# D1 Weather radar data requirements for climate monitoring

This is the document as of November 2017. It has strong connections with IPET\_OWR documents, and the corresponding details will be updated when relevant papers are available.

In a nutshell

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| We recommend saving:* Radar parameters (e.g., reflectivity in dBZ NOT accumulated rainfall rate in mm)
* 3-dimensional volume scans in the highest resolution possible (NOT 2-dim images or composites)
* Log of changes of important metadata (e.g., upgrades to Doppler).

We have defined minimum recommendations and a goal for metadata needed to use the radar data in Annexes of this document.We also recommend a glossary of radar matters, including metadata elements and quality control terms to be defined jointly with IPET-OWR |

## **Definition of key parameters**

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| The data shall be saved as Level 2 files. Key radar parameters\* are* Horizontal Reflectivity (ZH)
* Radial Velocity (VRAD)
* Spectrum Width (WRAD)
* Differential Reflectivity (ZDR)
* Correlation Coefficient (RhoHV)
* Differential phase (PhiDP)
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\*It is acknowledged, that single polarization radars cannot provide ZDR, RhoHV or PhiDP and that VRAD and WRAD are available only for Doppler radars.

For quality control purposes, when feasible, we also recommend saving uncorrected reflectivity (TH), signal quality index (SQI), and clutter-to-signal ration (CSR).

Defining a common data format is crucial and we endorse the efforts of IPET OWR and TT WRDE. From climate point of view, it is crucial to make sure that the data can still be processed after 20 years.

We cannot expect that the original data provider would take care of converting old stored data to new formats defined after the data was originally stored. However, the radar community can support the conversion efforts by collecting and sharing links to conversion software.

For ease-of-use, members can be tempted to save Level 3 products such as rainfall rate or hydrometeor classification. As processing algorithms develop over years, maintaining homogeneity in the time series is challenging, and for reprocessing purposes saving also the Level 2 data is strongly recommended.

Making the Level 4 products (e.g., gauge adjusted rainfall) can be even more tempting, because these can be directly used by many researchers and other parties. When people start using these climatological datasets, this may also help to reprocess Level 2 data to obtain better Level 4 data (e.g., by obtaining additional funding, because it could create a desire for better products).

Background:
Level 2 above refers to definitions in WIGOS guidance by IPET-OWR, draft of which is in table below. Both international satellite and operational weather radar community[[1]](#footnote-1) in USA have also defined “Level 2”. The differences between NEXRAD and WIGOS are not large.

Table 1. Full set of definitions following the IPET-OWR draft for a WIGOS guide (by Paul Joe; TBC when his document is final).

|  |  |
| --- | --- |
| Raw Data Definitions | Definition |
| Level 0 | Uncalibrated data at full resolution, with data collection artifacts removed.  Data record is as received at the sampling rate of the receiver.  Generally, only available internal to the system. |
| Level 1a | Uncalibrated data, annotated with ancillary information, calibration and timing information.  Data record has been sorted by range and by time.  Data has not been aggregated.  Generally, not recorded except for limited durations. |
| Level 1b | Calibrated data in sensor units (voltages) also known as “time series” or “I-Q for In-phase, Quadrature” data. Data before aggregation and filtering.  Generally, not recorded except for limited durations. |
| Level 2 | Derived radar variables or moments (reflectivity, radial velocity, differential reflectivity, etc.) at full resolution after aggregation, after filtering.  Also, known as “volume scan data”. |
| Level 3a | Generally known as radar products at full resolution of the Level 2 data.  May be in polar, Cartesian (projected) format. |
| Level 3b | Radar products in image form with perhaps reduced quantization. |
| Level 4 | Radar products with variables from multiple measurements (mosaics, gauge adjusted or should we make a distinction -> 4a, 4b) |

## **Describe essential Metadata relevant for climate**

In general, the metadata needed for climate monitoring are no different from those for other applications. However, from the point of view of climate monitoring, it is crucial to keep track of the history of hardware and algorithm changes.

The modern data models and formats include some metadata in connection with actual data. This is not the case for historical data. Even in the future, not all metadata can or should be included in the data files, at least some of the more static metadata should be available separately (for example the model type of the radome at a given time can help define the dataset to be used in a certain study).

The WIGOS Ad-Hoc meeting in Locarno (19-21 June 2017) concluded, that “Develop a minimal set of metadata elements necessary to characterize weather radars ("describe observations to enable adequate use"): Minimal set is probably described in OPERA.” OPERA has defined two sets: the ODIM data format has mandatory parameters (Annex2), and the data model for OPERA offline database, which is merely a network inventory (Annex 1).

We consider the table in annex 1 as minimum requirement to enable adequate use, and annex 2 as the goal which is recommended for any radar data intended for use in climate monitoring. Annex 1 as itself does not contain all the metadata elements needed for characterize a radar, but it can be complemented with typical values for certain radar types or analysis of the data itself to determine values such as the minimum detectable signal.

## **Quality control and its documentation**

In general, the methods which should be used for quality control for climate monitoring are no different than those for other applications. Differences may include levels of documentation of the applied quality control methods.

Just like in weather monitoring, climate monitoring can be done on several levels from purely qualitative to different levels of quantitative. From the point of view of climate monitoring, it is crucial to keep track of the history of changes in the quality control. A special challenge is the definition of terminology: “clutter removed” is completely ambiguous, but even “Doppler filter 3 applied” gives different error structures whether it was PP method or GMAP.

The team recommends a Glossary to be

It may become necessary to define a “Level 2b” which includes extensive metadata.

## **Recommendations for historical data**

During the first decades of digital weather radar networks, radar measurements were sometimes saved as 2-dimensional image files. Even though these images often are problematic for reconstruction of precipitation records, they may have value as sources of qualitative interpretation, such as monitoring frequency of severe weather phenomena.

For reprocessing of data, it is advisable to save intermittent products comparable to Level 2 data, including at least minimal metadata with a posteriori analysis. It is likely, that the reprocessing will be a repeated activity, and the goal is that the most cumbersome issues such as reading old data formats can be repeated only once. Bear in mind, that the technology needed for reading very old media (such as magnetic tapes) may not be available in the future decades.

For metadata, in our opinion if any dataset does not have the minimum metadata described in annex 1, it cannot be used for quantitative studies, and should be at best be considered qualitative data similar to image files (or photographs).

Special attention should be paid for saving the history of metadata. Because a lifetime of a radar is 10-20 years, most climatologically interesting time series would be containing data from different instruments at the same places. Even if the instrument has not been replaced, typically several upgrades have been implemented, so the present metadata is not describing the oldest data. Dates and types of major changes (such as from non-Doppler to Doppler capability, from single to dual polarization) should be indicated carefully.

## **Application of GCOS climate monitoring principles to radar data**

In general, most of the GCOS climate monitoring principles are applicable to radar data. However, radars as advanced electronic devices have a limited lifetime which cannot be prolonged, and technology is advancing at such a speed that typically any outdated instrument is replaced with a next generation system, not an identical one. Due to high cost of radars and their infrastructures, overlapping time series are seldom available. The global network is still very patchy, and purchase of new systems is often still not focusing in data sparse areas but in regions of high impact weather.

## Summary

The key points discussed are as follows:

1. The phenomena to be monitored with weather radar include in addition to precipitation also severe mesoscale phenomena such as hailstorms and tornadoes.
2. The central parameter is horizontal reflectivity, ZH, which is basis of precipitation estimates. The other key radar parameters have importance for two approaches: improving the quality of precipitation estimates, but also as independent variables related to mesoscale phenomena.
3. Saving the three-dimensional Level 2 data, instead of Level 3, allows homogenization of time series when more advanced methodologies are developed. It also supports studies related to three-dimensional structure of the atmosphere. The difference in amounts of stored data is not significant. 3D data are 10-30 times larger than 2D, but it is very easy to compress (zip). In OPERA, 150 radars, 1-2 Gb a day for reflectivity, with all parameters 10 Gb. Problem is not the disk space, but the management of data.
4. According to our survey, decade-long time series are common, and two decades available at several NMSes. Coverage is soon ready to address climate requirements. Even for NMSes starting their history now, it is better to start from the beginning in organized approach than trying to reprocess disparate datasets.
5. A number of NMHS’s has conducted promising prototype studies and is ready to invest into the development and generation of multi-decadal radar bases to support climate requirements.
6. Target applications are extreme precipitation statistics, long-term aggregations, severe convection statistics and reanalysis. The statistics are also useful for ground validation of satellite precipitation products, and development of hydrological models.
7. Quality control of radar data mandatory for climate application. Also, documentation of used processing algorithms is crucial, to avoid conclusions based on apparent trends.
8. On the global scale the effort to address climate requirement is huge. Several approaches are feasible, including an international data centre or a portal providing uniform access to a number of regional centres. Whatever solution is favoured, it should start with a proof of concept structure.

**Annex 1 data model for OPERA metadata database.**

|  |  |
| --- | --- |
| In OPERA | In WMO radar database by TSMS |
| Radar identifier | Yes |
| Country | Yes |
| Latitude | Yes |
| Longitude | Yes |
| Height of station (m) | Yes |
| Band (X/C/S) | Yes |
| Doppler (yes/no) | No (or station type ?) |
| Polarization (single/dual) | Yes |
| Max range (km) | no |
| Start year | yes |
| Height of antenna (m) | yes |
| Diameter of antenna (m) | no |
| Beam (degrees) | yes |
| Gain (dB) | no |
| Frequency (GHz) | yes |

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**Annex 2: mandatory metadata in ODIM 2.2**

Table 1: Mandatory top-level with header Attributes for all weather radar files.

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Format | Description |
| object | string | - | According to Table 2 |
| version | string | H5rad M.m | Format or information model version. “M” is the major version. “m” is the minor version. Software is encouraged to warn if it receives a file stored in a version which is different from the one it expects. The software should, however, proceed to read the file, ignoring Attributes it does not understand. |
| date | string | YYYYMMDD | Nominal Year, Month, and Day of the data/product |
| time | string | HHmmss | Nominal Hour, Minute, and Second, in UTC of the data/product |

Table 4: where attributes for polar data objects.

|  |  |  |
| --- | --- | --- |
| Name | Type | Description |
| lon | double | Longitude position of the radar antenna (degrees), normalized to the WGS-84 reference ellipsoid and datum. Fractions of a degree are given in decimal notation. |
| lat | double | Latitude position of the radar antenna (degrees), normalized to the WGS84 reference ellipsoid and datum. Fractions of a degree are given in decimal notation. |
| height | double | Height of the centre of the antenna in meters above sea level. |
| Dataset specific |
| elangle | double | Antenna elevation angle (degrees) above the horizon. |
| nbins | long | Number of range bins in each ray |
| rstart | double | The range (km) of the start of the first range bin |
| rscale | double | The distance in meters between two successive range bins |
| nrays | long | Number of azimuth or elevation gates (rays) in the object |
| a1gate | long | Index of the first azimuth gate radiated in the scan |

Table 13: Dataset-specific what header Attributes.

|  |  |  |  |
| --- | --- | --- | --- |
| Name | Type | Format | Description |
| product | string | - | According to Table 14 |
| prodpar | Tab. 15 | - | According to Table 15 for products. Only used for Cartesian products. |
| quantity | string | - | According to Table 16 |
| startdate | string | Starting YYYYMMDD | Year, Month, and Day for the product |
| starttime | string | Starting HHmmss | Hour, Minute, and Second for the product |
| enddate | string | Ending YYYYMMDD | Year, Month, and Day for the product |
| endtime | string | Ending HHmmss | Hour, Minute, and Second for the product |
| gain | double | - | Coefficient ’a’ in y=ax+b used to convert to unit. Default value is 1.0. |
| offset | double | - | Coefficient ’b’ in y=ax+b used to convert to unit. Default value is 0.0. |
| nodata | double | - | Raw value used to denote areas void of data (never radiated). **Note** that this Attribute is always a float even if the data in question is in another format. |
| undetect | double | - | Raw value used to denote areas below the measurement detection threshold (radiated but nothing detected). **Note** that this Attribute is always a float even if the data in question is in another format. |

Table 16: Quantity (variable) identifiers. Radar moments are those received by the radar or derived thereof.

|  |  |  |
| --- | --- | --- |
| String | Quantity [Unit] | Description |
| TH | *Th* [dBZ] | Logged horizontally-polarized total (uncorrected) reflectivity factor |
| TV | *Tv* [dBZ] | Logged vertically-polarized total (uncorrected) reflectivity factor |
| DBZH | *Zh* [dBZ] | Logged horizontally-polarized (corrected) reflectivity factor |
| DBZV | *Zv* [dBZ] | Logged vertically-polarized (corrected) reflectivity factor |
| ZDR | ZDR [dBZ] | Logged differential reflectivity |
| RHOHV | *ρhv* [0-1] | Correlation between *Zh* and *Zv* |

|  |  |  |
| --- | --- | --- |
| String | Quantity [Unit] | Description |
| LDR | *Ldr* [dB] | Linear depolarization ratio |
| PHIDP | *φdp* [degrees] | Differential phase |
| KDP | *Kdp* [degrees/km] | Specific differential phase |
| SQIH | SQI*h* [0-1] | Signal quality index - horizontally-polarized |
| SQIV | SQI*v* [0-1] | Signal quality index - vertically-polarized |
| SNRH | SNR*h* [0-1] | Normalized signal-to-noise ratio - horizontally-polarized |
| SNRV | SNR*v* [0-1] | Normalized signal-to-noise ratio - vertically-polarized |
| CCORH | CC*h* [dB] | Clutter correction - horizontally-polarized |
| CCORV | CC*v* [dB] | Clutter correction - vertically-polarized |
| RATE | RR [mm/h] | Rainfall rate |
| URATE | URR [mm/h] | Uncorrected rainfall rate |
| HI | HI [dB] | Hail intensity |
| HP | HP [%] | Hail probability |
| ACRR | RR*accum.* [mm] | Accumulated precipitation |
| HGHT | H [km] | Height (of echo tops) |
| VIL | VIL [kg/m2] | Vertical Integrated Liquid water |
| VRAD | V*rad* [m/s] | Radial velocity. Marked for DEPRECATION. |
| VRADH | V*rad,h* [m/s] | Radial velocity - horizontally-polarized. Radial winds towards the radar are negative, while radial winds away from the radar are positive (PANT). |
| VRADV | V*rad,v* [m/s] | Radial velocity - vertically-polarized. Radial winds towards the radar are negative, while radial winds away from the radar are positive (PANT). |
| VRADDH | V*rad,d* [m/s] | Dealiased horizontally-polarized radial velocity |
| VRADDV | V*rad,d* [m/s] | Dealiased vertically-polarized radial velocity |
| WRAD | W*rad* [m/s] | Spectral width of radial velocity. Marked for DEPRECATION. |
| WRADH | W*rad,h* [m/s] | Spectral width of radial velocity - horizontally-polarized |
| WRADV | W*rad,v* [m/s] | Spectral width of radial velocity - vertically-polarized |
| UWND | U [m/s] | Component of wind in x-direction |
| VWND | V [m/s] | Component of wind in y-direction |
| RSHR | SHR*r* [m/s km] | Radial shear |
| ASHR | SHR*a* [m/s km] | Azimuthal shear |
| CSHR | SHR*c* [m/s km] | Range-azimuthal shear |
| ESHR | SHR*e* [m/s km] | Elevation shear |
| OSHR | SHR*o* [m/s km] | Range-elevation shear |
| HSHR | SHR*h* [m/s km] | Horizontal shear |
| VSHR | SHR*v* [m/s km] | Vertical shear |
| TSHR | SHR*t* [m/s km] | Three-dimensional shear |
| BRDR | 0 or 1 | 1 denotes a border where data from two or more radars meet in composites, otherwise 0 |
| QIND | Quality [0-1] | Spatially analyzed quality indicator, according to OPERA II, normalized to between 0 (poorest quality) to 1 (best quality) |
| CLASS | Classification | Indicates that data are classified and that the classes are specified according to the associated legend object (Section 6.2) which must be present. |

1. The network is referred to as NEXRAD (Next-Generation Radar) or WSR-88D (Weather Surveillance Radar, 1988, Doppler). [↑](#footnote-ref-1)