Committee on Earth Observation Satellites	**Analysis Ready Data** ***For Land***	**Product Family Specification:** **Normalised Radar Backscatter**

Document Status

For Adoption as: Product Family Specification, Normalised Radar Backscatter

This Specification should next be reviewed on: Q1/2022

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

Document History

Version	Date	Description of Change	Author
0.0.2	23.03.2017	Zero Draft based on materials discussed in and leading up to LSI-VC-3, provided by SEO and others	Lewis
0.1.0	18.04.2017	Various revisions to structure.	Lewis
1.0.0	18.04.2017	Included material provided by Brian Killough/SEO reflecting input from a range of SAR experts/users.	Lewis
1.0.1	20.04.2017	Edits reflecting feedback from SEO, change to the figure/table in 'guidance'; removed item 4.2, which appeared redundant; moved reference to definitive ephemeris to a note under item 4.1; added reference to speckle under table 3 (radiometric corrections).	Lewis, Killough
2.0.0	30.08.2017	Feedback incorporated, circulated to LSI-VC.	Lewis
2.1.0	06.09.2017	Feedback from ESA included.	Lewis
2.1.1	06.09.2017	Edits rolled in.	Lewis
3.0	02.02.2018	Feedback from the teleconference (06/12/2018) and post teleconf (emails) Included.	Siqueira
3.1	03.04.2018	Nuno Miranda (ESA) comments addressed (uncertainty information to be required at the threshold level – 3.4 Radiometric corrections (Accuracy), split sensor acquisition mode).	Siqueira, Miranda
3.1.1	12.04.2018 04.06.2018	Ake Rosenqvist (JAXA) comments (split sensor acquisition mode into acquisition and processing parameters, include "global incidence angle"). Feedback from Ben Lewis, GA (process table update)	Siqueira Siqueira
3.2	07.08.2018 21.08.2018	Feedback from the "SAR ARD definition Team" before and at IGARSS 2018. Feedback on the 2nd SAR ARD definition Team teleconference (20/08/2018):	Siqueira Rosenqvist

		add a sentence on 1.19 that the radiometric performance metadata should be provided for each of the polarization channel when available	
3.2.1	14.12.2018	Clarification about per pixel NESZ provision for each channel when noise removal is implemented.	Chapman
3.2.2	05.02.2019	Abstract updated, metadata definition added and v3.2.2 shared with LSI-VC list and LSI-VC-7 participants.	Rosenqvist, Charbonneau & Siqueira
3.2.3	27.05.2019	Formatting and verbiage updated for consistency.	Metzger
4.0	02.03.2019	Version endorsed at LSI-VC7 meeting (14Feb 2019) with minor amendments to address feedback from the SAR Definition Team.	LSI-VC-7
4.1	06.26.2019	Added self-assessment columns	Bontje
4.2	20.12.2019	Integrated review at ESRIN CEOS WGCV SAR meeting.	Rosenqvist, Small, Chapman, Meyer, Lavalle, Miranda, Thankappan, Tadono, Zhou
4.3	11.01.2020	Integrated experiences with polarimetric document and clarified metadata descriptions for source data and products. Metadata specifications as separate document.	Small, Rosenqvist, Charbonneau & Zhou
4.4	12.01.2020	Single-source and Multi-source cases tentatively as separate documents.	Small & Rosenqvist
4.5	06.02.2020	2.3 Scattering Area Image added	Small, Rosenqvist Charbonneau, Yuan, Dadamia, Zhou & Kellndorfer
4.6	18.02.2020	Simple mosaic multi-source case tentatively added to single document. Separate multi-source case still in development and alignment with POL v.2.7	Rosenqvist
4.7	13.03.2020	Update to 4.4 Gridding Convention	Small, Kellndorfer, Rosenqvist & Charbonneau
4.8	23.04.2020 10.05.2020	• Definitions: Revised CARD4L Acronym for Interferometric Radar from “IR” to “InSAR” • Item 3.2. Name change from “Backscatter conversion” to “Scaling conversion”	Thankappan, Rosenqvist, Small, Charbonneau
4.9	12.05.2020	• Items 1.2 & 2.1: Aligned Target requirements with the SR 4.2 PFS and added NRB Metadata Specification as Target • Document history editorial	Rosenqvist, Labahn Rosenqvist, Chapman, Labahn
5.0	12.05.2020	PFS endorsed at LSI-VC-9, meeting #3	LSI-VC-9
5.1	03.03.2021	Proposed changes after Feb. 2021 telecon	Small, Charbonneau
5.2	14.04.2021	• Item 1.7.7: Text clarification • Item 2.3: Move to Target • Item 2.9: Added new per-pixel metadata: Resampled DEM (Target)	Rosenqvist, Logan, Charbonneau, Zhou, Small, Chapman, Kellndorfer, Yuan,

			Repse, Truckenbrodt, Tadono, Albinet
5.3	03.05.2021	• Item 1.6.6: Move source data looks to Target • Item 1.7.1: Product Level and Product ID information requirement removed • Item 1.7.5: Two corners sufficient • Item 2.3, 2.4: move proposed new descriptive text to forthcoming "Educational resources" document	Rosenqvist, Logan, Charbonneau, Zhou, Small, Chapman, Kellndorfer, Yuan, Repse, Truckenbrodt, Tadono, Albinet
5.4	20.05.2021 08.08.2021	• Item 4.3: Geolocation accuracy requirement (Threshold) relaxed as per LSI-VC-10 discussions • Editorial	Rosenqvist
5.5.01	31.08.2021 09.09.2021 29.09.2021 30.09.2024	• Items 1.6.3, 1.6.5, 1.6.9, 1.7.1, 1.7.6, 2.8, 4.3: Text clarifications • Item 1.6.9: Allowing for provision of mean and/or max/min noise level values • Item 1.7: Name change "Product Attributes" to "CARD4L Product Attributes" • Item 1.7.5: Require same CRS as in 1.7.9 • Item: 1.7.6: Format requirement • Item 1.7.9: Move EPSG code requirement to Threshold • Item 1.7.10: Removed (redundant) • Item 2.8: Name change "Acquisition Day" to "Acquisition ID" image. • Item 2.9: Name change "Resampled DEM" to "Per-pixel DEM" • 4.2: Added specifications of EGM used (Threshold) and methods for resampling of DEM and EGM (Target) • 4.3: Absolute localisation error given as bias and standard deviation (Threshold) • Item 1.6.7 (Source Data Image Attributes): Azimuth Pixel Spacing can be provided in units of metres or seconds.	Repse, Zhou, Rosenqvist, Yuan, Charbonneau, Truckenbrodt, Small
5.5	04.10.2021 14.10.2021	Editorial check	Bontje, Rosenqvist

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Description

Product Family Title: **Normalised Radar Backscatter (CARD4L-NRB)**

Applies to*:* Data collected by Synthetic Aperture Radar sensors.

The CARD4L Product Family Specifications for Synthetic Aperture Radar (SAR) data are specifically aimed at users interested in exploring the potential of SAR but who may lack the expertise or facilities for SAR processing. There are (as of September 2021) two CARD4L SAR products endorsed by CEOS LSI-VC, and two under development:

- Normalised Radar Backscatter [endorsed]
- Polarimetric Radar [endorsed]
- Geocoded Single-Look Complex [under development]
- Interferometric Products [under development]

The CARD4L Normalised Radar Backscatter product specification described below has been subject to Radiometric Terrain Correction (RTC) and is provided in the gamma-0 (γ^0) backscatter convention, which mitigates the variations from diverse observation geometries. It is recommended for most land applications. As the NRB product contains backscatter values only, it cannot be directly used for SAR polarimetry or interferometric applications that require local phase estimates.

It should be noted that while speckle is inherent in SAR acquisitions, speckle filtering has not been applied to the Normalised Radar Backscatter product in order to preserve spatial resolution and user freedom. Some applications (or processing methods) may require spatial or temporal filtering for stationary backscatter estimates.

Definitions

CARD4L	CEOS Analysis Ready Data for Land
NRB	Normalised Radar Backscatter
POL	Polarimetric Radar
GSLC	Geocoded Single-Look Complex
InSAR	Interferometric Radar
RTC	Radiometric Terrain Correction
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.
Spatial Resolution	The highest magnification of the sensor at the ground surface.
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	Recommended Requirement Modification
1.1	**Traceability**	Not required.	Data must be traceable to SI reference standard. *Note 1. Relationship to 3.4. Traceability requires an estimate of measurement uncertainty.* *Note 2: Information on traceability should be available in the metadata as a single DOI landing page.*				
1.2	**Metadata Machine Readability**	Metadata is provided in a structure that enables a computer algorithm to be used to consistently and automatically identify and extract each component part for further use.	As threshold, but metadata is formatted in accordance with CARD4L NRB Metadata Specifications, v.5.5, or a community endorsed standard that facilitates machine-readability, such as ISO 19115-2				
1.3	**Product type**	CARD4L product type name and (if required by the data provider) Copyright.	As threshold.				
1.4	**Document Identifier**	Reference to CARD4L-Normalised Radar Backscatter document as URL or DOI.	As threshold.				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
1.5	**Data Collection Time**	Number of source data acquisitions of the data collection is identified. The start and stop time of data collection is identified in the metadata, expressed in date/time (UTC). In case of composite products, the dates/times of the first and last data takes.	As threshold.				
1.6	**Source Data Attributes**	Sub-section describing (detailing) the SAR acquisition used to generate the CARD4L product. *Note: Source data attribute information are described for each acquisition and sequentially identified as acqID= 1, 2, 3, …*					
1.6.1	**Source Data Access**	The metadata identifies the location from where the source data can be retrieved, expressed as a URL or DOI.	The metadata identifies an online location from where the data can be consistently and reliably retrieved by a computer algorithm without any manual intervention being required.				
1.6.2	**Instrument**	The instrument used to collect the data is identified in the metadata: - Satellite name - Instrument name	As threshold, but including a reference to the relevant CEOS Missions, Instruments and Measurements Database record.				
1.6.3	**Source Data Acquisition Time**	The start date and time of source data is identified in the metadata, expressed in UTC in date and time, at least to the second.	As threshold.				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
1.6.4	**Source Data Acquisition Parameters**	Acquisition parameters related to the SAR antenna: - Radar band - Centre frequency Observation mode - Polarization(s) - Antenna pointing [Right/Left] - Beam ID	As threshold.				
1.6.5	**Source Data Orbit Information**	Information related to the platform orbit used for data processing: - Pass direction [asc/desc) - Orbit data source [e.g., predicted/definite/ precise/ downlinked etc.]	As threshold, including also: - Platform heading angle expressed in degrees [0 360] from North - Orbit data file containing state vectors (minimum of 5 state vectors, from 10% of scene length *before* start time to 10% of scene length *after* stop time) - Platform (mean) altitude				
1.6.6	**Source Data Processing Information**	Processing parameters details of the source data: - Processing facility - Processing date - Software version - Product ID (file name) - Product level - Azimuth number of Looks - Range number of Looks (separate values for each beam, as necessary)	As threshold, Plus additional relevant processing parameters, e.g., Range- and Azimuth Look Bandwidth and LUT applied				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
1.6.7	**Source Data Image Attributes**	Image attributes related to the source data: - Source Data geometry (slant range/ground range) - Azimuth pixel spacing [m] (alternatively, Azimuth pixel spacing can be provided in second [s], equivalent to the azimuth time sample interval) - Range pixel spacing - Azimuth resolution - Range resolution - Near range incident angle - Far range incident angle	The geometry of the image footprint expressed in WGS84 in a standardised format (e.g., WKT).				
1.6.8	**Sensor Calibration**	Not required.	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				
1.6.9	**Performance Indicators**	Provide performance indicators on data intensity noise level ($NE\sigma^0$ and/or $NE\beta^0$ and/or $NE\gamma^0$ (noise equivalent sigma and/or beta and/or gamma naught)). Provided for each polarization channel when available. Parameter may be expressed as the mean and/or minimum and maximum noise equivalent values of the source data.	Provide additional relevant performance indicators (e.g., ENL, PSLR, ISLR etc.)				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
		Values do not need to be estimated individually for each product, but may be estimated once for each acquisition mode, and annotated on all products.					
1.6.10	**Source Data Polarimetric Calibration Matrices**	Not Required.	The complex-valued polarimetric distortion matrices with the channel imbalance and the cross-talk applied for the polarimetric calibration.				
1.6.11	**Mean Faraday Rotation Angle**	Not Required.	The mean Faraday rotation angle estimated from the polarimetric data and/or from models with reference to the method or paper used to derive the estimate.				
1.6.12	**Ionosphere Indicator**	Not required.	Flag indicating whether the backscatter imagery is "significantly impacted" by the ionosphere (0- false, 1 – true). Significant impact would imply that the ionospheric impact on the backscatter exceeds the radiometric calibration requirement or goal for the imagery.				
1.7	**CARD4L Product Attributes**	Sub-section containing information related to the CARD4L product generation procedure and parameters					

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
1.7.1	**Product Data Access**	Processing parameters details of the CARD4L product: - Processing facility - Processing date - Software version - Location from where the CARD4L product can be retrieved, expressed as a URL or DOI.	The metadata identifies an online location from where the data can be consistently and reliably retrieved by a computer algorithm without any manual intervention being required.				
1.7.2	**Ancillary Data**	Not required.	The metadata identifies the sources of ancillary data used in the generation process, ideally expressed as DOIs. *Note: Ancillary data includes DEMs and any additional data sources used in the generation of the product.*				
1.7.3	**Product Sample Spacing**	CARD4L product processing parameters details: - Pixel (column) spacing - Line (row) spacing	As threshold.				
1.7.4	**Product Filtering**	Flag if filter has been applied [true/false] Metadata should include - Reference to algorithm - Input filtering parameters - Type - Window size - Other filter parameters	As threshold.				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
1.7.5	**Product Bounding Box**	Two opposite corners of the product file (bounding box) are identified, expressed in the coordinate reference system defined in 1.7.9.	As threshold.				
1.7.6	**Product Image Extent**	The geometry of the image footprint expressed in WGS84, in a standardised format (e.g., WKT).	As threshold.				
1.7.7	**Product Image Size**	Image attributes of the CARD4L product: - Number of lines - Number of pixels/line - File header size (if applicable) - Number of no-data border pixels (if appl.)	As threshold.				
1.7.8	**Product Pixel Coordinate Convention**	Coordinate referring to the Centre, or the Upper Left Corner or the Lower Left Corner of a pixel. Values are [pixel centre, pixel ULC or pixel LLC]	As threshold.				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
1.7.9	**Product Coordinate Reference System**	The metadata lists the map projection (or geographical coordinates, if applicable) that has been used and any relevant parameters required to use of data in that map projection, expressed in a standardised format (e.g., WKT). Indicate EPSG code, if defined for the CRS.	As threshold.				

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, but metadata is formatted in accordance with CARD4L NRB Metadata Specifications, v.5.5				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
2.2	**Data Mask Image**	Mask image indicating: - Valid data - Invalid data - No data File format specifications/ contents provided in metadata: - Sample Type [Mask] - Data Format [Raw/GeoTif/COG, …] - Data Type [Byte/Int/Float, ...] - Bits per sample - Byte order - Bit value representation	As threshold, including in addition e.g. - Layover (masked as invalid data in Threshold) - Radar shadow (masked as invalid data in Threshold) - Ocean water, etc.				
2.3	**Scattering Area Image**	Not required.	DEM-based scattering area image used for terrain normalisation is provided. File format specifications/ contents provided in metadata: - Sample Type [Scattering Area] - Data Format - Data Type - Byte Order - Bits per sample				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
2.4	**Local Incident Angle Image**	DEM-based Local Incident angle image is provided. File format specifications/ contents provided in metadata: - Sample Type [Angle] - Data Format - Data Type - Byte Order - Bits per sample	As threshold.				
2.5	**Ellipsoidal Incident Angle Image**	Not required.	Ellipsoidal incident angle is provided. Indicate which ellipsoidal height was used. File format specifications/ contents provided in metadata: - Sample Type [Angle] - Data Format - Data Type - Byte Order - Bits per sample				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
2.6	**Noise Power Image**	Not required.	Estimated noise equivalent σ^o (or β^0 or γ^o, as applicable) used for Noise Removal, if applied, for each channel. File format specifications/ contents provided in metadata: - Sample Type [NESZ or NEBZ] - Data Format - Data Type - Byte Order - Bits per sample				
2.7	**Gamma-to-Sigma Ratio Image**	Not required.	Ratio of the integrated area in the Gamma projection over the integrated area in the Sigma projection (ground). Multiplying RTC γ^o by this ratio results in an estimate of RTC σ^o . File format specifications/ contents provided in metadata: - Sample Type [Ratio] - Data Format - Data Type - Byte Order - Bits per sample				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
2.8	**Acquisition ID Image**	**Note: Required for multi-source product only.** Acquisition ID, or acquisition date, for each pixel is identified. In case of multi-temporal image stacks, use source acquisition ID (i.e., 1.6 acqID values) to list contributing images. In case of Date, data represent day offset to reference observation date [UTC]. Date used as reference ("Day 0") is provided in the metadata. Pixels not representing a unique date (e.g., pixels averaged in image overlap zones) are flagged with a pre-set pixel value that is provided in the metadata. File format specifications/ contents provided in metadata: - Sample Type [Day, ID] - Data Format - Data Type - Byte Order - Bits per sample	In case of image composites, the sources for each pixel are uniquely identified.				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
2.9	**Per-pixel DEM**	Not required.	Provide DEM as used during the geometric and radiometric processing of the SAR data, resampled to an exact geometric match in extent and resolution with the CARD4L SAR image product. File format specifications/ contents provided in metadata: - Sample Type [Height] - Data Format - Data Type - Byte Order - Bits per sample				

Radiometric Terrain Corrected Measurements

The following requirements must be met for all pixels in a collection. The requirements indicate the necessary outcomes and to some degree the minimum steps necessary to be deemed to have achieved those outcomes. Radiometric corrections must lead to normalised measurement(s) of backscatter intensity.

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
3.1	**Backscatter Measurements**	Terrain-flattened Gamma-Nought backscatter coefficient (γ^0_T) is provided for each polarization (e.g., HH, HV, VV, VH). File format specifications/contents provided in metadata: - Measurement Type [Gamma-Nought] - Backscatter Expression Convention [linear amplitude or linear power*] - Polarization [HH/HV/VV/VH] - Data Format [Raw/GeoTif/COG, …] - Data Type [Byte/Int/Float, ...] - Byte order - Bits per sample **Note: transformation to the logarithm decibel scale is not required or* desired *as this step can be easily completed by the user if necessary.*	As threshold.				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
3.2	**Scaling Conversion**	Indicate equation to convert from pixel linear amplitude/power to logarithmic decibel scale, including, if applicable, associated calibration (dB offset) factor.	As threshold.				
3.3	**Noise Removal**	Flag if noise removal* has been applied (Y/N). Metadata should include reference to algorithm as URL or DOI * *Note: Thermal noise removal and image border noise removal to remove overall scene noise and scene edge artefacts, respectively.*	As threshold.				
3.4	**Radiometric Terrain Correction Algorithms**	Adjustments are made for terrain by modelling the local illuminated reference area using the preferred choice of a traceable published peer reviewed algorithm to produce a radiometrically terrain corrected (RTC) Gamma-Nought (γ^0_T). Metadata references: - a citable peer-reviewed algorithm - technical documentation regarding the implementation of that algorithm expressed as URLs or DOIs - the sources of ancillary data used to make corrections.	Require resolution of DEM better than the output product resolution when applying terrain corrections.				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
		Note 1: Examples of technical documentation include an Algorithm, Theoretical Basis Document, product user guide, etc.					
3.5	**Radiometric Accuracy**	Not required.	Uncertainty (e.g., bounds on Υ^0) information is provided as document referenced as URL or DOI. SI traceability is achieved.				

Geometric Terrain 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 Algorithms**	Not required	Metadata references: - A metadata citable peer-reviewed algorithm, - Technical documentation regarding the implementation of that algorithm expressed as URLs or DOIs - The sources of ancillary data used to make corrections. - Resampling method used for geometric processing of the source data. *Note 1: Examples of technical documentation can include e.g., an Algorithm, Theoretical Basis Document, a Product User Guide.*				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
4.2	**Digital Elevation Model**	a) During ortho-rectification, the data provider shall use the same DEM that was used for the radiometric terrain flattening to ensure consistency of the data stack. b) Provide reference to Digital Elevation Model used for Geometric Terrain Correction. c) Provide reference to Earth Gravitational Model (EGM) used for Geometric Correction	a) A DEM with comparable or better resolution to the resolution of the output CARD4L product shall be used. b) Resampling method used for preparation of the DEM. c) Method used for resampling of EGM. d) As threshold.				
4.3	**Geometric Accuracy**	An estimate of the absolute localisation error is provided as bias and standard deviation, provided in slant range/azimuth, or Northing/Easting. *Note 1: Can be obtained from corner reflector measurements or mission calibration/ validation results.* *Note 2: Accurate geolocation is a prerequisite to radar processing to correct for terrain. To enable interoperability between radar sensors, absolute accuracy is required.*	Output product sub-sample accuracy should be less than or equal to 0.1-pixel radial root mean square error (rRMSE). Provide documentation of estimate of absolute localisation error as DOI or URL.				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
4.4	**Gridding Convention**	A consistent gridding/sampling frame is used. The origin is chosen to minimise any need for subsequent resampling between multiple products (be they from the same or different providers). This is typically accomplished via a “snap to grid” in relation to the most proximate grid tile in a global system.** ** If a product hierarchy of resolutions exists (or is planned), the multiple resolutions should nest within each other (e.g., 12.5m, 25m, 50m, 100m, etc.), and not be disjoint.	Provide DOI or URL to gridding convention used. When multiple providers share a common map projection, providers are encouraged to standardise the origins of their products among each other. In the case of UTM/UPS coordinates, the upper left corner coordinates should be set to an integer multiple of sample intervals from a 100 km by 100 km grid tile of the Military Grid Reference System's 100k coordinates (“snap to grid”). For products presented in geographic coordinates (latitude and longitude), the origin should be set to an integer multiple of samples in relation to the closest integer degree.				

Summary Self-Assessment Table

		Threshold	Target
1	**General Metadata**		
1.1	Traceability		
1.2	Metadata Machine Readability		
1.3	Product type		
1.4	Document Identifier		
1.5	Data Collection Time		
1.6	**Source Data Attributes**		
1.6.1	Source Data Access		
1.6.2	Instrument		
1.6.3	Source Data Acquisition Time		
1.6.4	Source Data Acquisition Parameters		
1.6.5	Source Data Orbit Information		
1.6.6	Source Data Processing Information		
1.6.7	Source Data Image Attributes		
1.6.8	Sensor Calibration		
1.6.9	Performance Indicators		
1.6.10	Source Data Polarimetric Calibration Matrices		
1.6.11	Mean Faraday Rotation Angle		
1.6.12	Ionosphere Indicator		
1.7	**CARD4L Product Attributes**		
1.7.1	Product Data Access		
1.7.2	Ancillary Data		
1.7.3	Product Sample Spacing		
1.7.4	Product Filtering		
1.7.5	Product Bounding Box		
1.7.6	Product Image Extent		
1.7.7	Product Image Size		
1.7.8	Product Pixel Coordinate Convention		
1.7.9	Product Coordinate Reference System		
2	**Per-Pixel Metadata**		
2.1	Metadata Machine Readability		
2.2	Data Mask Image		
2.3	Scattering Area Image		
2.4	Local Incident Angle Image		
2.5	Ellipsoidal Incident Angle Image		
2.6	Noise Power Image		
2.7	Gamma-to-Sigma Ratio Image		
2.8	Acquisition ID Image		
2.9	Per-Pixel DEM		
3	**Radiometric Terrain Corrected Measurements**		
3.1	Backscatter Measurements		
3.2	Scaling Conversion		
3.3	Noise Removal		
3.4	Radiometric Terrain Correction Algorithms		
3.5	Radiometric Accuracy		
4	**Geometric Terrain Corrections**		
4.1	Geometric Correction Algorithms		
4.2	Digital Elevation Model		
4.3	Geometric Accuracy		
4.4	Gridding Convention		

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 are 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:

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

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

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 (as subject to due process) become accepted as *threshold* requirements.

Reference Papers

The following papers provide scientific and technical guidance:

Hoekman D. and Reiche, J. Multi-model radiometric slope correction of SAR images of complex terrain using a two-stage semi-empirical approach. *Remote Sensing of Environment*, **156** (2015), pp. 1-10. https://doi.org/10.1016/j.rse.2014.08.037

Shimada, M., Itoh, T., Motohka, T., Watanabe, M., Shiraishi, T., Thapa, R., and Lucas, R. New global forest/non-forest maps from ALOS PALSAR data (2007–2010). *Remote Sensing of Environment* **155** (2014) pp. 13–31. https://doi.org/10.1016/j.rse.2014.04.014

Shimada, M. Ortho-Rectification and Slope Correction of SAR Data Using DEM and Its Accuracy Evaluation. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing.* Dec. 2010, 3(4), pp 657-671. https://doi.org/10.1109/JSTARS.2010.2072984

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Small D. Flattening Gamma: Radiometric Terrain Correction for SAR Imagery, *IEEE Transactions on Geoscience and Remote Sensing*, 2011, Vol. 49(8), pp. 3081-3093. https://doi.org/10.1109/TGRS.2011.2120616

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