|  | **Analysis Ready Data** | **Minimum Product Family****Specification --** **“Barebones”** |
| --- | --- | --- |

# Document Status

**Minimum Product Family Specification (PFS)**

This Specification should next be reviewed on: TBD.

Proposed revisions may be provided to: TBD

# Document History

| **Version** | **Date** | **Description of Change** | **Author** |
| --- | --- | --- | --- |
| 0.1.0 | 01.09.2021 | Initial draft  | Edward Armstrong, Adam Lewis, Steve Labahn, Matt Steventon |
| 1.0 | 22.10.2021 | Resolved all comments. Created unique section 4 (Geometric Accuracy). Removed Backlog. Overall polishing. | Edward Armstrong, Adam Lewis, Steve Labahn, Matt Steventon |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

# **CEOS Analysis Ready Data** <CEOS consensus definition not to be modified>

*CEOS Analysis Ready Data (CARD) are satellite data that have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with a minimum of additional user effort and interoperability both through time and with other datasets.*

< NOTE: For completing this template, the author is suggested to use as reference or source of examples the current set of existing CEOS ARD Product Family Specifications available at: <https://ceos.org/ard/index.html#slide3> >

# Description <To be populated by PFS authors>

## **Product Family Title:** <*Name* (*short name*)>

## **Description:** <*Including the anticipated benefits/advantages/uses of this type of CEOS ARD>*

## **Applies to:** *<Data collected with sensors .…>*

# Definitions <*these are examples*, *add, remove or adapt where necessary*>

| Ancillary Data | Data other than instrument measurements, originating in the instrument itself or from the satellite, required to perform processing of the data. They include orbit data, attitude data, time information, spacecraft engineering data, calibration data, data quality information, and data from other instruments or earth system models. |
| --- | --- |
| Auxiliary Data | The data required for instrument processing, which does not originate in the instrument itself or from the satellite. Some auxiliary data will be generated in the ground segment, whilst other data will be provided from external sources. |
| Metadata | Structured information that describes other information or information services. With well-defined metadata, users should be able to get basic information about data, without the need to have knowledge about its entire content. |
| Spectral Resolution | Defines the narrowest spectral feature that can be resolved by a spectrometer. |
| Spatial Resolution | The highest magnification of the sensor at the ground surface. |
| Spectral Sampling Distance | Spectral sampling is the interval, in wavelength units, between discrete data points in the measured spectrum. |
| Spatial Sampling Distance | Spatial sampling distance is the barycentre-to-barycentre distance between adjacent spatial samples on the Earth's surface. |

# Requirements and Recommendations

## *General Metadata*

*These are metadata records describing a distributed collection of products. The collection of pixels referred to must be contiguous in space and time.* ***General metadata should allow the user to assess the overall suitability of the dataset, and must meet the following requirements:***

| **#** | **Item (Term)** | **Threshold (Minimum)****Requirements** | **Target (Desired)Requirements** | **ThresholdSelf-Assessment** | **TargetSelf-Assessment** | **Self-AssessmentExplanation/ Justification** | **RecommendedRequirementModification** |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | ***The items are the things that, for this product family, need to be included.*** | *Threshold requirements are the MINIMUM that is needed for the data to be analysis ready. This must be practical and accepted by the data producers* | *Target requirements are the ideal; where we would like to be. Some providers may be able to meet these already.* | *This is used by a data provider, to indicate if they think they meet the threshold*  | *This is used by a data provider, to indicate if they think they meet the target* | *This is used by a data provider, to explain why they self-assess in the way they have* | *This is used to capture recommended changes to the specification, based on consideration of stakeholder feedback.* |
|  | **\* *= items required for all PFSs*** |  |  |  |  |  |  |
| **1.1** | **Traceability\*** | Not required | Data must be traceable to SI reference standard. Information on traceability should be available in the metadata as a single DOI landing page. |  |  |  |  |
| **1.2** | **Metadata Machine Readability\*** | Metadata is provided in a structure that enables a computer algorithm to be used consistently and to automatically identify and extract each component part for further use. | As threshold, but metadata should be provided in a community endorsed standard that facilitates machine-readability, such as ISO 19115-2, CF, ACDD etc. |  |  |  |  |
| **1.3** | **Data Collection Time\*** | The data collection time is identified in the metadata, expressed in date/time, to the second, with the time offset from UTC unambiguously identified. | Acquisition time for each pixel is identified (or can be reliably determined) in the metadata, expressed in date/time at UTC, to the second. |  |  |  |  |
| **1.4** | **GeographicalArea\*** | The surface location to which the data relates is identified, typically as a series of four corner points, expressed in an accepted coordinate reference system (e.g., WGS84). | The geographic area covered by the observations is identified specifically, such as through a set of coordinates of a closely bounding polygon (e.g., specified in GeoJSON or WKT). The location to which each pixel refers is identified (or can be reliably determined) with the projection system (if any) and reference datum provided.  |  |  |  |  |
| **1.5** | **Coordinate Reference System\*** | The metadata lists the coordinate reference system that has been used. | As threshold. |  |  |  |  |
| **1.7** | **Instrument\*** | The instrument used to collect the data is identified in the metadata. | As threshold, but information should be available in the metadata as a single DOI landing page with references to the relevant CEOS Missions, Instruments, and Measurements Database record. |  |  |  |  |
| **1.8** | **Algorithms\*** | All algorithms, and the sequence in which they were applied in the generation process, are identified in the metadata. For example, these may be available through Algorithm Theoretical Basis documents. Note 1: Information on algorithms should be available in the metadata as a single DOI landing page. | As threshold, but only algorithms that have been published in a peer-reviewed journal. Note 1: It is possible that high quality corrections are applied through non-disclosed processes. CARD4L does not per-se require full and open data and methods. Note 2: Information on algorithms should be available in the metadata as a single DOI landing page. |  |  |  |  |
| **1.9** | **Auxiliary Data\***  | The metadata identifies the sources of auxiliary data (if any) used in the generation process. See definition above.  | As threshold, but information on auxiliary data should be available in the metadata as a single DOI landing page and is also available for free online download, contemporaneously with the product or through a link to the source. |  |  |  |  |
| **1.10** | **Processing Chain Provenance\*** | Not required. | Information on processing chain provenance should be available in the metadata as a single DOI landing page containing detailed description of the processing steps used to generate the product, including the versions of software used, giving full transparency to the users |  |  |  |  |
| **1.11** | **Data Access\*\*** | Information on data access should be available in the metadata as a single DOI landing page. Note 1: Manual and offline interaction action (e.g., login) may be required. | Data discovery and access through well established protocols (e.g, STAC, OPeNDAP, Opensearch) |  |  |  |  |
| **1.12** | **Geometric methods metadata requirements\*** | Include here the threshold-level requirements for information on the methods used to implement geometric corrections. | Include here the target-level requirements for information on the methods used to implement geometric corrections |  |  |  |  |
| **1.13** | **Geometric accuracy metadata requirements\*** | Include here the threshold-level requirements for metadata on the geometric accuracy. E.g. that the geometric accuracy be expressed | Include here the target- level requirements for metadata on the geometric accuracy. E.g. that the geometric accuracy be expressed quantitatively in the coordinate reference system of the data and in terms of RMS distance or circular error probability (CEP). |  |  |  |  |
| **Additional parameters as needed** |
|  | **Map Projection** | The metadata lists the map projection that has been used and any relevant parameters required in relation to use of data in that map projection. Only applicable to remotely sensed data mapped to an earth projection. | As threshold. |  |  |  |  |

##

##

## Per-Sample/Pixel Metadata

***Per-sample/pixel metadata should allow users to discriminate between (choose) observations on the basis of their individual suitability for application.***

*The following minimum metadata specifications apply to each pixel. Whether the metadata are provided in a single record relevant to all pixels or separately for each pixel is at the discretion of the data provider. Besides the required assessment factors , examples of additional factors/tests are given. These will vary across product families.*

| **#** | **Item** | **Threshold (Minimum)****Requirements** | **Target (Desired)Requirements** | **ThresholdSelf-Assessment** | **TargetSelf-Assessment** | **Self-AssessmentExplanation/ Justification** | **RecommendedRequirementModification** |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | ***The items are the things that, for this product family, need to be included.*** | *Threshold requirements are the MINIMUM that is needed for the data to be analysis ready. This must be practical and accepted by the data producers* | *Target requirements are the ideal; where we would like to be. Some providers may be able to meet these already.* | *This is used by a data provider, to indicate if they think they meet the threshold*  | *This is used by a data provider, to indicate if they think they meet the target* | *This is used by a data provider, to explain why they self-assess in the way they have* | *This is used to capture recommended changes to the specification, based on consideration of stakeholder feedback.* |
| **2.1** | **Metadata Machine Readability\*** | Metadata is provided in astructure that enables acomputer algorithm to beused to consistently andautomatically identify andextract each component/variable/layer for further use. | As threshold, but metadata should be provided in a community endorsed standard that facilitates machine-readability, such as ISO 19115-2, CF, ACDD etc |  |  |  |  |
| **Quality tests (per pixel/sample)\*** ***Quality tests must contain at least a ‘No Data’ test. Also known previously as ‘No Data Mask’ . Additional tests highly recommended.***  |
| **2.2** | **No Data\*** | Pixels that do not correspond to an observation (‘empty pixels’) are flagged. | As threshold. |  |  |  |  |
| ***Examples of additional quality tests. for optical and Radar instruments. Community will choose/update/adapt or propose additional quality tests and requirements. See existing PFSs at https://ceos.org/ard/index.html#slide3*** |
|  | **IncompleteTesting** | The metadata identifies pixels for which the per-pixel tests (below) have not all been successfully completed. Note 1: This may be the result of missing ancillary data for a subset of the pixels. | The metadata identifies which tests have, and have not, been successfully completed for each pixel. |  |  |  |  |
|  | **Saturation** | Metadata indicates where one or more spectral bands are saturated. | Metadata indicates which pixels are saturated for each spectral band. |  |  |  |  |
|  | **Cloud** | Metadata indicates whether a pixel is assessed as being cloud. | As threshold, information on cloud detection should be available in the metadata as a single DOI landing page. |  |  |  |  |
|  | **Cloud Shadow** | Metadata indicates whether a pixel is assessed as being cloud shadow. | As threshold, but information on cloud shadow detection should be available in the metadata as a single DOI landing page |  |  |  |  |
|  | **Land/WaterMask** | Not required. | The metadata indicates whether a pixel is assessed as being land or water. Information on land/water mask should be available in the metadata as a single DOI landing page. |  |  |  |  |
|  | **Snow/Ice Mask** | Not required. | The metadata indicates whether a pixel is assessed as being snow/ice or not. Information on snow/ice mask should be available in the metadata as a single DOI landing page. |  |  |  |  |
|  | **Terrain Shadow Mask** | Not required. | The metadata indicates pixels that are not directly illuminated due to terrain shadowing. |  |  |  |  |
|  | **Scattering Area Image** | DEM-based local contributing area image used for normalisation is provided. | As threshold |  |  |  |  |
|  | **Noise Power Image**  | Not required | Estimated noise equivalent σo (or β0 , as applicable) used for Noise Removal, if applied, for each channel |  |  |  |  |
| **Observation conditions\*** ***Observational condition tests must be included*** |
| ***Examples of observations tests. Community will choose/update/adapt or propose new tests and requirements See existing PFSs at https://ceos.org/ard/index.html#slide3*** |
|  | **Terrain Occlusion** | Not required. | The metadata indicates pixels that are not visible to the sensor due to terrain occlusion during off-nadir viewing. |  |  |  |  |
|  | **Solar and Viewing Geometry** | Provide average solar and sensor viewing azimuth and zenith angles. | Provide per-pixel solar and sensor viewing azimuth and zenith angles. |  |  |  |  |
|  | **Terrain Illumination Correction** | Not required. | Coefficients used for terrain illumination correction are provided for each pixel. |  |  |  |  |
| **Additional correction parameters\* *(Other tests as needed)*** |
|  | **Aerosol Optical Depth Parameters** | Not required | To be determined. |  |  |  |  |

##

## Requirements for Radiometric Accuracy and Correction

*The aim is to produce measurements of known and acceptable accuracy. Radiometric corrections that lead to a valid measurement may be included. The requirements indicate both the necessary outcomes (3.1-3.3) and the minimum steps necessary to be deemed to have achieved those outcomes (3.4 onward). These will vary between product families.*

*The following requirements must be met for all pixels (observations) in a collection. Examples of additional corrections are given. These will vary across product families.*

| **#** | **Item** | **Threshold (Minimum)****Requirements** | **Target (Desired)Requirements** | **ThresholdSelf-Assessment** | **TargetSelf-Assessment** | **Self-AssessmentExplanation/ Justification** | **RecommendedRequirementModification** |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | ***The items are the things that, for this product family, need to be included.*** | *Threshold requirements are the MINIMUM that is needed for the data to be analysis ready. This must be practical and accepted by the data producers* | *Target requirements are the ideal; where we would like to be. Some providers may be able to meet these already.* | *This is used by a data provider, to indicate if they think they meet the threshold*  | *This is used by a data provider, to indicate if they think they meet the target* | *This is used by a data provider, to explain why they self-assess in the way they have* | *This is used to capture recommended changes to the specification, based on consideration of stakeholder feedback.* |
| **Measurement type, uncertainty, and normalisation** |
| **3.1** | **Measurement\*** | The measurement type (e.g, surface reflectance, temperature etc.)  | Measurements are SI traceable. |  |  |  |  |
| **3.2** | **Measurement Uncertainty\*** | Not required.Note 1: In current practice,users determine fitness forpurpose based on knowledgeof the lineage of the data,rather than on a specificestimate of measurementuncertainty | An estimate of the certaintyof the values is provided inmeasurement units.Note 1: This is a requirementfor SI traceability. See also1.1.Note 2: Information onmeasurement uncertaintyshould be available in themetadata as a single DOIlanding page. |  |  |  |  |
| **3.3** | **Measurement Normalisation\*** | Not required. | Measurements arenormalised for observing conditions (e.g, ., nadirview angle and average solarangles). This may includeterrain illumination and/orBi-Directional ReflectanceFunction (BRDF) correction.Note 1: Information onmeasurement normalisationshould be available in themetadata as single DOIlanding page. |  |  |  |  |
| **Measurement corrections** |
| ***Examples of algorithm corrections applied to address the major sources of measurement error. These will be discipline dependent. Community will choose/update/adapt or propose the final corrections and requirements*** |
|  | **Directional Atmospheric Scattering** | Corrections are applied for aerosols and molecular (Rayleigh) scattering. Metadata contains a single DOI landing page with references to: • a citable peer reviewed algorithm • technical documentation regarding the implementation of that algorithm • the sources of ancillary data used to make corrections Note 1: Examples of technical documentation include an Algorithm Theoretical Basis Document, product user guide, etc. | As threshold. |  |  |  |  |
|  | **Water Vapour Corrections** | Corrections are applied for water vapour. Metadata contains a single DOI landing page with references to: • a citable peer reviewed algorithm • technical documentation regarding the implementation of that algorithm Note 1: Examples of technical documentation include an Algorithm Theoretical Basis Document, product user guide, etc. | As threshold. |  |  |  |  |
|  | **Ozone Corrections** | Not required. | Data is corrected for ozone. Relevant metadata must be provided under 1.8 and 1.9. Metadata contains a single DOI landing page with references to: • a citable peer reviewed algorithm • technical documentation regarding the implementation of that algorithm |  |  |  |  |

##

##

##

## *Requirements for Geometric Accuracy and Correction*

*Geometric corrections are steps that are taken to place the measurement accurately on the surface of the Earth (that is, to geolocate the measurement) allowing measurements taken through time to be compared. This section specifies any geometric correction requirements that must be met in order for the data to be analysis ready.*

| **#** | **Item** | **Threshold (Minimum)****Requirements** | **Target (Desired)Requirements** | **ThresholdSelf-Assessment** | **TargetSelf-Assessment** | **Self-AssessmentExplanation/ Justification** | **RecommendedRequirementModification** |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | ***The items are the things that, for this product family, need to be included.*** | *Threshold requirements are the MINIMUM that is needed for the data to be analysis ready. This must be practical and accepted by the data producers* | *Target requirements are the ideal; where we would like to be. Some providers may be able to meet these already.* | *This is used by a data provider, to indicate if they think they meet the threshold*  | *This is used by a data provider, to indicate if they think they meet the target* | *This is used by a data provider, to explain why they self-assess in the way they have* | *This is used to capture recommended changes to the specification, based on consideration of stakeholder feedback.* |
| **4.1** | **Geometric****Correction****Methods\*** | Indicate any mandatory geometric corrections for the data to be considered analysis-ready at the threshold level. E.g use of a terrain model | Indicate any mandatory geometric corrections for the data to be considered analysis-ready at the target level.E.g.: Accuracy is assessed byindependent verification (aswell as internal model-fitwhere applicable). |  |  |  |  |
| **4.2** | **Geometric****Accuracy of****the Data\*** | Indicate the level of geometric accuracy required for the data to be considered analysis ready, at the threshold level. E.g. 0.5 pixel etc.  | Indicate the level of geometric accuracy required for the data to be considered analysis ready, at the target level. E.g. 0.25 pixel etc. Note 1: Information ongeometric accuracy of thedata should be available in the metadata as a single DOIlanding page. |  |  |  |  |

# Guidance

This section aims to provide background and specific information on the processing steps that can be used to achieve analysis ready data for a specific and well developed Product Family Specification. This Guidance material does not replace or override the specifications.

# Introduction to CARD

**What is CEOS Analysis Ready Data?**

CARD products have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with a minimum of additional user effort. In general, these products would be resampled onto a common geometric grid (for a given product) and would provide baseline data for further interoperability both through time and with other datasets.

CARD products are intended to be flexible and accessible products suitable for a wide range of users for a wide variety of applications, including particularly time series analysis and multi-sensor application development. They are also intended to support rapid ingestion and exploitation via high-performance computing, cloud computing and other future data architectures. They may not be suitable for all purposes and are not intended as a ‘replacement’ for other types of satellite products.

**When can a product be called CARD?**

The CARD branding is applied to a particular product once:

* that product has been assessed as meeting CARD requirements by the agency responsible for production and distribution of the product, and
* that the assessment has been peer reviewed by the relevant CEOS team(s).

Agencies or other entities considering undertaking an assessment process should consult the CEOS ARD [Governance Framework](https://docs.google.com/document/d/15grQ79D-Ge8PN1_4_XDmci5iezs8HAcOpLcM7d2wmAo/edit?usp=sharing).

A product can continue to use CARD branding as long as its generation and distribution remain consistent with the peer-reviewed assessment.

**What is the difference between Threshold and Target?**

Products that meet all threshold requirements should be immediately useful for scientific analysis or decision-making.

Products that meet target requirements will reduce the overall product uncertainties and enhance broad-scale applications. For example, the products may enhance interoperability or provide increased accuracy through additional corrections that are not reasonable at the *threshold* level.

Target requirements anticipate continuous improvement of methods and evolution of community expectations, which are both normal and inevitable in a developing field. Over time, *target* specifications may (and subject to due process) become accepted as *threshold* requirements.

**Advisory Notes**

Advisory notes provide additional technical guidance to the user community and will be added when available, e.g. on recommended data formats. Advisory notes will be found on the CEOS ARD website.

# Glossary of Terms

Each required assessment **Term** definition included in the PFS. The general *Category* for each **Term** is added as a prefix.

| *Category-* **Term** | Description  | References/Resources/Examples |
| --- | --- | --- |
| *GeneralMetadata* - **Traceability** | The reference standard for the physical measurement. Preferably an SI reference. | E.g., the blackbody methodology for Brightness Temperature calibration of a infrared radiometer |
| *GeneralMetadata* - **Metadata Machine Readability** | Referring to the file-level or global header metadata model structure, its attributes and readability  | Typical community metadata conventions and standards (e.g., CF, ACDD, ISO-19115)  |
| *GeneralMetadata* - **Data Collection Time** | The temporal bounds of the observations expressed in a community best practice format | Using well known formats like [ISO-8661](https://en.wikipedia.org/wiki/ISO_8601)  |
| *GeneralMetadata* - **GeographicalArea** | The spatial region with bounding coordinates. Can also include vertical dimensions. | Captured in units of the coordinate system |
| *GeneralMetadata* - **Coordinate Reference System** | Coordinate Reference System (CRS) documented in metadata  | E.g., WGS-84/CF coordinates/WKT/EPSG code |
| *GeneralMetadata* - **Instrument** | The remote sensing instrument(s) used | Name derived from a well known community vocabulary such as the [GCMD instrument keywords](https://gcmd.earthdata.nasa.gov/KeywordViewer/scheme/instruments/6015ef7b-f3bd-49e1-9193-cc23db566b69?gtm_keyword=Earth%20Remote%20Sensing%20Instruments&gtm_scheme=instruments)  |
| *GeneralMetadata* - **Algorithms** | Measurement processing algorithms and their versions | For example, algorithms published in peer review literature |
| *GeneralMetadata* - **Auxiliary** | Algorithm and processing inputs from external sources | For example, data from models and other remote sensing products |
| *GeneralMetadata* - **Processing Chain Provenance** | Data product provenance information and metadata | Product provenance including processing systems, and software versions  |
| *GeneralMetadata* - **Data Access** | Data landing page or access location endpoint  | A DOI that points to a landing page with further access locations/services/endpoints as URLs |
| *GeneralMetadata* - **Geometric Correction Metadata Requirements** | Description of geometric correction methodology  |  A DOI that points to the geometric correction documentation |
| *GeneralMetadata* - **Geometric Accuracy Metadata Requirements** | Requirements for metadata on the geometric accuracy | A DOI that points to geometric accuracy documentation |

| *Category-* **Term** | Description  | References/Resources/Examples |
| --- | --- | --- |
| *PerPixel* - **Metadata Machine Readability** | Referring to the variable-level metadata model structure, its attributes and readability  | Typical community metadata conventions and standards (e.g, CF, ACDD, ISO-19115/3)  |
| *PerPixel* - **Quality Tests/** | A collection of tests (masks) to filter the measurement variable for missing data, outliers, and other data quality metrics | The exact tests are dependent on the type of remote sensing observation and instrument technology. For example passive optical radiometers will have at least a cloud/land/water mask and others relevant to atmospheric conditions. Active radar will have at least backscattering and saturation masks.  |
| *PerPixel* - **Quality Tests/No Data** | A test for missing values for measurement | Typically delineated as scalar or bit flag |
| *PerPixel* - **Observation Conditions/** | Additional collections of factors to assess the observation conditions affecting the measurement | The exact tests are dependent on the type of remote sensing observation and instrument technology.  |
| *PerPixel* - **Additional Correction Parameters/** | Additional collections of factors to assess any additional correction affecting the measurement | The exact tests are dependent on the type of remote sensing observation and instrument technology |

| *Category-* **Term** | Description  | References/Resources/Examples |
| --- | --- | --- |
| *Corrections/Accuracy* - **Measurement**  | Biogeophysical measurement traceable to SI  | Documented with CF Standard Name or CSDMS Standard name if possible |
| *Corrections/Accuracy* - **Measurement Normalization** | Measurements are normalised for solar and viewing conditions  |  |
| *Corrections/Accuracy* - **Measurement Uncertainty** | Uncertainty expressed as standard deviation, standard error or RMS. There could be other measures as well, e.g., ……. | The uncertainty methodology should be detailed in peer reviewed literature. Ground truth reference system should be noted. |
| *Corrections/Accuracy* - **Corrections Applied** | A collection of corrections applied as part of measurement retrieval. The exact corrections are dependent on the measurement and instrument type | Peer reviewed published methodology. Examples are water vapor, aerosol scattering, ozone, RFI etc.  |

| *Category-* **Term** | Description  | References/Resources/Examples |
| --- | --- | --- |
| *Geometric Accuracy and Corrections* - **Geometric Accuracy of Data**  | The assessed geodetic accuracy of the data. Should be accessible from dataset landing page | Eg, assessed to 0.5 pixel accuracy |
| *Geometric Accuracy and Corrections* - **Geometric Correction Methods** | Mandatory geometric correction methods for the data to be considered analysis ready  |  A DOI that points to the geometric correction documentation |