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|  | **Analysis Ready Data**  ***For Land*** | **Product Family**  **Specification** |

**Description**

**Product family title**

Surface Reflectance

**Applies to**

*Data collected by (10-100m) resolution multispectral VIS/NIR/SWIR sensors.*

**Requirements**

**General metadata**

*A metadata records describing a distributed collection of pixels must comply with the following requirements. The collection of pixels must be contiguous in space and time.*

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| **Item** | **Threshold requirements** | **Target requirements** |
| **Traceability** | Not applicable | Data must be traceable to SI reference standard. |
| **Metadata machine readability** | Metadata is provided in a structure that enables a computer algorithm to be used to consistently and automatically identify and extract each component part for further use. | As threshold, but metadata is formatted in accordance with ISO 19115-2. |
| **Data collection time** | The start and stop time of data collection 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. |
| **Geographical area** | The surface locations to which the data relates is identified, typically as a series of four corner points, expressed in WGS84 coordinates. | The location to which each pixel refers is identified (or can be reliably determined), expressed in projection coordinates with reference datum. |
| **Coordinate reference system** | The metadata lists the coordinate reference system that has been used. | As threshold |
| **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. | As threshold |
| **Geometric correction source** | Not applicable | The geometric correction source is identified in the metadata. DOIs are used.  *Note 1: for example, the GCP chipset and digital elevation model are identified.* |
| **Geodetic correction methods** | Not applicable | The metadata describes the geodetic correction methods used, including reference database and elevation model(s) versions. DOIs are used. |
| **Geodetic accuracy** | Not applicable | The metadata includes metrics describing the assessed geodetic accuracy of the data, expressed in projection units. Uncertainties expressed as root mean square error (RMSE) for the model and independent verification. |
| **Instrument** | The instrument used to collect the data is identified in the metadata. | As threshold, but including a reference to the relevant CEOS Missions, Instruments and Measurements Database record. |
| **Spectral bands** | The central wavelength for each band for which data is included is identified in the metadata, expressed in SI units. | As threshold, with instrument spectral response details also included in the metadata, or directly accessible using details in the metadata. Central wavelength and bandwidth at full-width half maximum value of the relative spectral response function are provided. |
| **Sensor calibration** | Not applicable | Sensor calibration parameters are identified in the metadata, or can be accessed using details included in the metadata.  Note 1: for example, a calibration parameter file located through a DOI. |
| **Radiometric accuracy** | Not applicable | The metadata includes metrics describing the assessed absolute radiometric accuracy of the data, expressed as absolute radiometric uncertainty relative to a known reference standard (i.e. pseudoinvariant calibration sites (PICS)  *Note 1: for example, this may come from comparison with rigorously collected field spectra.* |
| **Algorithms** | All algorithms, and the sequence in which they were applied in the generation process, are identified in the metadata. | As threshold, but only algorithms that have been published in a peer-reviewed journal, and are openly available to users of the data, are identified.  DOIs for each algorithm are identified in the metadata. The versions of the algorithms are identified. |
| **Ancillary data** | The metadata identifies the sources of ancillary data used in the generation process, expressed as DOIs. The ancillary data can be requested from the owner.  *Note 1: a requestor may be required to pay for the ancillary data.*  *Note 2: ancillary data includes aerosol data source,* | As threshold, but the ancillary data is also available for free online download, contemporaneously with the product. |
| **Processing chain provenance** | Not applicable | The metadata includes a description of the processing chain used to generate the product, including the versions of software used. |
| **Data access** | The metadata identifies the location from where the product can be retrieved, expressed as a DOI.  *Note 1: Manual and offline interaction action (e.g. log in) may be required.* | The metadata identifies an online location from where the data (including any available new records) can be consistently and reliably retrieved by a computer algorithm without any manual intervention being required.  *Note 1: Some manual interaction action may be required on a ‘one off’ basis to establish ongoing access to the data.* |
| **Overall data quality** | Not applicable | Machine-readable metrics describing the overall quality of the data are included in the metadata, at minimum:   * Percentage of pixels contaminated by cloud and cloud shadows * For coastal scenes, percentage of land pixels contaminated by clouds and cloud shadows |

**Per-pixel metadata**

*The following minimum metadata specifications apply to each pixel. It is at the discretion of the data provider whether the metadata is provided in a single record that is relevant to all pixels, or is provided separately for each pixel.*

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| **Item** | **Threshold requirements** | **Target requirements** |
| **Metadata machine readability** | Metadata is provided in a structure that enables a computer algorithm to be used to consistently and automatically identify and extract each component part for further use. | As threshold, but metadata is formatted in accordance with ISO 19115-2. |
| **No data** | Pixels that do not correspond to an observation (‘empty pixels’) are clearly flagged. | As threshold. |
| **Untested pixels** | 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, if any, pixels are saturated in any spectral band. |
| **Cloud** | Metadata indicates whether a pixel is assessed as being cloud. | As threshold, with the metadata referencing a citable peer-reviewed algorithm for cloud/cloud shadow detection, expressed as a DOI. |
| **Cloud shadow** | Metadata indicates whether a pixel is assessed as being cloud shadow. |
| **Land/water mask** | Not applicable. | The metadata indicates whether a pixel is assessed as being land or water. The metadata references a citable peer-reviewed algorithm, expressed as a DOI. |
| **Snow/ice mask** | Not applicable | The metadata indicates whether a pixel is assessed as being snow/ice or not. The metadata references a citable peer-reviewed algorithm, expressed as a DOI. |
| **Terrain shadow mask** | Not applicable | Terrain occlusion for data acquired with an off-nadir viewing geometry. |

**Atmospheric corrections**

*The following requirements must be met for all pixels in a collection. BRDF correction is optional.*

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| **Item** | **Threshold requirements** | **Target requirements** |
| **Aerosol** | Data is corrected for aerosols.  Metadata references:   * a citable peer-reviewed algorithm, * technical documentation regarding the implementation of that algorithm   expressed as DOIs.  *Note 1: examples of technical documentation include an Algorithm Theoretical Basis Document, product user guide, etc.* | As threshold, and should denote whether aerosol estimated through an inversion model or other source (e.g. climatology product) |
| **Water vapor** | Data is corrected for water vapor.  Metadata references:   * a citable peer-reviewed algorithm, * technical documentation regarding the implementation of that algorithm   expressed as DOIs.  *Note 1: examples of technical documentation include an Algorithm Theoretical Basis Document, product user guide, etc.* | As threshold. |
| **Normalisation** | Data is normalized for solar-zenith angle (altitude). | Data is normalized to nadir view angle / defined solar altitude/azimuth. |
| **Ozone** | Not applicable | Data is corrected for ozone. Metadata references:   * a citable peer-reviewed algorithm, * technical documentation regarding the implementation of that algorithm,   expressed as DOIs. |
| **Solar incidence angle** | Not applicable | The solar incidence and sensor viewing angles are identified for each pixel, including coefficients used for terrain illumination correction. |
| **Directional scattering in the atmosphere** | Not applicable | The algorithm description document should |
| **Aerosol optical depth parameters** | Not applicable | Identified per pixel. |

**Geometric corrections**

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| **Item** | **Threshold requirements** | **Target requirements** |
| **Accuracy** | Sub-pixel accuracy in geolocation, less than or equal to 0.5 pixel radial root mean square error (rRMSE). rRMSE value is included in metadata. | Pixels are located with sub-pixel accuracy relative to an independent spatial referencing system.  Metadata provides references to published and citable correction methods, which are expressed as DOIs.  *Note 1: This requirement is intended to enable cross-referencing with non-image spatial data such as GIS layer and terrain models, and also with other data sources that meet this level of correction.* |

**Introduction to CARD4L**

**What is CEOS Analysis Ready Data for Land (CARD4L) products?**

CARD4L 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 and interoperability both through time and with other datasets.

CARD4L 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 CARD4L?**

The CARD4L branding is applied to a particular product once:

* that product has been assessed as meeting CARD4L requirements by the agency responsible for production and distribution of the product.
* that assessment has been peer reviewed by the CEOS Land Surface Imaging Virtual Constellation in consultation with the CEOS Working Group on Calibration and Validation.

Agencies or other entities considering undertaking an assessment process should contact the co-leads of the Land Surface Imaging Virtual Constellation (hyperlink).

A product can continue to use CARD4L branding as long as its generation and distribution remain consistent with the peer-reviewed assessment.

**What is the difference between threshold and breakthough?**

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.