

	<b>Analysis Ready Data</b>  <b><i>For Land</i></b>	<b>Product Family</b>  <b>Specification</b>  <b>Surface Reflectance</b> <b>(CARD4L-SR)</b>
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## 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](mailto: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: <ul style="list-style-type: none"> <li>- various minor edits</li> <li>- revised 1.4 'target'</li> <li>- 1.7, 1.8, 1.9 may need revisiting</li> <li>- Added 3.1, measurement</li> <li>- Added 3.2, uncertainty</li> <li>- Added 2.10, terrain occlusion</li> </ul>	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 Reflectance products (Landsat and Sentinel-2). Minor editorial changes were done throughout the document. Requirements <i>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</i> have been updated.  Feedback from USGS added (email: 21/05/2020).  Tech edit.	Siqueira
4.3	25.05.2020		Siqueira
5.0	08.06.2020		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

CRS	Coordinate Reference System
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	WGCV Comments
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>	Yes, 'Not required'	No	In PROBA-V C2, no measurement or uncertainty is provided, but it is under consideration for a future Collection.	<b>Not Required at Threshold</b>
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	Yes	Each PROBA-V C2 product file is accompanied by 2 metadata files in XML. The inspire metadata file is conform INSPIRE metadata ISO 19115-2 and is validated against the MI_Metadata schema( <a href="http://www.isotc211">http://www.isotc211</a> ).	<b>Verified at Threshold</b>  <b>(Metadata conforms to ISO 19139-2)</b>

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	WGCV Comments
						<a href="http://org/2005/gmi/gmi.xsd">org/2005/gmi/gmi.xsd</a> ). The hma metadata file is HMA conform (Heterogeneous Mission Accessibility (GSCDA/ESA))	
1.3	<b>Data Collection Time</b>	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.	Yes	Yes (timegrid per pixel)	The metadata file contains the begin time (gml) and end time (gml) of the acquisition. Example: <pre> &lt;gml:TimePeriod   gml:id="ID_4"&gt;   &lt;gml:beginPosition&gt;2019-05-24T03:18:27Z&lt;/gml:beginPosition&gt;   &lt;gml:endPosition&gt;2019-05-24T03:38:44Z&lt;/gml:endPosition&gt; &lt;/gml:TimePeriod&gt; </pre> The Level 3 products include a TIME band	<b>Verified at Threshold</b>

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/Justification	WGCV Comments
						with the timegrid per pixel.	
1.4	<b>Geographical Area</b>	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.	Yes	Yes	The metadata file contains Bounding Box and Polygon with the applicable CRS.	<b>Verified at Threshold</b>
1.5	<b>Coordinate Reference System</b>	The metadata lists the coordinate reference system that has been used.	As threshold.	Yes	Yes	The metadata file includes referenceSystemInfo (gml) with URL to a known CRS, e.g. <a href="http://www.opengis.net/def/crs/EPSSG/0/4326">http://www.opengis.net/def/crs/EPSSG/0/4326</a>	<b>Verified at Threshold</b>
1.6	<b>Map Projection</b>	The metadata lists the map projection that has been used and any relevant parameters required in	As threshold.	Yes	Yes	The metadata file of L3 surface reflectance products includes the referenceSystemInfo	<b>Verified at Threshold</b>

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	WGCV Comments
		relation to use of data in that map projection.				<p>and links to an EPSG code.</p> <p>Example:</p> <pre> &lt;gmd:referenceSystemInfo xmlns:gco="http://www.isotc211.org/2005/gco" xmlns:gml="http://www.opengis.net/gml" xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"&gt;  &lt;gmd:MD_ReferenceSystem&gt;  &lt;gmd:referenceSystemIdentifier xlink:type="simple"&gt;  &lt;gmd:RS_Identifier&gt;  &lt;gmd:code&gt; </pre>	

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/Justification	WGCV Comments
						<pre> &lt;gco:CharacterString&gt;http://www.open gis.net/def/crs/EP SG/0/4326&lt;/gco:Cha racterString&gt;  &lt;/gmd:code&gt;  &lt;gmd:codeSpace&gt;  &lt;gco:CharacterStri ng&gt;EPSG&lt;/gco:Chara cterString&gt;  &lt;/gmd:codeSpace&gt;  &lt;/gmd:RS_Identifie r&gt;  &lt;/gmd:referenceSys temIdentifier&gt;  &lt;/gmd:MD_Reference System&gt; </pre>	



#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/Justification	WGCV Comments
						</gmd:referenceSystemInfo>	
1.7	<b>Geometric Correction Methods</b>	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 chipsets.	Yes, 'Not required'	Yes	For the PROBA-V C2 surface reflectance product a landing page has been introduced, linked to a DOI. Within the collection and product metadata, there is a reference to this DOI. More info see General information  The landing page refers to the PUM (Product User Manual) in which geometric processing is described.	<b>Not Required at Threshold</b>
1.8	<b>Geometric Accuracy of the Data</b>	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	Yes, 'Not required'	Yes	INSPIRE metadata includes dataQualityInfo with DQ_GriddedDataPositionalAccuracy. Additional information on geometric accuracy is available in the PUM accessible	<b>Not Required at Threshold</b>

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/Justification	WGCV Comments
			<p>where applicable).            Uncertainties are expressed quantitatively, for example, as root mean square error (RMSE) or Circular Error Probability (CEP90, CEP95), etc.</p> <p><i>Note 1: Information on geometric accuracy of the data should be available in the metadata as a single DOI landing page.</i></p>			<p>through the single DOI landing page for the PROBA-V C2 TOC collection (see General information ). Overall information on geometric accuracy is available on the PROBA-V quality webpage:  <a href="https://proba-v.vgt.vito.be/en/quality/geolocation-accuracy">https://proba-v.vgt.vito.be/en/quality/geolocation-accuracy</a>.</p>	
1.9	<b>Instrument</b>	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	No	<p>The metadata file includes the instrument info in the gmi:acquisitionInformation tag.            For the Target Requirement:            No reference to the CEOS Missions Instruments, and Measurements Database record but this can be included in the PUM accessible through the single DOI landing page.</p>	<p><b>Verified at Threshold</b>  <b>(also in PROBA C2 PUM doc p14)</b></p>

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/Justification	WGCV Comments
1.10	<b>Spectral Bands</b>	The central wavelength for each band for which data is included is identified in the metadata, expressed in SI units.	<p>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.</p> <p><i>Note 1: Information on spectral bands should be available in the metadata as a single DOI landing page.</i></p>	Yes	Yes	<p>Central wavelength (peakResponse) of the bands is available in the metadata. Expressed in nanometer (10<sup>-9</sup> meters).</p> <pre> &lt;gmi:MI_Band&gt;     &lt;gmd:sequenceIdentifier&gt;         &lt;gco:MemberName&gt;             &lt;gco:aName&gt;                 &lt;gco:CharacterString&gt;BLUE&lt;/gco:CharacterString&gt;             &lt;/gco:aName&gt;         &lt;/gco:MemberName&gt;         &lt;gco:attributeType gco:nilReason='unknown' /&gt;     &lt;/gco:MemberName&gt; </pre>	<p><b>Verified at Threshold</b> <b>(also in PROBA C2 PUM doc p14)</b></p>

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/Justification	WGCV Comments
						<pre> &lt;/gmd:sequenceIdentifier&gt;  &lt;gmd:peakResponse&gt;&lt;gco:Real&gt;464&lt;/gco:Real&gt;&lt;/gmd:peakResponse&gt;  &lt;gmd:bitsPerValue&gt;&lt;gco:Integer&gt;16&lt;/gco:Integer&gt; &lt;/gmd:bitsPerValue&gt;  &lt;gmd:scaleFactor&gt;&lt;gco:Real&gt;0.0005&lt;/gco:Real&gt;&lt;/gmd:scaleFactor&gt;  &lt;gmd:offset&gt;&lt;gco:Real&gt;0.0&lt;/gco:Real&gt;&lt;/gmd:offset&gt;  &lt;gmi:nominalSpatialResolution&gt;&lt;gco:Real&gt;333&lt;/gco:Real&gt;&lt;/gmi:nominalSpatialResolution&gt;  &lt;/gmi:MI_Band&gt; </pre>	

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	WGCV Comments
1.11	<b>Sensor Calibration</b>	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>	Yes, 'Not required'	No	Upstream L1C(TOA) and L2A products metadata refer to used radiometric ICP file (root group) but not the values. These values are part of the ICP files which are currently not public. This information is excluded from L3 surface reflectance (TOC) products metadata.  Detailed information is available in the PUM via the single DOI landing page.	<b>Not Required at Threshold</b>
1.12	<b>Radiometric Accuracy</b>	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-	Yes, 'Not required'	No	Idem as above. Per month a file / camera. ICP reference.	<b>Not Required at Threshold</b>

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/Justification	WGCV Comments
			<p>invariant calibration sites, rigorously collected field spectra, PICS, Rayleigh, DCC, etc.)</p> <p><i>Note 1: Information on radiometric accuracy should be available in the metadata as a single DOI landing page.</i></p>				
1.13	<b>Algorithms</b>	<p>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.</p> <p><i>Note 1: Information on algorithms should be available in the metadata as a single DOI landing page.</i></p>	<p>As threshold, but only algorithms that have been published in a peer-reviewed journal.</p> <p><i>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.</i></p> <p><i>Note 2: Information on algorithms should be available in the metadata as a single DOI landing page.</i></p>	Yes	? (TBC)	<p>All algorithms, processing steps are listed in the metadata (lineage /ProcessStep). Detailed documentation is available as citation to the PROBA-V Products User Manual (PUM) via the single DOI landing page.</p>	<b>Verified at Threshold</b>
1.14	<b>Auxiliary Data</b>	<p>The metadata identifies the sources of auxiliary data used in the generation</p>	<p>As threshold, but information on auxiliary data should be available in the metadata as a single DOI landing page and is</p>	Yes	Partly	<p>Detailed information including which auxiliary data is used for the generation of</p>	<p><b>Verified at Threshold</b></p> <p><b>PUM C2 p21-22. Links broken/Doc unavailable</b></p>

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/Justification	WGCV Comments
		<p>process, ideally expressed as a single DOI landing page.</p> <p><i>Note 1: Auxiliary data includes DEMs, aerosols, etc. data sources.</i></p>	<p>also available for free online download, contemporaneously with the product or through a link to the source.</p>			<p>the products is available in the citation to the PROBA-V Products User Manual (PUM) via the single DOI landing page.</p>	
1.15	<b>Processing Chain Provenance</b>	Not required.	<p>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.</p>	Yes, 'Not required'	Yes	<p>All algorithms, processing steps are listed in the metadata (lineage /ProcessStep) Detailed information is available in the citation to the PROBA-V Products User Manual (PUM) via the single DOI landing page.</p>	<b>Not Required at Threshold</b>
1.16	<b>Data Access</b>	<p>Information on data access should be available in the metadata as a single DOI landing page.</p> <p><i>Note 1: Manual and offline interaction action (e.g., login) may be required.</i></p>	As threshold.	Yes	Yes	<p>The metadata includes information on data access in the gmd:distributionOrder Process tag. Detailed information on data access is available in the citation to the single DOI landing page.</p>	<b>Verified at Threshold</b>

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/Justification	WGCV Comments
1.17	<b>Overall Data Quality</b>	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.: <ul style="list-style-type: none"> <li>• Proportion of observations over land (c.f. ocean) affected by non-target phenomena, e.g., cloud and cloud shadows</li> </ul>	Yes, 'Not applicable'	Yes	The product metadata includes information on cloud cover, snow cover, ...	<b>Not Required at Threshold</b>



## 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 based on their individual suitability for application.

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/Justification	WGCV Comments
2.1	<b>Metadata Machine Readability</b>	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	Yes	Each PROBA-V C2 product file is accompanied by 2 metadata files in XML. The inspire metadata file is conform INSPIRE metadata ISO 19115-2.	<b>Verified at Threshold</b>
2.2	<b>No Data</b>	Pixels that do not correspond to an observation ('empty pixels') are flagged.	As threshold.	Yes	Yes	The product metadata contains a no data value for users to mask out missing data.  More info on the no value data can be found in the Product User Manual (PUM).	<b>Not in Geotiff metadata xml, but present in HDF5 metadata attached to individual layers</b>  <b>PUM c2 p38 T11</b>
2.3	<b>Incomplete Testing</b>	The metadata identifies pixels for which the per-pixel tests (below) have not all been successfully completed.	The metadata identifies which tests have, and have not, been successfully completed for each pixel.	Yes	No	The pixels for which cloud detection could not be performed e.g. due to missing radiometry are	<b>PUM c2 p43-44 T12/13</b>

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/Justification	WGCV Comments
		<i>Note 1: This may be the result of missing ancillary data for a subset of the pixels.</i>				flagged as undefined in the Status Map	
2.4	<b>Saturation</b>	Metadata indicates where one or more spectral bands are saturated.	Metadata indicates which pixels are saturated for each spectral band.	Yes	Yes	<p>This is included in the products since PROBA-V C2. Saturated pixels in the PROBA-V TOC products have the maximum value (4095).</p> <p>More info on saturation can be found in the Product User Manual (PUM).</p>	<p><b>Verified at Threshold</b></p> <p><b>PUM c2 p43 T12</b></p>
2.5	<b>Cloud</b>	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.	Yes	Yes	<p>Cloud detection information is available from Bit0 &amp; Bit1 in the Status Map. Detailed information on cloud detection is available in the citation to the single DOI landing page with a link to the PUM.</p>	<p><b>L1C Product PUM c2 p43 T12</b></p> <p><b>L2 L3 Products – Status Map (SM) dataset PUM c2 p44 T13</b></p>

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/Justification	WGCV Comments
2.6	<b>Cloud Shadow</b>	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	Yes	<p>Cloud shadow detection information is available in the Status Map.</p> <p>Detailed information on cloud shadow detection is available in the citation to the single DOI landing page with a link to the PUM.</p>	<p><b>L1C Product PUM c2 p43 T12</b></p> <p><b>L2 L3 Products – Status Map (SM) dataset PUM c2 p44 T13</b></p>
2.7	<b>Land/Water Mask</b>	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.	Yes, 'Not required'	Yes	<p>Land/Water mask information is available in the Status Map.</p> <p>Detailed information on cloud detection is available in the citation to the single DOI landing page with a link to the PUM.</p>	<p><b>Not Required at Threshold</b></p> <p><b>L2 L3 Products – Status Map (SM) dataset PUM c2 p44 T13</b></p>

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/Justification	WGCV Comments
2.8	<b>Snow/Ice Mask</b>	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.	Yes, 'Not required'	Yes	Snow/Ice detection information is available the Status Map.  Detailed information on snow/ice detection is available in the citation to the single DOI landing page with a link to the PUM.	<b>Not Required at Threshold</b>  <b>L2 L3 Products – Status Map (SM) dataset PUM c2 p44 T13</b>
2.9	<b>Terrain Shadow Mask</b>	Not required.	The metadata indicates pixels that are not directly illuminated due to terrain shadowing.	Yes, 'Not required'	No	Less relevant for the PROBA-V data	<b>Not Required at Threshold</b>
2.10	<b>Terrain Occlusion</b>	Not required.	The metadata indicates pixels that are not visible to the sensor due to terrain occlusion during off-nadir viewing.	Yes, 'Not required'	No	Less relevant for the PROBA-V data	<b>Not Required at Threshold</b>
2.11	<b>Solar and Viewing Geometry</b>	Provide average solar and sensor viewing azimuth and zenith angles.	Provide per-pixel solar and sensor viewing azimuth and zenith angles.	Yes	Yes	The product provides per-pixel solar and sensor viewing azimuth and zenith angles. Average solar and sensor viewing azimuth and zenith angles are not	<b>L2 L3 Products – GEOMETRY dataset PUM c2 p29 T8</b>

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/Justification	WGCV Comments
						<p>provided however the threshold requirement with a per-pixel solar and sensor viewing azimuth and zenith angles are already in place.</p> <p>The threshold level can be reached by averaging the per-pixel value.</p>	
2.12	Terrain Illumination Correction	Not required.	Coefficients used for terrain illumination correction are provided for each pixel.	Yes, 'Not required'	No	Less relevant for the PROBA-V data	<b>Not Required at Threshold</b>
2.13	Aerosol Optical Depth Parameters	Not required.	To be determined.	Yes, 'Not required'	/		<b>Not Required at Threshold</b>

## 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	WGCV Comments
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	Yes	Surface reflectance SI is indicated as a dimensionless value.	Verified at Threshold L1/L2/L3 Product PUM c2 p37-38
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, rather than on a specific estimate of measurement uncertainty.</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> <i>Note 2: Information on measurement uncertainty should be available in the metadata as a single DOI landing page.</i>	Yes, 'Not required'	No	No uncertainty available	Not Required at Threshold
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	Yes, 'Not required'	No	No BRDF correction is applied, so not applicable.	Not Required at Threshold

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/Justification	WGCV Comments
			Bi-Directional Reflectance Function (BRDF) correction.  <i>Note 1: Information on measurement normalisation should be available in the metadata as single DOI landing page.</i>				
3.4	<b>Directional Atmospheric Scattering</b>	Corrections are applied for aerosols and molecular (Rayleigh) scattering.  Metadata contains a single DOI landing page with references to: <ul style="list-style-type: none"> <li>• a citable peer-reviewed algorithm</li> <li>• technical documentation regarding the implementation of that algorithm</li> </ul>	As threshold.	Yes	Yes	Detailed information on the directional atmospheric scattering is available in the PUM accessible through the single DOI landing page for the PROBA-V C2 collections (see General information )	<b>Verified at Threshold</b>  <b>L1/L2/L3 Product PUM c2 p21-24</b>

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	WGCV Comments
		<ul style="list-style-type: none"> <li>the sources of ancillary data used to make corrections</li> </ul> <p><i>Note 1: Examples of technical documentation include an Algorithm Theoretical Basis Document, product user guide, etc.</i></p>					
3.5	<b>Water Vapour Corrections</b>	<p>Corrections are applied for water vapour.</p> <p>Metadata contains a single DOI landing page with references to:</p> <ul style="list-style-type: none"> <li>a citable peer-reviewed algorithm</li> <li>technical documentation regarding the implementation of that algorithm</li> </ul> <p><i>Note 1: Examples of technical documentation include an Algorithm Theoretical Basis Document, product user guide, etc.</i></p>	As threshold.	Yes	Yes	Detailed information on the water vapour corrections is available in the PUM accessible through the single DOI landing page for the PROBA-V C2 collections (see General information )	<p><b>Verified at Threshold</b></p> <p><b>L1/L2/L3 Product PUM c2 p21-24</b></p>



#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	WGCV Comments
3.6	Ozone Corrections	Not required.	<p>Data is corrected for ozone.</p> <p>Relevant metadata must be provided under 1.8 and 1.9.</p> <p>Metadata contains a single DOI landing page with references to:</p> <ul style="list-style-type: none"> <li>• a citable peer-reviewed algorithm</li> <li>• technical documentation regarding the implementation of that algorithm</li> </ul>	Yes, 'Not required'	Yes	Detailed information on ozone corrections is available in the PUM accessible through the single DOI landing page for the PROBA-V C2 collections (see General information )	<b>Not Required at Threshold</b>

## 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	WGCV Comments
4.1	Geometric Correction	<p>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.</p> <p>Sub-pixel accuracy is taken to be less than or equal to 0.5-pixel radial root mean square error (rRMSE) (<b>PROBA-MD-ACS-VITO-0102 p90-91</b>) or equivalent in Circular Error Probability (CEP) relative to a defined reference image (<b>PROBA-MD-ACS-VITO-0102 p35-36</b>)</p> <p>A consistent gridding/sampling frame is used, including common cell size, origin, and nominal sample point location within the cell (centre, ll, ur).</p>	<p>Sub-pixel accuracy is achieved relative to an identified absolute independent terrestrial referencing system (such as a national map grid).</p> <p>A consistent gridding/sampling frame is necessary to meet this requirement.</p> <p>Relevant metadata must be provided under 1.8 and 1.9.</p> <p><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></p>	Yes	Yes	<p>The sub pixel accuracy is 150m for the VNIR bands and 225 m for the VNIR/SWIR together.</p> <p>The PROBA-V acquisition are systematically compared to Landsat well known ground location. The multi-temporal accuracy is monitored and reported every 3 months.</p> <p>Detailed information on the geometric correction is available in the PUM accessible through the single DOI landing page for the PROBA-V C2 collections (see General information )</p>	<p><b>Verified at Threshold</b></p> <p><b>PROBA-MD-ACS-VITO-0102 or N77D7-PV02-US-5-IQC-GC-ATBD-ACS-0102-2.1 p11</b></p> <p><b>PROBA-MD-ACS-VITO-0102 p13-14, 49,63</b></p> <p><b>PUM v3.01 – Link Verified</b></p>

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	WGCV Comments
		<p>Relevant metadata must be provided under 1.8 and 1.9.</p> <p><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></p>					

## General information on the PROBA-V Collection 2 products and DOI landing page

The PROBA-V products comprise the following elements:

- Segment products (Level-1C and Level-2A, both consisting of TOA reflectances)**  
 The Level-1C product contains the raw, non-projected observations in segments, as well as calibration information, while the Level-2A (L-2A) products contain the projected segment data. The latter were named "P products" for SPOT-VGT.
- Synthesis products (Level-3, both TOA and TOC)**  
 These products contain daily (S1, available at all resolutions) and multi-daily (S5 for 100 m) TOA reflectances that are composed of cloud, shadow, and snow/ice screened observations. Additionally, Top-of-Canopy (TOC) reflectance and Normalized Difference Vegetation Index (NDVI) products are corrected for atmospheric reflectance contributions, such as aerosols and gaseous absorption. For the TOC reflectances, also 10-daily composites are available (S10 for 300 m and 1 km) next to the S1 (for all resolutions) and 5-daily (S5) for the 100 m products. Synthesis products were previously known as S products for SPOT-VGT.

In Collection 1, all product metadata were CF-1.6-compliant. To further facilitate the access for non-experienced users, Collection 2 aims to follow the CARD4L specifications. However **only the PROBA-V Level 3 TOC products are Surface Reflectance Products** and are subject to the current self assessment for compliance against the Surface Reflectance Product Family Specifications.

VITO has implemented DOI landing pages for hosting all the PROBA-V Collection 2 reprocessing information and documentation. The registration of the DOIs is handled via ESA on the ISO 26324 DOI System website. The DOI pages will be activated at PROBA-V C2 release.

Only the DOI and landing page describing the Level3-TOC products is relevant for the current self assessment document and listed in the table below.

PROBA-V C2 Level	DOI (To be activated)	Landing page	# collections
<b>Level3-TOC</b>	<a href="https://doi.org/10.5270/PRV-7dte3c2">10.5270/PRV-7dte3c2</a>	<a href="https://proba-v.vgt.vito.be/en/product-types/c2/level-3TOC">https://proba-v.vgt.vito.be/en/product-types/c2/level-3TOC</a>	6 collections (S1-1Km, S1-333m, S1-100m, S5-100m, S10-1km, S10-333m)

*Table 1: DOI landing page*

## Summary Self-Assessment Table

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

<b>4. Geometric Corrections</b>		
4.1 Geometric Correction	Yes	Yes

## 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>.