

CEOS-ARD Product Family Specification

Surface Reflectance

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Version 5.0.1
December 2023



Document Status

Product Family Specification, Surface Reflectance

Proposed revisions may be provided to:

ard-contact@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.	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	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 during and after (emails) the teleconference (06/12/2018) included.	Siqueira
3.1	31.01.2019	Proposed final SR PFS draft shared with USGS, ESA, and GA self-assessment leads seeking further comments. The draft addressed the feedback provided by the agencies' ARD data self-assessment process.	Siqueira
3.1.1	06.02.2019	Final draft shared with LSI-VC list and LSI-VC-7 meeting participants seeking support for document endorsement at the LSI-VC-7.	Siqueira
3.1.1	22.02.2019	Comments and suggestions from LSI-VC-7 meeting (minutes) and feedback from USGS incorporated.	Siqueira
3.1.2	28.02.2019	Formatting and verbiage updated for consistency.	Metzger
4.0	02.03.2019	Version endorsed at LSI-VC7 meeting (14Feb 2019)	LSI-VC
4.1	26.06.2019	Added self-assessment columns	Bontje
4.2	08.05.2020	This review cycle considers feedback received from USGS and ESA after the formal self-assessment for Surface	Siqueira

4.3 5.0	25.05.2020 08.06.2020	Reflectance products (Landsat and Sentinel-2). Minor editorial changes were done throughout the document. Requirements 1.2, 1.3, 1.7, 1.12, 1.13, 1.14, 1.16, 2.1, 2.11, 2.12, 2.13 and 3.3 have been updated. Feedback from USGS added (email: 21/05/2020). Tech edit.	Siqueira Bontje, Labahn
5.0.1	6 December 2023	Minor update to resolve the issue with parameter 1.6 (Map Projection) of the Surface Reflectance PFS (Ref: LSI-VC-13-07) by adopting the same wording used in section 1.7.11 of the recently endorsed Combined CEOS-ARD for Synthetic Aperture Radar PFS, that is, adding “(or geographical coordinates, if applicable)” after the requirement that “The metadata lists the map projection that has been used...”. Also: changed ‘Target’ to ‘Goal’ throughout, updated POC email address, replaced ‘CARD4L’ with ‘CEOS-ARD’, and made various minor editorial changes.	Labahn, Steventon, LSI-VC

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Jonathon Ross, Geoscience Australia, Australia
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Darcie Bontje, USGS, USA
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Matt Steventon, LSI-VC Secretariat

Description

Product Family Title: Surface Reflectance (CEOS-ARD-SR)

Applies to: Data collected with multispectral optical sensors operating in the VIS/NIR/SWIR wavelengths at all ground sample distances and resolutions.

Definitions

SR	Surface Reflectance
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.

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.
MTF	Modulation Transfer Function
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

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	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
1.1	Traceability	Not required.	Data must be traceable to SI reference standard. <i>Note 1: Relationship to 3.2. Traceability requires an estimate of measurement uncertainty.</i> <i>Note 2: Information on traceability should be available in the metadata as a single DOI landing page.</i>	Not Required		Not Required	Not Required
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.	Yes		Metadata provided in JSON object types as defined by the SpatioTemporal Asset Catalog (STAC) family of specifications and exposed via STAC service. <i>Note: examples provided here conform to STAC version 1.0.0.</i>	Verified at Threshold
1.3	Data Collection Time	The data collection time is identified in the metadata, expressed in date/time, to the	Acquisition time for each pixel is identified (or can be reliably determined) in the metadata, expressed in	Yes		The properties object of the STAC Item contains the acquisition date/time, to the millisecond, at the	Verified at Threshold

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
		second, with the time offset from UTC unambiguously identified.	date/time at UTC, to the second.			center of the scene (datetime) and start/stop (start/stop_datetime) of data collection, in ISO 8601 format. Example: <pre> "properties": { "datetime": "2021-09-23T17:12:40.033513Z", "start_datetime": "2021-09-23T17:12:29.616231Z", "end_datetime": "2021-09-23T17:12:50.435969Z", }</pre>	
1.4	Geographic 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)	Yes		The STAC Item contains: • bbox: the bounding box of the product, in EPSG:4326 • geometry: the GeoJSON polygon of the product, in EPSG:4326 The location of each pixel can be identified from the GeoTIFF file directly.	Verified at Threshold

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
			and reference datum provided.				
1.5	Coordinate Reference System	The metadata lists the coordinate reference system that has been used.	As threshold.	Yes		The properties object of the STAC Item contains the coordinate reference system (<code>proj:epsg</code>) Example: <pre>"properties": { "proj:epsg": 32615, }</pre>	Verified at Threshold, Goal Level not assessed.
1.6	Map Projection	The metadata lists the map projection that has been used (or geographical coordinates, if applicable) and any relevant parameters required in relation to use of data in that map projection.	As threshold.	Yes		The product GeoTIFF files contain information about the map projection. Additionally, the assets object of the STAC Item contains <code>proj:transform</code> and <code>proj:shape</code> for each asset included. Example: <pre>"proj:shape": [27232, 10256], "proj:transform": [5.0, 0.0, 368080.0, 0.0, -5.0, 4546240.0]</pre>	Verified at Threshold, Goal Level not assessed.

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
1.7	Geometric Correction Methods	Not required. The user is not explicitly advised of the geometric correction source and methods.	Information on geometric correction methods should be available in the metadata as a single DOI landing page, including reference database and auxiliary data such as elevation model(s) and reference chip-sets.	Not Required		Not Required. Product spec detailing all algorithms used in the generation process is included in the links object of the STAC Item, under about. See section "Geometric Refinement" in provided documentation.	Not Required
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. <i>Note 1: Information on geometric accuracy of the data should be available in</i>	Not Required		Not Required. RMSE is included in the properties object of the STAC Item as <code>accuracy:geometric_rmse</code> Example: <pre>"properties": { "accuracy:geometric_rmse": 2.0982960740470653, }</pre>	Not Required

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
			<i>the metadata as a single DOI landing page.</i>				
1.9	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.	Yes		The properties object of the STAC Item contains information about the instrument on the <code>constellation</code>, <code>platform</code>, and <code>instruments</code> fields. Example: <pre>"properties": { "constellation": "edc", "platform": "edc03", "instruments": ["vnir", "swir"], }</pre>	Verified at Threshold
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. <i>Note 1: Information on</i>	Yes		The properties object of the STAC Item contains the central wavelength for each band on the <code>eo:bands</code> field. Additionally, the assets object of the STAC Item contains <code>eo:bands</code> for each asset included. Example: <pre>"properties": {</pre>	Verified at Threshold

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
			<i>spectral bands should be available in the metadata as a single DOI landing page.</i>			<pre> "eo:bands": [{ "center_wavelength": 0.6645, "common_name": "red", "description": "Red", "name": "R" }] </pre>	
1.1 1	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. <i>Note 1: Information on sensor calibration should be available in the metadata as a single DOI landing page.</i>	Not Required		Not Required. Product spec detailing all algorithms used in the generation process is included in the links object of the STAC Item, under <code>about</code>. See section “Calibration & Validation” in provided documentation.	Not Required
1.1 2	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 version of the data or product, expressed as absolute radiometric uncertainty relative to	Not Required		Not Required	Not Required

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
			appropriate, known reference sites and standards (for example, pseudo-invariant calibration sites, rigorously collected field spectra, PICS, Rayleigh, DCC, etc.) <i>Note 1: Information on radiometric accuracy should be available in the metadata as a single DOI landing page.</i>				
1.1 3	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. <i>Note 1: Information on algorithms should be available in the metadata as a single DOI landing page.</i>	As threshold, but only algorithms that have been published in a peer-reviewed journal. <i>Note 1: It is possible that high quality corrections are applied through non-disclosed processes. CEOS-ARD does not per-se require full and open data and methods.</i> <i>Note 2: Information on algorithms should be available in the metadata as a single DOI landing page.</i>	Yes		Product spec detailing all algorithms used in the generation process is included in the links object of the STAC Item, under about .	Verified at Threshold
1.1 4	Auxiliary Data	The metadata identifies the sources of auxiliary	As threshold, but information on auxiliary	Yes		Product spec detailing all algorithms used in the	Verified at Threshold

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
		data used in the generation process, ideally expressed as a single DOI landing page. <i>Note 1: Auxiliary data includes DEMs, aerosols, etc. data sources.</i>	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.			generation process is included in the links object of the STAC Item, under about . See section “Auxiliary Data” in provided documentation.	
1.1 5	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.	Not Required		Not Required. Product spec detailing all algorithms used in the generation process is included in the links object of the STAC Item, under about . See section “Processing Baseline” in provided documentation.	Not Required
1.1 6	Data Access	Information on data access should be available in the metadata as a single DOI landing page. <i>Note 1: Manual and offline interaction action (e.g., login) may be required.</i>	As threshold.	Yes		Information on data access is included in the links object of the STAC Item, under access .	Verified at Threshold, Goal Level not assessed.

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
1.1 7	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	Not Applicable		Not applicable. The properties object of the STAC Item contains information about the cloud cover and the unusable cover on the <code>eo:cloud_cover</code> and <code>eda:unusable_cover</code> fields. Example: <pre>"properties": { "eo:cloud_cover": 0.097716462489117, "eda:unusable_cover": "0.1820500184598164", }</pre>	Not applicable, Goal Level not assessed.

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 discriminate between (choose) observations on the basis of their individual suitability for application.

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
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.	Yes		Per-pixel metadata is provided in GeoTIFF format. See: - Quality mask file (<code><product_name>_MASK.tif</code>) - Saturation mask files (<code><product_name>_SATURATION.tif</code>) - Solar angles file (<code><product_name>_VIEW.tif</code>) - View angles file (<code><product_name>_VIEW.tif</code>)	Verified at Threshold, Goal Level not assessed.
2.2	No Data	Pixels that do not correspond to an observation ('empty pixels') are flagged.	As threshold.	Yes		Band 1 in the quality mask file is the "Data" layer.	Verified at Threshold, Goal Level not assessed.

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
						<i>Note: The definition of pixel values in the data layer is:</i> 1 = valid imagery. 0 = blackfill	
2.3	Incomplete Testing	The metadata identifies pixels for which the per-pixel tests (below) have not all been successfully completed. <i>Note 1: This may be the result of missing ancillary data for a subset of the pixels.</i>	The metadata identifies which tests have, and have not, been successfully completed for each pixel.	Yes		As indicated in requirements 2.4-2.8, the metadata identifies with 0 if a pixel contains blackfill or no assessment is available for each test.	Verified at Threshold.
2.4	Saturation	Metadata indicates where one or more spectral bands are saturated.	Metadata indicates which pixels are saturated for each spectral band.	Yes		Saturation mask files indicate which pixels are saturated for each spectral band. <i>Note: The definition of pixel values in the saturation mask is:</i> 0 = blackfill or no assessment available 1 = valid, unsaturated 2 = saturated	Verified at Threshold.
2.5	Cloud	Metadata indicates whether a pixel is	As threshold, information on cloud detection should	Yes		Band 2 in the quality mask file is the	Verified at Threshold.

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
		assessed as being cloud.	be available in the metadata as a single DOI landing page.			“cloud” layer. <i>Note: The definition of pixel values in the cloud layer is:</i> • 2 = cloud • 1 = clear • 0 = blackfill / no assessment	
2.6	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.	Yes		Band 4 in the quality mask file is the “cloud shadow” layer. <i>Note: The definition of pixel values in the cloud shadow layer is:</i> • 2 = shadow • 1 = clear • 0 = blackfill / no assessment	Verified at Threshold.
2.7	Land/Water Mask	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.	Not Required		Band 7 in the quality mask file is the “water” layer. <i>Note: The definition of pixel values in the water layer is:</i> • 2 = water • 1 = clear • 0 = blackfill / no assessment	Not Required
2.8	Snow/Ice Mask	Not required.	The metadata indicates whether a pixel is	Not Required		Band 6 in the quality mask file is the	Not Required

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
			assessed as being snow/ice or not. Information on snow/ice mask should be available in the metadata as a single DOI landing page.			“snow” layer. <i>Note: The definition of pixel values in the snow layer is:</i> • 2 = snow • 1 = clear • 0 = blackfill / no assessment	
2.9	Terrain Shadow Mask	Not required.	The metadata indicates pixels that are not directly illuminated due to terrain shadowing.	Not Required		Not Required	Not Required
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.	Not Required		Not Required	Not Required
2.11	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.	Yes		<product_name>_SOLAR.tif file contains solar angles (i.e. sun azimuth and elevation) as individual bands over a grid covering the product, with pixel spacing of at most 2 km. <product_name>_VIEW.tif file contains viewing angles (i.e. azimuth	Verified at Threshold.

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
						and incidence) as individual bands over a grid covering the product, with pixel spacing of at most 2 km. Additionally, the propertyed object of STAC Item includes the fields view:azimuth, view:incidence_angle, view:off_nadir, view:sun_azimuth and view:sun_elevation Example: <pre>"properties": { "view:azimuth": 103.86866018749645 , "view:incidence_angle": 8.969184960500073, "view:off_nadir": 8.125357532049144, "view:sun_azimuth"</pre>	

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
						: 158.89766843803034 , "view:sun_elevation": 47.295183511526915 , }	
2.1 2	Terrain Illumination Correction	Not required.	Coefficients used for terrain illumination correction are provided for each pixel.	Not Required		Not Required	Not Required
2.1 3	Aerosol Optical Depth Parameters	Not required.	To be determined.	Not Required		Not Required	Not Required.

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 onward). Radiometric corrections must lead to a valid measurement of surface reflectance.

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
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).	Yes		Pixel values are expressed as a measurement of the Surface Reflectance, with scale = 0.0001 and offset = -0.1 $SR = DN * scale + offset$ The scale and offset values are available in the raster:bands properties of the STAC asset and are also embedded in the GeoTIFF file metadata.	Verified at Threshold.
3.2	Measurement Uncertainty	Not required. <i>Note 1: In current practice, users determine fitness for purpose based on knowledge of the lineage of the data,</i>	An estimate of the certainty of the values is provided in measurement units. <i>Note 1: This is a requirement for SI traceability. See also 1.1.</i>	Not Required		Not Required	Not Required

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
		<i>rather than on a specific estimate of measurement uncertainty.</i>	<i>Note 2: Information on measurement uncertainty should be available in the metadata as a single DOI landing page.</i>				
3.3	Measurement Normalisation	Not required.	Measurements are normalised for solar and viewing conditions (i.e., nadir view angle and average solar angles). This may include terrain illumination and/or Bi-Directional Reflectance Function (BRDF) correction. <i>Note 1: Information on measurement normalisation should be available in the metadata as a single DOI landing page.</i>	Not Required		Not Required	Not Required
3.4	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	As threshold.	Yes		Atmospheric corrections for aerosols and molecular (Rayleigh) scattering are applied to the Top-of-atmosphere (TOA) reflectance to derive the	Verified at Threshold, Goal Level not assessed.

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
		- algorithm - technical documentation regarding the implementation of that algorithm - the sources of ancillary data used to make corrections <i>Note 1: Examples of technical documentation include an Algorithm Theoretical Basis Document, product user guide, etc.</i>				surface reflectance. Band 1 in the atmospheric parameters file <product_name>_ATM.tif contains the aerosol optical thickness map derived for the product. Product spec detailing all algorithms used in the generation process is included in the links object of the STAC Item, under about and atmospheric-scattering. See section "Atmospheric Correction" in provided documentation.	
3.5	Water Vapour Corrections	Corrections are applied for water vapour.	As threshold.	Yes		Atmospheric corrections for water vapour are	Verified at Threshold, Goal Level not assessed.

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
		Metadata contains a single DOI landing page with references to: • a citable peer-reviewed algorithm • technical documentation regarding the implementation of that algorithm <i>Note 1: Examples of technical documentation include an Algorithm Theoretical Basis Document, product user guide, etc.</i>				applied to the Top-of-atmosphere (TOA) reflectance to derive the surface reflectance. Band 2 in the atmospheric parameters file <product_name>_ATM.tif contains the total column water vapour map derived for the product. Product spec detailing all algorithms used in the generation process is included in the links object of the STAC Item, under about and water-vapor. See section "Atmospheric Correction" in provided	

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
						documentation.	
3.6	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	Not Required		Not Required	Not Required

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	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
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 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).	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. <i>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.</i>	Yes		EDC imagery products are delivered as orthorectified scenes, where each pixel is projected onto a consistent pixel grid to avoid subpixel shifts between independent products covering the same map projection and target pixel size. This ensures accurate geolocation and compatibility across multi-temporal datasets. RMSE is included in the properties object of the STAC Item as <code>accuracy:geom</code>	Verified at Threshold.

#	Item	Threshold (Minimum) Requirements	Goal (Desired) Requirements	Threshold Self-Assessment	Goal Self-Assessment	Self-Assessment Explanation/Justification	Recommended Requirement Modification
		Relevant metadata must be provided under 1.8 and 1.9. <i>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.</i>				etric_rmse Example: <pre>"properties": { "accuracy:geometric_rmse": 2.0982960740470653, }</pre> Product spec detailing all algorithms used in the generation process is included in the links object of the STAC Item, under about. See section “Geometric Refinement” in provided documentation.	

Summary Self-Assessment Table

	Threshold	Goal
1. General Metadata		
1.1 Traceability	Not Required	Not Assessed
1.2 Metadata Machine Readability	Yes	Not Assessed
1.3 Data Collection Time	Yes	Not Assessed
1.4 Geographical Area	Yes	Not Assessed
1.5 Coordinate Reference System	Yes	Not Assessed
1.6 Map Projection	Yes	Not Assessed
1.7 Geometric Correction Methods	Not Required	Not Assessed
1.8 Geometric Accuracy of the Data	Not Required	Not Assessed
1.9 Instrument	Yes	Not Assessed
1.10 Spectral Bands	Yes	Not Assessed
1.11 Sensor Calibration	Not Required	Not Assessed
1.12 Radiometric Accuracy	Not Required	Not Assessed
1.13 Algorithms	Yes	Not Assessed
1.14 Auxiliary Data	Yes	Not Assessed
1.15 Processing Chain Provenance	Not Required	Not Assessed
1.16 Data Access	Yes	Not Assessed
1.17 Overall Data Quality	Not applicable	Not Assessed
2. Per-Pixel Metadata		
2.1 Metadata Machine Readability	Yes	Not Assessed
2.2 No Data	Yes	Not Assessed
2.3 Incomplete Testing	Yes	Not Assessed
2.4 Saturation	Yes	Not Assessed
2.5 Cloud	Yes	Not Assessed
2.6 Cloud Shadow	Yes	Not Assessed
2.7 Land/Water Mask	Not Required	Not Assessed
2.8 Snow/Ice Mask	Not Required	Not Assessed
2.9 Terrain Shadow Mask	Not Required	Not Assessed
2.10 Terrain Occlusion	Not Required	Not Assessed
2.11 Solar and Viewing Geometry	Yes	Not Assessed
2.12 Terrain Illumination Correction	Not Required	Not Assessed
2.13 Aerosol Optical Depth Parameters	Not Required	Not Assessed
3. Radiometric and Atmospheric Corrections		
3.1 Measurement	Yes	Not Assessed
3.2 Measurement Uncertainty	Not Required	Not Assessed
3.3 Measurement Normalisation	Not Required	Not Assessed
3.4 Directional Atmospheric Scattering	Yes	Not Assessed
3.5 Water Vapour Corrections	Yes	Not Assessed
3.6 Ozone Corrections	Not Required	Not Assessed
4. Geometric Corrections		
4.1 Geometric Correction	Yes	Not Assessed

Guidance

This section aims to provide background and specific information on the processing steps that can be used to achieve CEOS Analysis Ready Data (CEOS-ARD). This guidance material does not replace or override the specifications.

Introduction to CEOS-ARD

What are CEOS Analysis Ready Data (CEOS-ARD) products?

CEOS-ARD 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.

CEOS-ARD are intended to be flexible and accessible products suitable for a wide range of users for a wide variety of applications, 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 CEOS-ARD?

The CEOS-ARD branding is applied to a particular product once:

- that product has been assessed as meeting CEOS-ARD requirements by the agency responsible for production and distribution of the product, and
- that assessment has been peer reviewed by the CEOS Working Group on Calibration and Validation.

Agencies or other entities considering undertaking an assessment process should contact ard-contact@lists.ceos.org.

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

What is the difference between Threshold and Goal?

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

Products that meet Goal 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.

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

Reference Papers

The following paper provides 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* 124 756–770.
<https://doi.org/10.1016/j.rse.2012.06.018>.