WMO Information Model for Radial Radar and Lidar Data

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1 Introduction

This document describes an information model for the representation of weather radar and scanning lidar data, metadata, and products. While effort has been made to be general, the weather-radar technology in question is assumed to be that commonly used in real-time operations throughout the world: scanning X, C, and S-band systems. Radar and lidar together in this context are referred to here as Pulsed Polar Systems (PPS). Emphasis is placed on comprehensive information representation in the instruments' native polar coordinate system. The representation of data quality is also of central importance. Cartesian surfaces, and other geometries to which radar/lidar information may be derived are not addressed here.

This information model is independent of any data model or file format by which an implementation of the conveyed information may be achieved. Instead, the objective is for this information model to act as common ground for such practical implementation, thereby ensuring that data files are as complete as possible, while also facilitating interoperability among file formats by ensuring that the same information is represented irrespective of file format.

1.1 Types of data relative to how they have been processed

The following definitions are used to distinguish between different data Types. The delineation is based on the extent to which data have been processed. While the information model in this document addresses and specifies data in native polar coordinates, the Types given here identify data that have been processed both before and after this Type. The objective is to define the data Types to facilitate understanding of that which is specified in this document. Each data Type's relevance in terms of international data exchange is also given.

Type 0

The information is in the form of voltages inside, and passed among, the electronic components of the instrument hardware. Special recording equipment is required to measure and record such data. International exchange of such information is not considered relevant.

Type 1

Such data are also known as "time series" and in-phase and quadrature "I/Q" data that are processed and produced by the instrument's signal processor. These are commonly digitized, and it is becoming easier to record such data. A standardized representation may be considered useful, although international exchange may not be relevant for the foreseeable future.

Type 2

The information has been processed from Type 1 and are organised in native polar coordinates by rays, bins, and quantities. Such data are highly relevant for international exchange, and they are the subject of the information model presented in this document.

Type 3

The information has been processed from Type 2 data to derive higher-order products from a single site, or data that have been consolidated from several sites into a single product. Such products may be one-dimensional vertical profiles, transformed to Cartesian space, vectors, or other representation.

Each of the above data Types can be potentially divided into sub-types, but this is not attempted here.

2 Object Model

This section introduces the core object types which are described by the information model. The primary data content of each object type is described, along with its relationship to other object types. Individual instances of each of the object types may be further described through the use of object metadata. Standard metadata for each of the object types is listed in Section 3, however a user of the information model is free to associate additional user-defined metadata with any object.

The common use of the term “scan” is ambiguous. It can be used to mean alternatively an entire volume of radar sweeps, or a single sweep at a single elevation angle. For this reason, use of the term “scan” is avoided by this document in favour of the unambiguous terms “volume” and “sweep”.

2.1 Overview

The object model is implemented as a simple hierarchy of types. The type at each level of the hierarchy is strictly a collection of the type(s) at the next lower level. An example of this arrangement is illustrated in Figure 1.

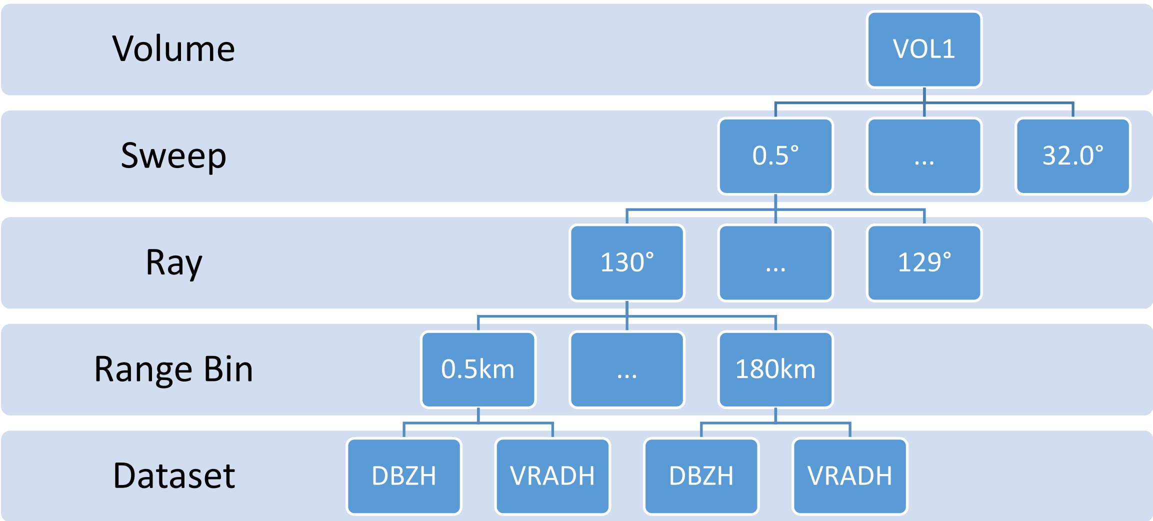

Figure 1. Object Model Hierarchy. Horizontal sweep-based example shown.

This nested arrangement of object types provides a conceptually simple, yet highly flexible scheme for the organisation of PPS data. The model is able to serve the needs of both common operational and highly specialised research scanning strategies. Figure 2, Figure 3 and Figure 4 show how the model may be used to represent standard operational PPI[1], RHI [2] and vertically pointing scan strategies respectively.

[1] Plan Position Indicator. It represents a complete 0-360° sweep of data. In this document, the PPI is always preserved in polar coordinates.
[2] Range-Height Indicator.

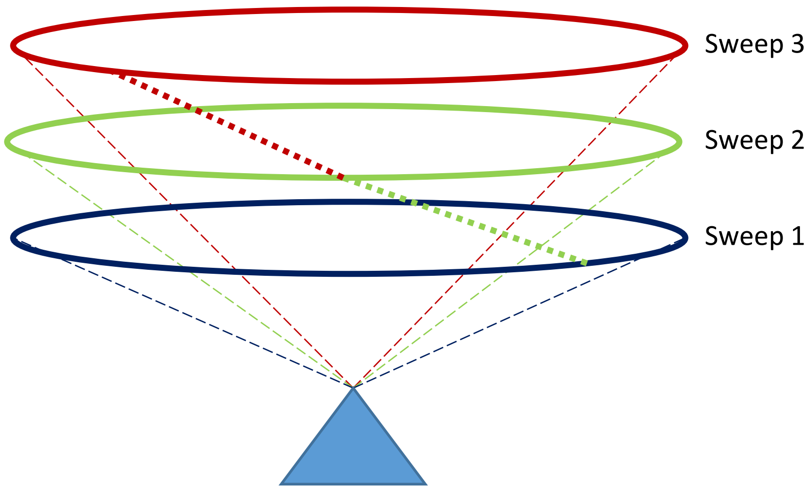

Figure 2. Horizontal sweep-based volume. One sweep per elevation angle. Heavy dotted lines represent rays recorded while antenna is in transition to target elevation angle for each sweep. Such transition rays are not normally exchanged, but are useful to represent in a scientific context.

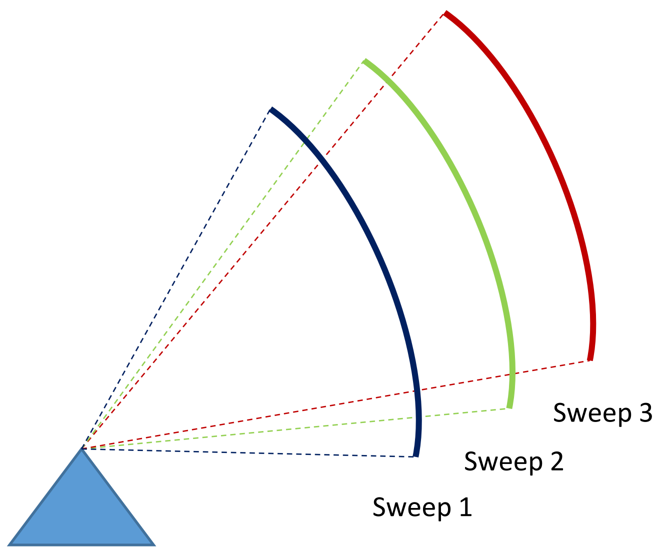

Figure 3. RHI based volume. One sweep per azimuth angle.

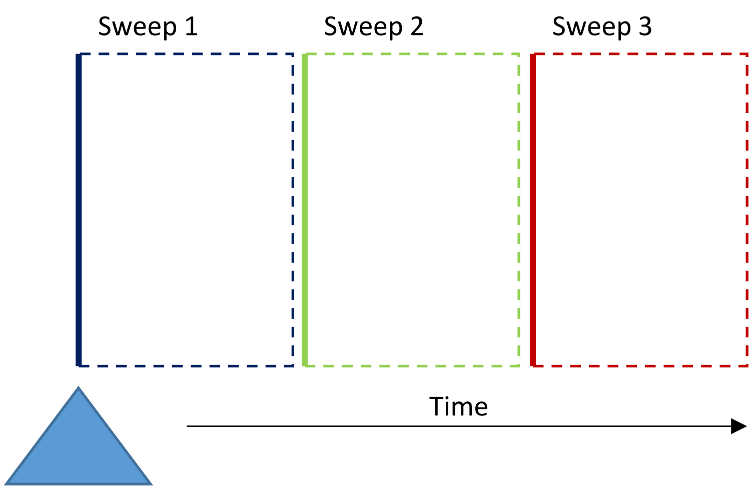

Figure 4. Vertical Pointing based volume. Volume divided into sweeps by time windows.

2.1.1 Object storage model

The object model introduced by Figure 1 provides a clear hierarchy of PPS data which outlines the conceptual relationships of the data types involved. When PPS data must be practically stored and exchanged, generally accepted practice is to group ray and range bin data together on a per-dataset basis so that the ray and range bin objects are implied rather than explicitly represented. This allows for efficient storage of each dataset as a simple two-dimensional array. As such, implementations of this information model are expected to store PPS data according to the refined model illustrated in Figure 5.

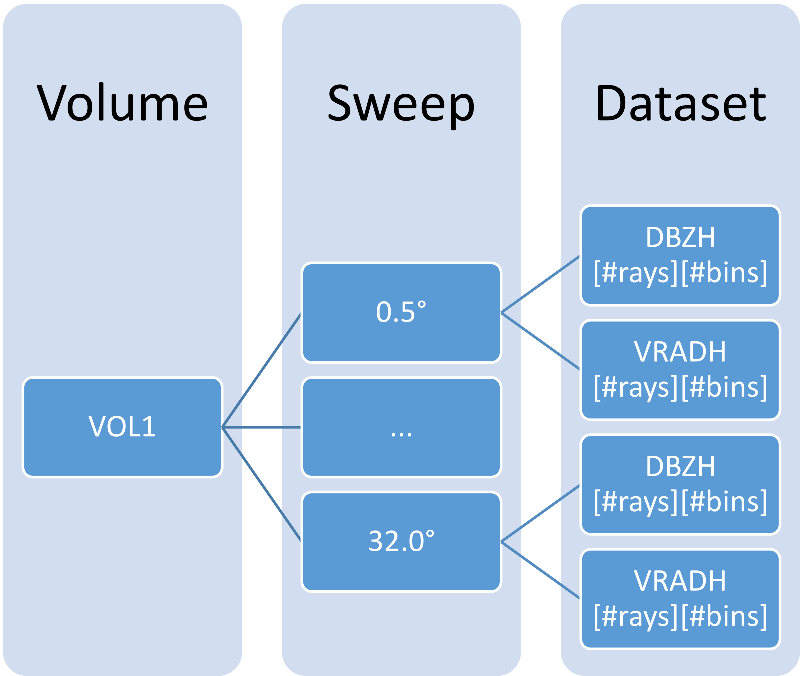

Figure 5. Object model hierarchy as refined for efficient storage. Horizontal sweep-based example shown.

The structure of the refined object model imposes some homogeneity restrictions on the ray, range bin and dataset objects:

- Metadata for the implied ray and range bin objects must be stored at the sweep level.
- The number of range bins must be uniform for each ray in a sweep.
- Metadata applied to a range bin must apply to the same range bin (by index) of every ray in the sweep.
- Metadata applied to a dataset must apply to all rays and range bins in the sweep.
- Each dataset must supply a value for every ray/range bin in the sweep. Should a dataset not be available for a particular ray/range bin, then a special value indicating missing data must be stored.

2.2 Volume Object

A volume is the top-level object represented by the information model. A volume represents a collection of logically associated PPS data. Typically, although not necessarily, these data will represent a continuous or near-continuous series of observations acquired from the instrument. Often, volumes of a similar structure will be produced at fixed intervals to fulfil operational needs.

2.3 Sweep Object

The PPS data which comprises a volume are divided into a number of logical groups called sweeps. A single sweep represents a subset of data in the volume over which certain fundamental conditions such as frequency, pulse width and commanded fixed angle remain constant. For a full list of conditions which must remain constant for the duration of a sweep refer to Section 0.

Typical examples of sweeps include the PPI and RHI where either the elevation or azimuth angle is fixed while the other varies. Vertically pointing instruments, or scan strategies where both the elevation and azimuth angle change continuously could be represented by breaking the volume into sweeps based on time – i.e. containing all of the rays in a given time interval. In such a case a volume may only contain a single sweep.

Independently of the volume, a horizontal sweep scanning less than 360° represents a sector.

2.4 Ray Object

The ray represents a collection of data which are considered to be at a single elevation and azimuth angle from the instrument. The propagation of the radiated pulses and reflections through time allows the time of observation to be related to a distance from the instrument along the propagation path. This allows a ray to be considered as a collection of data over distance (rather than over time).

2.5 Range Bin Object

The subset of data within a ray which are considered to be representative of the same short observation time window are known as a range bin, or bin. The fact that the data are representative for a time window means that they are also representative for a continuous span of distance, known as slant range, along the ray.

Range bins within a ray may be of varying lengths; however the pattern of bin lengths must always be consistent within a sweep. This implies that the structure (length and number of range bins, as well as contained datasets) of each ray in a single sweep must be identical. This restriction is imposed to allow for efficient representation of sweep objects within implementing data models and file formats as simple two-dimensional arrays.

2.6 Dataset Object

A single range bin may contain any number of datasets which represent various quantities associated with that bin. The quantities may be values observed by the instrument, values inferred by signal processing, or even quality control or analytical metrics added by downstream systems. Section 0 enumerates commonly used dataset quantities; however, a user of the information model is free to define any number of custom dataset quantities provided they are not exchanged internationally.

The number and type of datasets available for a bin must always be consistent within a sweep. This restriction is imposed to allow for efficient representation of sweep objects within implementing data models and file formats as simple two dimensional arrays.

Two subclasses of dataset object are supported by the information model. Each dataset will either be a scalar, or spectrum dataset.

2.6.1 Scalar dataset

A scalar dataset is one for which a single numerical value is stored per range bin. This is the most common type of dataset and is used to represent both standard observed moments (e.g. reflectivity, Doppler velocity, spectral width) and quality control metrics (e.g. percent beam blockage by topography).

2.6.2 Spectrum dataset

A spectrum dataset is one for which a vector of numerical values, representing a spectrum, is stored per range bin. This type of dataset is infrequently used within operational networks; however, they are more common within research and scientific contexts, and specifically with some vertically-pointing radars.

3 Standard Metadata

This section describes the metadata which may be associated with each of the objects detailed in section 2.

3.1 Overview

3.1.1 Mandatory metadata

The level of metadata available from a PPS varies greatly by system and operator. This information model therefore imposes very few requirements on which metadata must be made available. Only metadata which is absolutely necessary for accurate time referencing and geographic referencing of the data is considered mandatory. For the sake of completeness, however, providing as much additional metadata as possible is highly recommended as they are inevitably useful in supporting science.

Mandatory metadata is indicated in the tables of this section using shaded background.

3.1.2 Fundamental types

All metadata applied to an object must be either a whole number, a real (floating-point) number, a Boolean, or a character string. In this document, these are referred to as "integer", "real", "Boolean", and "string" respectively. An "enum" is a special constant integer value used for identification purposes. The depth (number of bits or bytes) of the numerical types is not specified, nor is the character encoding of strings. Such determinations are the responsibility of the implementing data model and file format representation. Rather, the information model specifies the minimum precision with which certain metadata must be stored. Implementers are free to store metadata at a precision which exceeds the stated minimum.

It is also possible for metadata to consist of an array of any of the fundamental types. In such situations the type for the metadata will list the fundamental type name followed by '[n]'.

3.1.3 Unit conventions

3.1.3.1 Geographic coordinates

Longitude and latitude coordinates shall be expressed in decimal-degree format with positive longitudes towards the east and positive latitudes towards north. Heights shall be expressed in metres above mean sea level.

3.1.3.2 Polar coordinate system angles

Azimuthal angles shall be expressed as clockwise from true north (0°). Elevation angles shall be expressed as positive above the horizontal plane (0°).

3.1.3.3 Times

Several different methods of defining and representing a point in time are relevant for use with PPS data. Time-based metadata shall be specified according to the following two classifications:

- **Absolute** or **relative** time. An absolute time is a time point defined according to an external time standard (such as UTC). A relative time is defined as an offset from a known absolute time.
- **Low-precision** or **high-precision** time. A low-precision time must be represented with precision of at least seconds. A high-precision time must be represented with a precision of at least nanoseconds.

For example, the time associated with a volume start may be specified as a low-precision absolute time. A conforming implementation could store this time as an ISO 8601 string representing the UTC time of the product (e.g.: “2016-07-26T09:00:00Z”).

Conversely, the data acquisition time associated with a ray may be specified as a high-precision time relative to the volume start time. A conforming implementation could store this time as a real representing the number of nanoseconds offset from the volume start time.

3.1.4 User-defined metadata

Users of the information model are free to apply custom metadata to any information model object provided that the metadata does not already have a standard representation listed in this document.

3.1.5 Application restrictions

The following conditions are imposed on the application of metadata to information model objects:

- Standard metadata listed in this section must be associated only with the object type under which they are listed. It is not permissible, for example, to apply metadata for a sweep to individual range bins. This implies that metadata for an object is constant throughout that object and applicable to all contained objects. Should it be necessary to break this condition, the PPS data should be split into several sweeps and/or volumes.
- Metadata applied to a range bin applies to the same ordinal range bin in every ray of the containing sweep.
- Metadata applied to a dataset applies to every range bin in every ray of the containing sweep.

These restrictions are imposed to allow for efficient representation of sweep objects within implementing data models and file formats as simple two-dimensional arrays.

3.2 Volume Object Metadata

3.2.1 Product information

Table 1. Product information.

ID	Description	Type	Unit	Precision
	Instrument type, distinguishing between “radar” and “lidar”	string	-	-
	Site identifier, e.g. WIGOS identifier (see below)	string	-	-
	Volume start time	time	absolute	low
	Volume end time	time	absolute	low
	Scan strategy name	string	-	-
	Instrument identifier (e.g. WSR-88D)	string	-	-
	Whether instrument has malfunctioned	Boolean	-	-
	Instrument error message	string	-	-
	Whether acquired data are simulated	Boolean	-	-

The WIGOS identifier[3] structure consists of four parts. The part of the structure called “Local identifier” is the only part consisting of characters. Following the ODIM convention (Michelson et al., 2014), it is suggested as a best practice, but not required, that the local identifier be harmonized

[3] http://wis.wmo.int/page=WIGOS-Identifiers

to a five-character string, where the first two characters are the member country's ISO 3166-1 alpha 2 ccTLD[4] code (lower case), and the latter three characters are freely-selectable (also lower case).

3.2.2 Geographical reference information

For moving platforms, the metadata in this section relate to the position of the instrument at the start of data acquisition, which applies to the first ray of the volume.

Table 2. Geographical reference information.

ID	Description	Type	Unit	Precision
	Site longitude	real	degrees	0.000001
	Site latitude	real	degrees	0.000001
	Site altitude above geodetic datum. For a scanning instrument this is the center of rotation of the antenna.	real	m	1
	Site altitude above ground level	real	m	0.1
	Geodetic datum name	string	-	-
	Magnetic declination at site, positive clockwise	real	degrees	0.001
	Whether platform is moving	Boolean	-	-

3.2.3 Radar characteristics

The metadata in this section only apply to instrument type 'radar'.

Table 3. Radar characteristics.

ID	Description	Type	Unit	Precision
	Nominal antenna gain H	real	dBi	0.01
	Nominal antenna gain V	real	dBi	0.01
	Antenna beam width H	real	degrees	0.01
	Antenna beam width V	real	degrees	0.01
	Bandwidth of radar receiver	real	s^{-1}	
	Frequency	real	Hz	1 000 000

3.2.4 Lidar characteristics

The metadata in this section only apply to instrument type 'lidar'.

Table 4. Lidar characteristics.

ID	Description	Type	Unit	Precision
	Beam divergence (transmit side)	real	milliradians	
	Field of view (receive side)	real	milliradians	
	Aperture diameter	real	cm	
	Aperture efficiency	real	percent	
	Peak power	real	watts	
	Pulse energy	real	joules	

3.3 Sweep Object Metadata

3.3.1 Sweep characteristics

Table 5. Sweep characteristics.

ID	Description	Type	Unit	Precision

[4] http://www.iso.org/iso/country_codes

	Sweep mode, ie. Plan Position Indicator (PPI), Range-Height Indicator (RHI), Vertical, and Sun scan. Other specialized sweep modes are permitted.	enum	-	-
	Target fixed angle (elevation angle for PPI mode, azimuth angle for RHI mode)	real	degrees	0.01
	Target scan rate	real	degrees/s	0.001
	Polarization mode, ie. Horizontal, Vertical, Horizontal-vertical alternating, Horizontal-vertical simultaneous, and Circular. Other specialized polarization modes are permitted.	enum	-	-
	PRT mode, ie. Fixed, Staggered, and Dual. Other specialized PRT modes are permitted.	enum	-	-

3.3.2 Radar calibration

The metadata in this section only apply to instrument type 'radar'. A separate set of radar calibration metadata may be supplied for each pulse width used. For single polarization radars, only the horizontally polarized metadata are relevant.

Note H and V indicate horizontal and vertical polarization respectively. Co-polar indicates transmit and receive on the same polarization. Cross-polar indicates transmit and receive on opposite polarization, with the receiving polarization listed. (i.e. H cross-polar = transmit V, receive H)

Table 6. Radar calibration metadata.

ID	Description	Type	Unit	Precision
	Pulse width	real	nanoseconds	1 (see above)
	Derived antenna gain H	real	dBi	0.1
	Derived antenna gain V	real	dBi	0.1
	Nominal transmit power H	real	W	Peak or Average 1 MW, 250KW, 40 W in the old days
	Nominal transmit power V	real	W	0.1 precision
	2-way waveguide loss measurement plane to feed horn H	real	dB	0.1
	2-way waveguide loss measurement plane to feed horn V	real	dB	0.1

2-way radome loss H	real	dB	0.1
2-way radome loss V	real	dB	0.1
Receiver filter bandwidth mismatch loss	real	dB	0.1
Receiver filter bandwidth mismatch loss H	real	dB	0.1
Receiver filter bandwidth mismatch loss V	real	dB	0.1
Radar constant H	real	dB	0.1
Radar constant V	real	dB	0.1
Probert Jones correction	real	-	0.1
Measured noise level H co-polar	real	dBm	0.1
Measured noise level V co-polar	real	dBm	0.1
Measured noise level H cross-polar	real	dBm	0.1
Measured noise level V cross-polar	real	dBm	0.1
Measured receiver gain H co-polar	real	dB	0.1
Measured receiver gain V co-polar	real	dB	0.1
Measured receiver gain H cross-polar	real	dB	0.1
Measured receiver gain V cross-polar	real	dB	0.1
Reflectivity at 1km for SNR=0dB H co-polar	real	dBZ	0.1
Reflectivity at 1km for SNR=0dB V co-polar	real	dBZ	0.1
Reflectivity at 1km for SNR=0db H cross-polar	real	dBZ	0.1
Reflectivity at 1km for SNR=0db V cross-polar	real	dBZ	0.1
Calibrated sun power H co-polar	real	dBm	0.1
Calibrated sun power V co-polar	real	dBm	0.1
Calibrated sun power H cross-polar	real	dBm	0.1
Calibrated sun power V cross-polar	real	dBm	0.1
Noise source power H	real	dBm	0.1
Noise source power V	real	dBm	0.1
Power measurement loss in coax and connectors H	real	dB	0.1
Power measurement loss in coax and connectors V	real	dB	0.1
Coupler loss into waveguide H	real	dB	0.1
Coupler loss into waveguide V	real	dB	0.1
ZDR correction	real	dB	0.1
LDR correction H	real	dB	0.1
LDR correction V	real	dB	0.1
System PhiDP as seen in drizzle close to the radar	real	degrees	0.1
Calibration test power H	real	dBm	0.1
Calibration test power V	real	dBm	0.1
Computed receiver slope H co-polar	real	-	0.01
Computed receiver slope V co-polar	real	-	0.01
Computed receiver slope H cross-polar	real	-	0.01
Computed receiver slope V cross-polar	real	-	0.01

3.3.3 Lidar calibration

No calibration metadata for lidar instruments are currently identified.

Table 7. Lidar calibration metadata.

3.4 Ray Object Metadata

3.4.1 Ray characteristics

Table 8. Ray characteristics.

ID	Description	Type	Unit	Precision
	Elevation angle	real	degrees	0.1
	Azimuth angle	real	degrees	0.1
	Time of acquisition (relative to volume start time)	time	relative	high
	Width of ray (dwell)	real	degrees	0.01
	Measured scan rate, positive clockwise and/or ascending	real	degrees/s	0.01
	Whether the antenna is in transition to fixed angle during this ray	Boolean	-	-
	Whether geographic reference information for moving platforms has been applied to correct the elevation and azimuth angles	Boolean	-	-
	Pulse width	real	seconds	10 nanoseconds
	Pulse repetition time(s)	real[n]	seconds	1 millisec
	Nyquist velocity	real	m/s	0.1
	Unambiguous range	real	m	1
	Number of samples used to compute moments	integer	-	-

3.4.2 Moving platform geographic reference information

The shaded metadata of this section are only required for moving platforms.

Table 9. Moving platform geographic reference information.

ID	Description	Type	Unit	Precision
	Latitude of the instrument	real	degrees	0.000001
	Longitude of the instrument	real	degrees	0.000001
	Altitude of the instrument above the geodetic datum. For scanning PPS, this is the center of rotation of the antenna.	real	m	1m
	Heading of the platform relative to true north, looking down from above	real	degrees	0.01
	Roll about longitudinal axis of platform. Positive is left side up, looking forward.	real	degrees	0.01
	Pitch about the lateral axis of the platform. Positive is up at the front.	real	degrees	0.01
	Difference between heading and track over the ground (drift). Positive drift implies track is clockwise from heading, looking from above. Not applicable to land-based moving platforms.	real	degrees	0.01
	Angle between the PPS beam and the vertical axis of the platform (rotation). Zero is along the vertical axis, positive is clockwise looking forward from behind the platform.	real	degrees	0.01
	Angle between the radar beam (when it is in a plane containing the longitudinal axis of the platform) and a	real	degrees	0.01

	line perpendicular to the longitudinal axis (tilt). Zero is perpendicular to the longitudinal axis, positive is towards the front of the platform.			
	East/west velocity of the platform. Positive is eastwards.	real	m/s	
	North/south velocity of the platform. Positive is northwards.	real	m/s	
	Vertical velocity of the platform. Positive is upwards.	real	m/s	
	East/west wind at the platform location. Positive is eastwards.	real	m/s	
	North/south wind at the platform location. Positive is northwards.	real	m/s	
	Vertical wind at the platform location. Positive is upwards.	real	m/s	
	Rate of change of heading	real	degrees/s	
	Rate of change of roll of the platform	real	degrees/s	
	Rate of change of pitch of the platform	real	degrees/s	

3.4.3 Radar monitoring

Table 10. Radar monitoring metadata.

ID	Description	Type	Unit	Precision
	Measured transmit power H	real	dBm	
	Measured transmit power V	real	dBm	
	Noise measured at the receiver when connected to the antenna with no noise source connected	real	dBm	
	Noise measured at the receiver when connected to the noise source which is disabled	real	dBm	
	Noise measured at the receiver when it is connected to the noise source which is enabled	real	dBm	

3.5 Range Bin Object Metadata

Table 11. Range bin object metadata.

ID	Description	Type	Unit	Precision
	Range to center of bin	real	m	1
	Length of bin	real	m	1

3.6 Dataset Object Metadata

3.6.1 Basic dataset information

Table 12. Basic dataset information.

ID	Description	Type	Unit	Precision
	Dataset identifier (user specified)	string	-	-
	Quantity name (see section 4)	string	-	-
	Quantity units	string	-	-
	Quantity value used to indicate missing data	real	-	-
	Quantity value used to indicate no signal	real	-	-
	Whether dataset is represented by discrete values	Boolean	-	-

	Discrete values used in dataset	real[n]	-	-
	Labels for discrete values used in dataset	string[n]	-	-
	Whether dataset is a quality dataset	Boolean	-	-
	Identifiers of quality datasets which qualify this dataset	string[n]	-	-

3.6.2 Quality dataset information

In addition to the basic dataset information, the following metadata are defined for datasets which are used to represent a quality metric.

Table 13. Quality dataset information.

ID	Description	Type	Unit	Precision
	Identifiers of datasets which are qualified by this dataset	string[n]	-	-
	Identifier of the algorithm that generated the dataset (see below)	string	-	-
	Arguments or configuration provided to the algorithm that generated the dataset	string[n]	-	-
	Literature reference to the algorithm that generated the dataset	string	-	-

It is suggested, although not required, that quality algorithm identifiers take the form of “org.name” where ‘org’ is a short mnemonic identifying the original source of the algorithm, such as an organization or researcher, and ‘name’ is a short identifier for the algorithm itself. This arrangement allows a single organization to provide a common prefix for all algorithms it has developed, thereby preventing name clashes with other algorithms used for a similar purpose.

Examples of algorithm identifiers in the suggested format are provided in Table 14 below.

Table 14. Example algorithm identifiers.

Identifier	Organization	Algorithm
bom.spike	Bureau of Meteorology	External emitter detection algorithm
smhi.beamb	Swedish Meteorological and Hydrological Institute	BALTRAD beam blocking analysis algorithm
ncar.pid	National Center for Atmospheric Research	Particle Identification Algorithm
nssl.hca	National Severe Storms Laboratory	Hydrometeor Classification Algorithm

Note that the intention of the algorithm identifier metadata is to allow data exchange of quality output by unambiguously identifying the algorithm used to produce it. This identifier should not be used to identify the particular software the algorithm was implemented within, configuration used, nor the organization executing it unless these factors cause incompatibility with the output of the original implementation.

3.6.3 Spectrum dataset

Table 15. Spectrum dataset metadata.

ID	Description	Type	Unit	Precision
	Value represented by each point in the spectrum	real	Hz	-
	Length of FFT used to compute the spectrum	int	-	-
	Length of averaging block used to compute the	int		

spectrum

4 Standard Datasets

The following table lists standard datasets associated with polar pulsed systems. Users of the information model are free to use custom datasets which are not listed here.

4.1 Scalar quantities

Table 16. Scalar quantities.

ID	Description	Unit	Precision
	Equivalent reflectivity factor	dBZ	0.1
	Linear equivalent reflectivity factor	Mm^6/m^3	0.1
	Radial velocity of scatterers away from instrument	m/s	0.1
	Doppler spectrum width	m/s	0.1
	Log differential reflectivity H/V	dB	0.1
	Log-linear depolarization ratio HV	dB	0.1
	Log-linear depolarization ratio H	dB	0.1
	Log-linear depolarization ratio V	dB	0.1
	Differential phase HV	degrees	0.001 (16 bit)
	Specific differential phase HV	degrees/km	0.001 (16 bit)
	Cross-polar differential phase	degrees	0.1
	Cross-correlation ratio HV		0.1
	Co-to-cross polar correlation ratio H		0.1
	Co-to-cross polar correlation ratio V		0.1
	Log power	dBm	0.1
	Log power co-polar H	dBm	0.1
	Log power cross-polar H	dBm	0.1
	Log power co-polar V	dBm	0.1
	Log power cross-polar V	dBm	0.1
	Linear power	mW	Typical -113 dBm which is $10^{-11.3\ mW}$
	Linear power co-polar H	mW	Typical -113 dBm which is $10^{-11.3}$ mW
	Linear power cross-polar H	mW	Typical -113 dBm which is $10^{-11\ mW}$
	Linear power co-polar V	mW	Typical -113 dBm which is $10^{-11.3\ mW}$
	Linear power cross-polar V	mW	Typical -113 dBm which is $10^{-11.3}$ mW and so
	Signal-to-noise ratio	dB	0.1
	Signal-to-noise ratio co-polar H	dB	0.1
	Signal-to-noise ratio cross-polar H	dB	0.1
	Signal-to-noise ratio co-polar V	dB	0.1
	Signal to noise ratio cross polar V	dB	0.1
	Normalized coherent power (also known as signal quality index)		0.1

	Corrected equivalent reflectivity factor	dBZ	0.1
	Corrected radial velocity of scatterers away from instrument	m/s	0.1
	Corrected log differential reflectivity HV	dB	0.1
	Radar estimated rain rate	mm/hr	0.01
	Rain rate	kg/m2/s	????
	Radar echo classification	-	

4.2 Spectrum quantities

Table 17. Spectrum quantities.

ID	Description	Unit
	Spectrum of co-polar H	Power units dBm or mW for all of these
	Spectrum of co-polar V	
	Spectrum of cross-polar H	
	Spectrum of cross-polar V	
	Cross spectrum of co-polar H	
	Cross spectrum of co-polar V	
	Cross spectrum of cross-polar H	
	Cross spectrum of cross-polar V	

5 References

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