new radar/lidar centric grid mapping has been created and will be submitted to the CF Conventions Committee for consideration. The proposal references the common 4/3 earth model for radar beam propagation.

### Guidance Material on Use of Exchange Format (Task 4, Deliverable 3)

The weather radar data representation specified by the IM, DM and file format provides a large amount of flexibility with regard to the scan geometry, data types and metadata which are stored. This allows the representation to support a wide range of technologies and users in operational and research contexts. Flexibility in the representation is critical if widespread adoption is to be achieved.

For the purposes of international data exchange, it is helpful to restrict some flexibility as a way of promoting consistency between data feeds. This in turn minimizes the effort required to utilize exchanged data in downstream applications. Guidance material on the use of CfRadial 2.0 will be produced which specifies how the file format should be utilized when the data is intended for international exchange.

The guidance material will specify:

* Mandatory use of canonical variable names for common radar quantities. CfRadial specifies a 'standard name' attribute in the metadata of each dataset, but does not restrict the dataset name itself (i.e. the NetCDF variable name). The guidance will require that the quantity names provided in the DM be used as the dataset names for exchange purposes.
* Expanded set of mandatory metadata. The IM specifies a minimal set of mandatory metadata which are needed to identify the data and specify the basic scan geometry. The set of mandatory metadata will be expanded to include a set of metadata which are universally applicable to applications that use radar data.
* Recommendations on which quantities, or sets of quantities, should be made available for exchange. This will include separate profiles for basic reflectivity, Doppler and Dual-Polarization radars.
* Recommendations on the use of compression and other encoding options which may have an impact on data size or read/write performance which are important in a data exchange context.

An early draft of the guidance material has been produced which provides a direct mapping between metadata attributes identified in the IM and their names in the CfRadial 2.0 format. Work on the guidance material is an ongoing task and due for completion in June 2018.

## Related Activities and WMO Engagement

A netCDF-CF workshop will be held in June 2018, Reading, UK. This meeting will continue steering work on the CF Metadata Conventions of which CfRadial is an extension. Prior engagement with the community has indicated that functional extensions introduced by CfRadial 2.0 are consistent with the approach and intended future direction of CF. It will be important to monitor the output of this workshop and update CfRadial 2.0 as needed to maintain ensure consistency with the parent CF conventions is maintained.

In February 2018 the tenth session of the Implementation-Coordination Team on Integrated Observing Systems (ICT-IOS-10) was held. ICT-IOS is the team responsible for implementation of WIGOS (WMO Integrated Global Observing System). IPET-OWR's work on the development of a standardized weather radar data representation was presented to the meeting and well received.

Action 5 of Task 4 in the IPET-OWR work plan calls for engagement with CBS OPAG-ISS for validation, approval and maintenance of the representation. The goal of this action is to identify and commence the process necessary for inclusion of the standardized weather radar data representation in the WMO Manual on Codes. Several IPET-OWR members who are well placed to engage with OPAG-ISS have been asked to begin this work.

# 2. ISSUES TO BE DISCUSSED

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| **Issue #1.0.0** | **Dependency on Climate and Forecast (CF) Metadata Conventions** | | |
| **Background** | The CfRadial 1.0 file format was developed as an extension to the CF Metadata Conventions 1.5. This version of CF does not support the use of NetCDF groups which can be used to introduce hierarchical structure.  The CfRadial 2.0 file format was developed in anticipation of CF 2.0 which is expected to support the use of NetCDF groups. The development status of CF 2.0 is unknown. IPET-OWR must decide how to proceed with CfRadial 2.0 in the absence of an official CF 2.0. | | |
| **Rationale for the proposed decision/action or recommendation** |  | | |
| **Proposed decision(s)/action(s)** | *What* | *By whom* | *Deadline* |
| Seek clarification of status of CF 2.0 |  |  |
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| **Proposed recommendation(s) to** | *What* | *To whom (e.g. CIMO, EC-70, Cg-18, …)* | *Time frame* |
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