Committee on Earth Observation Satellites	**Analysis Ready Data *For Land***	**Product Family Specification** **Surface Reflectance (CARD4L-SR)**

Document Status

Product Family Specification, Surface Reflectance

This Specification should next be reviewed on: March 2021, or no later than 2 weeks before LSI-VC-11 meeting.

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.	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	Siqueira

		incorporated.	
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 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.	Siqueira
4.3	25.05.2020	Feedback from USGS added (email: 21/05/2020).	Siqueira
5.0	08.06.2020	Tech edit.	Bontje, Labahn

Adam Lewis, Geoscience Australia, Australia
Jonathon Ross, Geoscience Australia, Australia
Andreia Siqueira, Geoscience Australia, Australia
Darcie Bontje, USGS, USA
Steve Labahn, USGS, USA
Mary Metzger, USGS, USA

Description

Product Family Title: **Surface Reflectance (CARD4L-SR)**

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 of 10-100m; however, the Specification is not inherently limited to this resolution.

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	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Review Comments
1.1	**Traceability**	Not required.	Data must be traceable to SI reference standard. *Note 1: Relationship to 3.2. Traceability requires an estimate of measurement uncertainty.* *Note 2: Information on traceability should be available in the metadata as a single DOI landing page.*	n.a.	no		Not required at Threshold, not met at Target
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.	ok, as ISO 19115 (plus ISO 19119) are INSPIRE, so conformity is given	ok, as ISO 19115 (plus ISO 19119) are INSPIRE, so conformity is given	See -METADATA.XML	Verified for Threshold and Target
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.	ok	no	*<temporalCoverage> <startTime>2017-06-26T10:20:20.999936Z</startTime> <stopTime>2017-06-26T10:20:25.545157Z</stopTime> </temporalCoverage>* **---AND---**	Verified at Threshold, not met at Target

Commented [1]: In the following, the related excerpts form the following product metadata are provided:

Source:
https://www.enmap.org/data_tools/testdata/

Dataset:
L2A_Alps_1_land

File:
ENMAP01-____L2A-DT000326721_20170626T102020Z_001_V000204_20200406T201930Z-METADATA.XML

For the definition of this file, see Product Specification provided with the test data:
EN-PCV-ICD-2009-2_HSI_Product_Specification_Level1_Level2_v1.5_excerpt_draft_public.pdf

						<datatakeStart>2017-06-26T10:20:20.999936Z</datatakeStart> <datatakeStop>2017-06-26T10:20:34.512331Z</datatakeStop>	
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.	ok	ok corner coordinates and RPCs	<spatialCoverage> <boundingPolygon> <point> <frame>upper_left</frame> <latitude unit="DEG">47.7875252</latitude> <longitude unit="DEG">10.7960234</longitude> <utcTime>2017-06-26T10:20:20.999936Z</utcTime> </point> <point> <frame>lower_left</frame> <latitude unit="DEG">47.5192797</latitude> <longitude unit="DEG">10.7108641</longitude> <utcTime>2017-06-26T10:20:25.545157Z</utcTime> </point> <point> <frame>lower_right</frame> <latitude unit="DEG">47.4554646</latitude>	Verified for Threshold and Target

						<longitude unit="DEG">11.0813528</longitude> <utcTime>2017-06-26T10:20:25.545157Z</utcTime> </point> <point> <frame>upper_right</frame> <latitude unit="DEG">47.7235135</latitude> <longitude unit="DEG">11.1687202</longitude> <utcTime>2017-06-26T10:20:20.999936Z</utcTime> </point> <point> <frame>upper_left</frame> <latitude unit="DEG">47.787525214</latitude> <longitude unit="DEG">10.796023441</longitude> <utcTime>2017-06-26T10:20:20.999936Z</utcTime> </point> <point> <frame>center</frame> <latitude unit="DEG">47.6216059</latitude> <longitude unit="DEG">10.9392424</longitude> <utcTime>2017-06-26T10:20:23.272547Z</utcTime> </point> </boundingPolygon>	

						</spatialCoverage> **---AND---** *<RPC>* *<bandID number="1">* *<ROW_OFF>512.000000000</ROW_OFF>* *<COL_OFF>500.000000000</COL_OFF>* *<LAT_OFF>47.6256020945</LAT_OFF>* *<LONG_OFF>10.9371050116</LONG_OFF>* *<HEIGHT_OFF>1792.4974941261</HEIGHT_OFF>* *<ROW_SCALE>517.1199951172</ROW_SCALE>* *<COL_SCALE>504.9999952316</COL_SCALE>* *<LAT_SCALE>0.1653056884</LAT_SCALE>* *<LONG_SCALE>0.2272712079</LONG_SCALE>* *<HEIGHT_SCALE>1507.4228814314</HEIGHT_SCALE>* *<ROW_NUM_01>3.289674862860473e-03</ROW_NUM_01>* *<ROW_NUM_02>-2.750158980421163e-01</ROW_NUM_02>* *<ROW_NUM_03>-1.167389271593728e+00</ROW_NUM_03>* *<ROW_NUM_04>-2.821781425495592e-*	

						04</ROW_NUM_04> *<ROW_NUM_05>3.939956 440957156e-03</ROW_NUM_05>* *<ROW_NUM_06>2.618954 949189879e-04</ROW_NUM_06>* ...	
1.5	**Coordinate Reference System**	The metadata lists the coordinate reference system that has been used.	As threshold.	ok	ok	As embedded in the GeoTIFF: *UTM, Zone 32N* *WGS-84* *EPSG:32632*	Verified for Threshold and Target
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.	ok	ok	As embedded in the GeoTIFF: *UTM, Zone 32N* *WGS-84* *EPSG:32632* **---AND---** <mapProjection>UTM_Zone_of_Scene_Center</mapProjection> **---AND---** <ortho> <projection>UTM_Zone32_North</projection> <resolution>30</resolution> <resampling>bilinear</re	Verified for Threshold and Target

						sampling> </ortho>	
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.	n.a.	ok	*<citation>DLR (2020): EnMAP Product 000326721_01_2A_20170626T112025_000204_200406+U0BLNNTS300G. doi:10.15489/rlyibn8gjc58</citation>* **---AND---** *<URLToProductType>enmap.org/product_STANDARD_ALL</URLToProductType>*	Not required at Threshold, verified at Target
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. *Note 1: Information on geometric accuracy of the data should be available in the metadata as a single DOI landing page.*	n.a.	ok	*<orthoRMSE>39</orthoRMSE>* *<orthoRMSE_x>9</orthoRMSE_x>* *<orthoRMSE_y>38</orthoRMSE_y>*	Not required at Threshold, verified at Target
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,	ok	ok Link to ATBD on enmap.org	*<mission>EnMAP</mission>* *<satelliteID>01</satelliteID>* *<sensor>HSI</sensor>*	Verified at Threshold, Target compliance to be assessed after confirming status of ATBD and link to DOI landing page

Commented [BM2]: ATBDs will be provided for review, and will be published on enmap.org before launch

Details on the instrument characteristics are provided in the various ATBDs whenever required, see e.g.
L1C ATBD (EN-PCV-TN-5006), Ch, 4.4 and 5.2

Currently the „reference publication" from both Space, Ground and Science Segment is the following Open Access publication:
https://doi.org/10.3390/rs70708830

After commissioning phase, an updated publication is planned, summarizing all instrument parameters and processing performance.

			Instruments, and Measurements Database record.		(not yet published)	**---AND---** *<citation>DLR (2020): EnMAP Product 000326721_01_2A_20170626T112025_000204_200406+U0BLNNTS300G. doi:10.15489/rlyibn8gjc58 </citation>*	
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. *Note 1: Information on spectral bands should be available in the metadata as a single DOI landing page.*	ok	ok	*<bandCharacterisation> <bandID number="1"> <wavelengthCenterOfBand>423.03</wavelengthCenterOfBand> <FWHMOfBand>6.93</FWHMOfBand> <GainOfBand>0.0001</GainOfBand> <OffsetOfBand>0</OffsetOfBand> </bandID> <bandID number="2"> <wavelengthCenterOfBand>428.8</wavelengthCenterOfBand> <FWHMOfBand>6.58</FWHMOfBand> <GainOfBand>0.0001</GainOfBand> <OffsetOfBand>0</OffsetOfBand> </bandID> ...*	Verified for Threshold and Target
1.11	**Sensor Calibration**	Not required. The general metadata does	Sensor calibration parameters are identified in	n.a.	no		Not required at Threshold, not met at

		not include sensor calibration details.	the metadata, or can be accessed using details included in the metadata. Ideally this would support machine-to-machine access. *Note 1: Information on sensor calibration should be available in the metadata as a single DOI landing page.*				Target
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 version of the data or product, expressed as absolute radiometric uncertainty relative to appropriate, known reference sites and standards (for example, pseudo-invariant calibration sites, rigorously collected field spectra, PICS, Rayleigh, DCC, etc.) *Note 1: Information on radiometric accuracy should be available in the metadata as a single DOI landing page.*	n.a.	no		Not required at Threshold, not met at Target
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. *Note 1: Information on algorithms should be available in the metadata*	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*	Ok Link to ATBD on enmap.org (not yet published)	Partially, see: https://www.enmap.org/science/publications/	*<citation>DLR (2020): EnMAP Product 000326721_01_2A_20170626T112025_000204_200406+U0BLNNTS300G. doi:10.15489/rlyibn8gjc58 </citation>* **---AND---** *<URLToProductType>enmap.org/product_STANDARD_ALL</URLToProductTy*	Threshold and Target compliance to be assessed after confirming status of ATBD and link to DOI landing page

Commented [BM3]: ATBDs will be provided for review, and will be published on enmap.org before launch

For processing sequence, an overview incl. flowchart is provided in the first chapters of each ATBD:

-L0 ATBD (EN-PCV-TN-3006), Fig. 4-1 on p. 16
-L1B ATBD (EN-PCV-TN-4006), Fig. 4-1 on p. 15, Fig. 4-2 on p. 16
-L1C ATBD (EN-PCV-TN-5006), Fig. 4-1 on p. 17
-L2A ATBD (EN-PCV-TN-6007) Fig. 4-1 on p. 17 on the overall and Fig. 5-1 on p. 19 on the atm. corr. processing

		as a single DOI landing page.	*available in the metadata as a single DOI landing page.*			*pe>*	
1.14	**Auxiliary Data**	The metadata identifies the sources of auxiliary data used in the generation process, ideally expressed as a single DOI landing page. *Note 1: Auxiliary data includes DEMs, aerosols, etc. data sources.*	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.	ok (also link to ATBDs on enmap.org)	no	*<digitalElevationModelDatabase>SRTM_C1ARC</digitalElevationModelDatabase>* *<digitalElevationModelDatabaseAccuracy>16</digitalElevationModelDatabaseAccuracy>* *<referenceDatabase>S2</referenceDatabase>* *<referenceImageDatabaseAccuracy>10</referenceImageDatabaseAccuracy>*	Threshold compliance to be assessed after confirming status of ATBD and link to DOI landing page. Not met Target
1.15	**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.	n.a.	no		Not required at Threshold, not met at Target
1.16	**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.*	As threshold.	ok	ok	*<citation>DLR (2020): EnMAP Product 000326721_01_2A_20170626T112025_000204_200406+U0BLNNTS300G. doi:10.15489/rlyibn8gjc58</citation>* **---AND---** *<URLToProductType>enmap.org/product_STANDARD_ALL</URLToProductTy*	Threshold and Target compliance to be assessed after confirming status of ATBD and link to DOI landing page

Commented [BM4]: ATBDs will be provided for review, and will be published on enmap.org before launch

The description to the most important Auxiliary datasets can be found as follows:
- -DEM: L1C ATBD (EN-PCV-TN-5006), Ch. 5.6.1
- -Reference Image database: L1C ATBD (EN-PCV-TN-5006), Ch. 6.4
- -Radiative transfer code: L2A ATBD (EN-PCV-TN-6007) CH. 5.2
- -Solar Irradiance Spectrum: L2A ATBD (EN-PCV-TN-6007) Ch. 5.3

Commented [BM5]: ATBDs will be provided for review, and will be published on enmap.org before launch

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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	n.a.	ok	*<qualityFlag> <spare_1>-999</spare_1> <spare_2>-999</spare_2> <spare_3>-999</spare_3> <sensorLogVNIR>-999</sensorLogVNIR> <processorLogVNIR>0</processorLogVNIR> <overallQualityVNIR>0</overallQualityVNIR> <deadPixelsVNIR>0</deadPixelsVNIR> <defectivePixelsVNIR>0</defectivePixelsVNIR> <generalArtifactsVNIR>0</generalArtifactsVNIR> <saturationCrosstalkVNIR>0</saturationCrosstalkVNIR> <stripingBandingVNIR>0</stripingBandingVNIR> <qualityRadiometryVNIR>0</qualityRadiometryVNIR> <smileIndicationVNIR>-999</smileIndicationVNIR> <sensorLogSWIR>-999</sensorLogSWIR> <processorLogSWIR>0</processorLogSWIR> <deadPixelsSWIR>0</deadPixelsSWIR>*	Not required at Threshold, verified at Target

						<defectivePixelsSWIR>0</defectivePixelsSWIR> *<generalArtifactsSWIR>0</generalArtifactsSWIR>* *<saturationCrosstalkSWIR>0</saturationCrosstalkSWIR>* *<stripingBandingSWIR>0</stripingBandingSWIR>* *<overallQualitySWIR>0</overallQualitySWIR>* *<qualityRadiometrySWIR>0</qualityRadiometrySWIR>* *<smileIndicationSWIR>-999</smileIndicationSWIR>* *<overallQuality>1</overallQuality>* *<numTilesUsed>3</numTilesUsed>* *<levelOfRejection>2</levelOfRejection>* *<numPointsGCP>607</numPointsGCP>* *<numPointsICP>2271</numPointsICP>* *<numPointsAll>2878</numPointsAll>* *<numPointsDiscardedGCP>3</numPointsDiscardedGCP>* *<orthoResidual>10</orthoResidual>*	

						<orthoResidual_x>9</orthoResidual_x> <orthoResidual_y>5</orthoResidual_y> <orthoMean>0</orthoMean> <orthoMean_x>0</orthoMean_x> <orthoMean_y>0</orthoMean_y> <orthoRMSE>39</orthoRMSE> <orthoRMSE_x>9</orthoRMSE_x> <orthoRMSE_y>38</orthoRMSE_y> <sceneSZA>26.961616</sceneSZA> <qualityAtmosphere>1</qualityAtmosphere> <orthoTerrain>0</orthoTerrain> <sceneSunglint>-999</sceneSunglint> <cloudCover>0</cloudCover> <hazeCover>0</hazeCover> <cirrusCover>0</cirrusCover> <snowCover>0</snowCover> <waterCover>2</waterCover>	

						<cloudShadow>8</cloudShadow> *<noncloudShadow>0</noncloudShadow>* *<sceneWV>2159</sceneWV>* *<sceneAOT>190</sceneAOT>* *<sceneAtmParam>0</sceneAtmParam>* *<sceneTerrain>0</sceneTerrain>* *</qualityFlag>* *<instrumentStatus>* *<statusOK>true</statusOK>* *<statusVNIR>on</statusVNIR>* *<statusSWIR>on</statusSWIR>* *<configVNIR>standard</configVNIR>* *<configSWIR>standard</configSWIR>* *<statusSCM>OK</statusSCM>* *<statusDiffuserProtectionHatch>OK</statusDiffuserProtectionHatch>* *<statusSunDiffuserHatch>OK</statusSunDiffuserHatch>*	

						<emergencyStatusOfSCM>0</emergencyStatusOfSCM> <emergencyStatusOfSSM>0</emergencyStatusOfSSM> <emergencyStatusOfSDH>0</emergencyStatusOfSDH> <SWIRAOrSWIRBSelected>SWIRA</SWIRAOrSWIRBSelected> <mcsSequenceType>1</mcsSequenceType> </instrumentStatus> <productQuality> <screeningResult> <status>FAILED</status> <failedGroups>STATUS</failedGroups> </screeningResult>	

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	Target (Desired) Requirements	Threshold Self-Assessment	Target 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.	ok	ok	See files: -METADATA.XML -QL_PIXELMASK.TIF -QL_QUALITY_CIRRUS.TIF -QL_QUALITY_CLASSES.TIF -QL_QUALITY_CLOUD.TIF -QL_QUALITY_CLOUDSHADOW.TIF -QL_QUALITY_HAZE.TIF -QL_QUALITY_SNOW.TIF -QL_QUALITY_TESTFLAGS.TIF	Verified for Threshold and Target
2.2	**No Data**	Pixels that do not correspond to an observation ('empty pixels') are flagged.	As threshold.	ok	ok	*<backgroundValue>0</backgroundValue>*	Verified for Threshold and Target
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.	ok	ok	Within QL_QUALITY_TESTFLAGS.TIF: Bits (0-1) as "11: not produced")	Verified for Threshold and Target
2.4	**Saturation**	Metadata indicates where	Metadata indicates which				Threshold and Target

Commented [6]: In the following, the related excerpts form the following product metadata are provided:

Source:
https://www.enmap.org/data_tools/testdata/

Dataset:
L2A_Alps_1_land

File:
ENMAP01-____L2A-DT000326721_20170626T102020Z_001_V000204_20200406T201930Z-METADATA.XML

		one or more spectral bands are saturated.	pixels are saturated for each spectral band.	ok	Partially. Aggregated information (if number of saturated bands for a spatial pixel exceeds threshold)	Within QL_QUALITY_TESTFLAGS.TIF: VNIR: Bit 5 SWIR: Bit 4	compliance to be assessed after clarification
2.5	**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.	ok	ok (also link to ATBDs on enmap.org)	-QL_QUALITY_CLOUD.TIF	Target compliance to be assessed after confirming status of ATBD and DOI landing page
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.	ok	ok (also link to ATBDs on enmap.org)	-QL_QUALITY_CLOUDSHADOW.TIF	Target compliance to be assessed after confirming status of ATBD and DOI landing page
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.	n.a.	ok (also link to ATBDs on enmap.org)	-QL_QUALITY_CLASSES.TIF	Not required at Threshold, Target compliance to be assessed after confirming status of ATBD and DOI landing page
2.8	**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.	n.a.	ok (also link to ATBDs on enmap.org)	-QL_QUALITY_SNOW.TIF	Not required at Threshold, Target compliance to be assessed after confirming status of ATBD and DOI landing page
2.9	**Terrain Shadow Mask**	Not required.	The metadata indicates pixels that are not directly illuminated due to terrain shadowing.	n.a.	no		Not required at Threshold, not met at Target

Commented [BM7]: ATBDs will be provided for review, and will be published on enmap.org before launch

Saturation is assessed twice, see:
-L1B ATBD (EN-PCV-TN-4006), Ch. 4.4.6.2
-L2A ATBD (EN-PCV-TN-6007), within the Ch. 5.1.1.3

Commented [BM8]: ATBDs will be provided for review, and will be published on enmap.org before launch

Details on the detection algorithms are described in L2A ATBD (EN-PCV-TN-6007), within the Ch. 5.1 (separated for clouds, cirrus, haze)

Commented [BM9]: ATBDs will be provided for review, and will be published on enmap.org before launch

Details on the detection algorithms are described in L2A ATBD (EN-PCV-TN-6007), Ch. 5.1.1.6

Commented [BM10]: ATBDs will be provided for review, and will be published on enmap.org before launch

Details on the detection algorithms are described in L2A ATBD (EN-PCV-TN-6007), Ch. 5.1.1.1 & 5.1.1.2

Commented [BM11]: ATBDs will be provided for review, and will be published on enmap.org before launch

Details on the detection algorithms are described in L2A ATBD (EN-PCV-TN-6007), Ch. 5.1.1.7

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.	n.a.	no		Not required at Threshold, not met at Target
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.	ok	no	*<sunElevationAngle> <upper_left unit="DEG">62.843017</upper_left> <upper_right unit="DEG">63.025996</upper_right> <lower_right unit="DEG">63.232013</lower_right> <lower_left unit="DEG">63.048052</lower_left> 63.038384 </sunElevationAngle> <sunAzimuthAngle> <upper_left unit="DEG">148.98072</upper_left> <upper_right unit="DEG">149.614311</upper_right> <lower_right unit="DEG">149.224083</lower_right> <lower_left unit="DEG">148.59262</lower_left> 149.106702 </sunAzimuthAngle> <acrossOffNadirAngle> <upper_left unit="DEG">1.27641076292</upper_left> <upper_right unit="DEG">-1.35358251158</upper_right>*	Verified

						<lower_right unit="DEG">-1.4507597324</lower_right> <lower_left unit="DEG">1.17928885285</lower_left> -0.0871606570525 </acrossOffNadirAngle> <alongOffNadirAngle> <upper_left unit="DEG">-0.0692040225255</upper_left> <upper_right unit="DEG">-0.0695301149423</upper_right> <lower_right unit="DEG">-0.167785438271</lower_right> <lower_left unit="DEG">-0.16870825914</lower_left> -0.11880695872 </alongOffNadirAngle> <sceneAzimuthAngle> <upper_left unit="DEG">14.2906888082</upper_left> <upper_right unit="DEG">14.2906888082</upper_right> <lower_right unit="DEG">14.2149804324</lower_right> <lower_left unit="DEG">14.2149804324</lower_left> 14.2528346203 </sceneAzimuthAngle>	

						---AND--- *<sceneSZA>26.961616</sceneSZA>*	
2.12	**Terrain Illumination Correction**	Not required.	Coefficients used for terrain illumination correction are provided for each pixel.	n.a.	no		Not required at Threshold, not met at Target
2.13	**Aerosol Optical Depth Parameters**	Not required.	To be determined.	n.a.	tbd	*<sceneAOT>190</sceneAOT>*	Not required at Threshold, Target requirement not clear

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	Target (Desired) Requirements	Threshold Self-Assessment	Target 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).	ok	no	Reflectance (signed integer) scaled by 100 (DN 10.000 ⇔ 100% reflectance)	Verified at Threshold, not met at Target
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.* *Note 2: Information on measurement uncertainty should be available in the metadata as a single DOI landing page.*	n.a.	Partially Typical uncertainties provided by publications Also the L2A correction software PACO/ATCOR is included in ACIX & ACIX2		Not required at Threshold, Target compliance to be assessed after confirming status of DOI landing page
3.3	**Measurement Normalisatio**	Not required.	Measurements are normalised for solar and viewing conditions (i.e.,	n.a.	no		Not required at Threshold, not met at Target

Commented [12]: In the following, the related excerpts form the following product metadata are provided:

Source:
https://www.enmap.org/data_tools/testdata/

Dataset:
L2A_Alps_1_land

File:
ENMAP01-____L2A-DT000326721_20170626T102020Z_001_V000204_20200406T201930Z-METADATA.XML

Commented [BM13]: Uncertainty estimates will be generated during Commissioning Phase and published in peer-review publications, and also made available at enmap.org.

As an example, for the DESIS mission we have created such a study, which is currently under peer review. Parts of it can be found within the following presentation:

https://desis2021.welcome-manager.de/archiv/web/userfiles/desis2021/DESIS_L2A_processor_validation_Tue1600_delosReyes_169.pdf

	n		nadir view angle and average solar angles). This may include terrain illumination and/or Bi-Directional Reflectance Function (BRDF) correction. *Note 1: Information on measurement normalisation should be available in the metadata as single DOI landing page.*				
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 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.	ok Link to ATBD on enmap.org (not yet published)	ok	*<citation>DLR (2020): EnMAP Product 000326721_01_2A_20170626T112025_000204_200406+U0BLNNTS300G. doi:10.15489/rlyibn8gjc58</citation>* **---AND---** *<URLToProductType>enmap.org/product_STANDARD_ALL</URLToProductType>* **---AND---** *<sceneAOT>190</sceneAOT>*	Threshold and Target compliance to be assessed after confirming status of ATBD and link to DOI landing page

Commented [BM14]: ATBDs will be provided for review, and will be published on enmap.org before launch

Details on the detection algorithms are described in L2A ATBD (EN-PCV-TN-6007), Ch. 5.4

3.5	**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.	ok Link to ATBD on enmap.org (not yet published)	ok	*<citation>DLR (2020): EnMAP Product 000326721_01_2A_20170626T112025_000204_200406+U0BLNNTS300G. doi:10.15489/rlyibn8gjc58</citation>* **---AND---** *<URLToProductType>enmap.org/product_STANDARD_ALL</URLToProductType>* **---AND---** *<sceneWV>2159</sceneWV>*	Threshold and Target compliance to be assessed after confirming status of ATBD and link to DOI landing page
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	n.a.	Ok Link to ATBD on enmap.org (not yet published)	*<citation>DLR (2020): EnMAP Product 000326721_01_2A_20170626T112025_000204_200406+U0BLNNTS300G. doi:10.15489/rlyibn8gjc58</citation>* **---AND---** *<URLToProductType>enmap.org/product_STANDARD_ALL</URLToProductType>* **---AND---** *<ozoneValue>300</ozoneValue>*	Not required at Threshold, Target compliance to be assessed after confirming status of ATBD and DOI landing page

Commented [BM15]: ATBDs will be provided for review, and will be published on enmap.org before launch

Details on the detection algorithms are described in L2A ATBD (EN-PCV-TN-6007), Ch. 5.5

Commented [BM16]: ATBDs will be provided for review, and will be published on enmap.org before launch

Details on the detection algorithms are described in L2A ATBD (EN-PCV-TN-6007), Ch. 5.10

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	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
4.1	**Geometric Correction**	Sub-pixel accuracy is achieved in relative 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 different sources as the*	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.*	ok	ok	*<orthoRMSE>39</orthoRMSE>* *<orthoRMSE_x>9</orthoRMSE_x>* *<orthoRMSE_y>38</orthoRMSE_y>* As embedded in the GeoTIFF: *UTM, Zone 32N* *WGS-84* *EPSG:32632* *NOTE: the system requirement is 1 pixel at nadir (absolute). Based on experience with other missions, the accuracy w.r.t. the used reference image will be approx. 0.5 - 1 pixel.*	Threshold and Target compliance to be assessed after clarification of values / units in XML file

Commented [17]: In the following, the related excerpts form the following product metadata are provided:

Source:
https://www.enmap.org/data_tools/testdata/

Dataset:
L2A_Alps_1_land

File:
ENMAP01-____L2A-DT000326721_20170626T102020Z_001_V000204_20200406T201930Z-METADATA.XML

Commented [BM18]: Units within the METADATA are in "[pxiels * 10]", as documented in the corresponding Product Specifications, see P. 19 of the currently published version at:
https://www.enmap.org/data/test_data/EN-PCV-ICD-2009-2_HSI_Product_Specification_Level1_Level2_v1.5_excerpt_draft_public.pdf

ATBDs will be provided for review, and will be published on enmap.org before launch

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		geometric corrections for each of the sources may differ.					

Summary Self-Assessment Table

	Threshold	Target
1. General Metadata		
1.1 Traceability	n.a.	no
1.2 Metadata Machine Readability	ok	ok
1.3 Data Collection Time	ok	no
1.4 Geographical Area	ok	ok
1.5 Coordinate Reference System	ok	ok
1.6 Map Projection	ok	ok
1.7 Geometric Correction Methods	n.a.	ok
1.8 Geometric Accuracy of the Data	n.a.	ok
1.9 Instrument	ok	ok
1.10 Spectral Bands	ok	ok
1.11 Sensor Calibration	n.a.	no
1.12 Radiometric Accuracy	n.a.	no
1.13 Algorithms	ok	partially
1.14 Auxiliary Data	ok	no
1.15 Processing Chain Provenance	n.a.	no
1.16 Data Access	ok	ok
1.17 Overall Data Quality	n.a.	ok
2. Per-Pixel Metadata		
2.1 Metadata Machine Readability	ok	ok
2.2 No Data	ok	ok
2.3 Incomplete Testing	ok	ok
2.4 Saturation	ok	partially
2.5 Cloud	ok	ok
2.6 Cloud Shadow	ok	ok
2.7 Land/Water Mask	n.a.	ok
2.8 Snow/Ice Mask	n.a.	ok
2.9 Terrain Shadow Mask	n.a.	no
2.10 Terrain Occlusion	n.a.	no
2.11 Solar and Viewing Geometry	ok	no
2.12 Terrain Illumination Correction	n.a.	no
2.13 Aerosol Optical Depth Parameters	n.a.	tbd
3. Radiometric and Atmospheric Corrections		
3.1 Measurement	ok	no
3.2 Measurement Uncertainty	n.a.	partially
3.3 Measurement Normalisation	n.a.	no
3.4 Directional Atmospheric Scattering	ok	ok
3.5 Water Vapour Corrections	ok	ok
3.6 Ozone Corrections	n.a.	ok
4. Geometric Corrections		
4.1 Geometric Correction	ok	ok

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.

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 Surface Reflectance CARD4L:

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

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

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

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

Specific Examples

Processes to produce Threshold Optical Surface Reflectance CARD4L:

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

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.