	Analysis Ready Data *For Land*	**Product Family Specification** **Optical Surface Reflectance** **(CARD4L-OSR)**

Document status

For Adoption as: <u>**Product Family Specification, Surface Reflectance, Working Draft (2017)**</u>

This Specification should next be reviewed at: September 2018.

Proposed revisions may be provided to: lsi@lists.ceos.org

Document history

Version	**Date**	**Description of change**	**Author**
0.0.2	01-03-2017	Zero Draft translating previous materials to this format. With many thanks to all CEOS contributors.	Jono Ross
1.0.0	16-04-2017	Included document history; added numbering and pagination to improve navigability and internal referencing of sections; Added Guidance Section; - various minor edits - revised 1.4 'target' - 1.7, 1.8, 1.9 may need revisiting - Added 3.1, measurement - Added 3.2, uncertainty - Added 2.10, terrain occlusion -	Adam Lewis
2.0.0	30-08-2017	Feedback incorporated, circulated to LSI-VC	Lewis
2.1.0	06-09-2017	Feedback from ESA incorporated and comments noted on 1.11, 1.12, 1.8; 1.15; 1.17; 3.6-3.8; 4.1.	Lewis
2.1.1	06-09-2017	Tracked changes rolled in	Lewis
2.1.2	11-11-2017	Edits	Lewis
3.0	22.01.2018	Feedback from the teleconference (06/12/2018) and post teleconf (emails) included	Siqueira

Description

Product family title: **Optical Surface Reflectance** (CARD4L-OSR)

Applies to: Data collected with multispectral sensors operating in the VIS/NIR/SWIR wavelengths. These typically operate with ground sample distance and resolution in the order 10-100m however the Specification is not inherently limited to this resolution.

Definitions

OSR	Optical Surface Reflectance
Ancillary Data	Ancillary data is 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.
Auxiliary Data	Auxiliary data is 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.
MTF	Modulation Transfer Function
Spectral Resolution	The 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

1. General Metadata

These are metadata records describing a distributed collection of pixels. 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	Threshold (minimum requirements)	Target (desired) requirements
1.1	Traceability	Not required	Data must be traceable to SI reference standard. For further information see, for example, http://l-a-b.com/information/traceability/ *Note 1. Relationship to 3.2. Traceability requires an estimate of measurement uncertainty*
1.2	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.
1.3	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.
1.4	Geographical area	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. 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
1.6	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

1.7	**Geometric correction methods**	Not required. The user is not explicitly advised of the geometric correction source and methods.	The metadata describes the geodetic correction methods used, including reference database and ancillary data such as elevation model(s) and reference chip-sets. DOIs are used.
1.8	**Geometric accuracy of the data**	Not required. The user is not provided with results of geometric accuracy assessments pertaining to the dataset	The metadata includes metrics describing the assessed geodetic accuracy of the data, expressed units of the coordinate system of the data. Accuracy is assessed by independent verification (as well as internal model-fit where applicable). Uncertainties are expressed quantitatively, for example, as root mean square error (RMSE) or Circular Error Probability (CEP90, CEP95), etc.
1.9	**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.
1.10	**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 (e.g. full spectral response function) also included , 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 at least.
1.11	**Sensor calibration**	Not required. The general metadata does not include sensor calibration details	Sensor calibration parameters are identified in the metadata, or can be accessed using details included in the metadata. Ideally this would support machine to machine access. *Note 1: for example, a calibration parameter file located through a DOI.*
1.12	**Radiometric accuracy**	Not required. The general metadata does not include information on the radiometric accuracy of the data.	The metadata includes metrics describing the assessed absolute radiometric uncertainty of the data, expressed as absolute radiometric uncertainty relative to appropriate, known reference sites and standards (for example,. pseudoinvariant calibration sites, rigorously collected field spectra, , PICS, Rayleigh, DCC etc.)
1.13	**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.	As threshold, but only algorithms that have been published in a peer-reviewed journal. *Note: 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.*

			DOIs for each algorithm are identified in the metadata. The versions of the algorithms are identified.
1.14	**Ancillary data**	The metadata identifies the sources of ancillary data used in the generation process, ideally expressed as DOIs. *Note 1: ancillary data includes DEMs, aerosols etc. data sources*	As threshold, but the ancillary data is also available for free online download, contemporaneously with the product.
1.15	**Processing chain provenance**	Not required.	The metadata include a detailed description of the processing steps used to generate the product, including the versions of software used, giving full transparency to the users
1.16	**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 <u>in the first instance</u> ('one off' basis) to establish ongoing access to the data.*
1.17	**Overall data quality**	Not applicable	Machine-readable metrics describing the overall quality of the data are included in the metadata, at minimum the cloud cover extent, i.e.: ● Proportion of observations over land (c.f. ocean) affected by non-target phenomena, e.g., cloud and cloud shadows.

2. Per-pixel metadata

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

	Item	Threshold (minimum) requirements	Target (desired) requirements
2.1	**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.
2.2	**No data**	Pixels that do not correspond to an observation ('empty pixels') are flagged.	As threshold.
2.3	**Incomplete testing**	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.
2.4	**Saturation**	Metadata indicates where one or more spectral bands are saturated.	Metadata indicates which pixels are saturated for each spectral band.
2.5	**Cloud**	Metadata indicates whether a pixel is assessed as being cloud	As threshold, with referencing (DOI) to a peer-reviewed algorithm for cloud detection.
2.6	**Cloud shadow**	Metadata indicates whether a pixel is assessed as being cloud shadow.	As threshold, with referencing (DOI) to a peer-reviewed algorithm for cloud shadow detection.
2.7	**Land/water mask**	Not required	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.
2.8	**Snow/ice mask**	Not required	The metadata indicates whether a pixel is assessed as being snow/ice or not. The metadata references a citable peer-reviewed algorithm, as a DOI.
2.9	**Terrain shadow mask**	Not required	The metadata indicates pixels that are not directly illuminated due to terrain shadowing
2.10	**Terrain occlusion**	Not required	The metadata indicates pixels that are not visible to the sensor due to terrain occlusion during off-nadir viewing.
2.11	**Illumination and viewing geometry**	Provide average viewing and average illumination for the threshold requirement	The solar incidence and sensor viewing angles are identified for each pixel, including coefficients used for terrain illumination correction.

		Threshold (minimum) requirements	Target (desired) requirements
2.12	**Aerosol optical depth parameters**	Not required	to be determined

3. Radiometric and atmospheric corrections

The following requirements must be met for all pixels in a collection. 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 onwards). Radiometric corrections must lead to a valid measurement of surface reflectance.

	Item	Threshold (minimum) requirements	Target (desired) requirements
3.1	**Measurement**	Pixel values that are expressed as a measurement of the Surface Reflectance of the land. This is a dimensionless value.	Surface Reflectance measurements are SI traceable (see also 1.1)
3.2	**Measurement uncertainty**	Not required *Note 1: in current practice, users determine fitness for purpose based on knowledge of the lineage of the data, rather than on a specific estimate of measurement uncertainty.*	An estimate of the certainty of the values is provided in measurement units. *Note 1. This is a requirement for SI traceability. See also 1.1.*
3.3	**Measurement Normalisation**	Not required	Measurements are normalised for illumination and viewing conditions including nadir view angle and specified solar altitude and azimuth. This may include BRDF correction. Relevant meta-data (pixel-level solar illumination an viewing geometry, etc.) are included as per 2.11
3.4	**Directional Atmospheric Scattering**	Corrections are applied for aerosols and molecular (Rayleigh) scattering. Metadata references: ● a citable peer-reviewed algorithm, ● technical documentation regarding the implementation of that algorithm expressed as DOIs ● the sources of ancillary data used to make corrections.	As threshold.

		Note 1: examples of technical documentation include an Algorithm Theoretical Basis Document, product user guide, etc. *Note 2: requirement for metadata are better placed in 1.13 and 1.14.*	
3.5	**Water vapour corrections**	Corrections are applied for water vapour. 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.* *Note 2: requirement for metadata are are better placed in 1.13 and 1.14.*	As threshold.
3.6	**Ozone corrections**	Not required	Data is corrected for ozone. Relevant metadata must be provided under 1.8 and 1.9 Metadata references: ● a citable peer-reviewed algorithm, ● technical documentation regarding the implementation of that algorithm, expressed as DOIs.

4. Geometric corrections

Geometric corrections must place the measurement accurately on the surface of the Earth (that is, geolocate the measurement) allowing measurements taken through time to be compared.

	Item	Threshold (minimum) requirements	Target (desired) requirements
4.1	**Geometric correction**	Sub-pixel accuracy is achieved in <u>relative</u> geolocation, that is, the pixels from the same instrument and platform are consistently located, and in thus comparable, through time. Sub-pixel accuracy is taken to be less than or equal to 0.5-pixel radial root mean square error (rRMSE) or equivalent in Circular Error Probability (CEP) relative to a defined reference image. A consistent gridding / sampling frame is used, including common cell size, origin, and nominal sample point location within the cell (centre, ll, ur) Relevant metadata must be provided under 1.8 and 1.9 *Note 1. The threshold level will not necessarily enable interoperability between data from <u>different</u> sources as the geometric corrections for each of the sources may differ. Therefore, this may be too low a bar to meet the objectives of CARD4L*	Sub-pixel accuracy is achieved relative to an identified absolute independent terrestrial referencing system (such as a national map grid). A consistent gridding / sampling frame is necessary to meet this requirement. Relevant metadata must be provided under 1.8 and 1.9 *Note 1: This requirement is intended to enable interoperability between imagery from different platforms that meet this level of correction, and with non-image spatial data such as GIS layers and terrain models.*

Guidance

This section aims to provide background and specific information on the processing steps that can be used to achieve analysis ready data. This Guidance material does not replace or over-ride the specifications.

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. 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.

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, and.
- that assessment has been peer reviewed by the CEOS Land Surface Imaging Virtual Constellation in consultation with other CEOS working groups as appropriate, including the CEOS Working Group on Calibration and Validation.

Agencies or other entities considering undertaking an assessment process should contact 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 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.

Procedural examples

Processes to produce Threshold Optical Surface Reflectance CARD4L

The following correction processes would typically be applied to produce CARD4L-OSR Threshold

- *no processes are provided at this point in time*

The following additional processes could be applied to produce CARD4L-OSR Target

- *no example processes are provided at this time.*

Specific examples

Processes to produce Threshold Optical Surface Reflectance CARD4L

Reference papers

The following papers provide scientific and technical guidance:

Li, F., Jupp, D.L.B., Thankappan, M., Lymburner, L., Mueller, N., Lewis, A., Held, A. (2012). A physics-based atmospheric and BRDF correction for Landsat data over mountainous terrain. *Remote Sensing of Environment* 124 (2012) 756–770