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

Document Status

Product Family Specification, Normalised Radar Backscatter

This Specification should next be reviewed on: December 2019

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 and Killough
2.0.0	30-08-2017	Feedback incorporated, circulated to LSI-VC.	Lewis
2.1.0	6-09-2017	Feedback from ESA included.	Lewis
2.1.1	6-09-2017	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
3.1.1	12-04-2018	Ake Rosenqvist (JAXA) comments (split sensor acquisition mode into acquisition and processing parameters, include "global incidence angle").	Siqueira
3.1.1	04-06-2018	Feedback received from Dr. Ben Lewis (process table update).	Siqueira
3.2	07-08-2018	Feedback from the "SAR ARD definition Team" before	Siqueira

		and at IGRASS 2018.	
3.2	21-08-2018	Feedback on the 2nd SAR ARD definition Team teleconference (20/08/2018): add a sentence on 1.19 that the radiometric performance metadata should be provided for each of the polarization channel when available (from Ake Rosenqvist).	Siqueira
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 meeting 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

Description

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

Applies to*:* Data collected by synthetic aperture radar sensors.

Abstract

CARD4L (CEOS Analysis-Ready Data for Land) is an effort by the Committee on Earth Observation Satellites (CEOS) to address this Big Data challenge. It provides voluntary standards for satellite data providers with regard to the geometric and radiometric accuracy, and content and availability of relevant meta data. For each parameter, the CARD4L specifications define a minimum (Threshold) requirement, considered sufficient to render the product ready for analysis, and a more stringent (Target) requirement, that further improves the product quality/usefulness. CARD4L also aims to facilitate access to a broader Earth observation user community by definition of data products that do not require expert knowledge to ingest and analyse.

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 currently five CARD4L SAR products:

- *Normalised Radar Backscatter*
- *Geocoded Single-Look Complex*
- *Polarimetric Radar Decomposition*
- *Normalised Radar Covariance Matrix*
- *Differential Interferometry Products*

The CARD4L Normalised Radar Backscatter product specification described below has been subject to Radiometric Terrain Correction (RTC) and is given in gamma-0 (γ^0) backscatter, which mitigates the incidence angle effect. It is recommended for most land applications. Sigma-0 (σ^0) backscatter can however be retrieved by using local incidence angle information provided in the per-pixel meta data. As the NRB product contains backscatter values only, it cannot be used for SAR polarimetry or interferometric applications.

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, As a result, the number of looks is very small; most applications (or processing methods) therefore require spatial or temporal filtering for stationary backscatter estimates. Generally, the user cannot process the samples directly and independently as with CARD4L optical products. If no advanced speckle filter is applied by the user, the default recommendation is to apply at least a 7x7 averaging window to the NRB product data layer(s) for common applications.

Definitions

NRB	Normalised Radar Backscatter
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
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
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.*
1.2	**Metadata Machine Readability**	Metadata is provided in a structure that enables a computer algorithm to be used to consistently and automatically identify and extract each component part for further use.	As threshold, but metadata is formatted in accordance with ISO 19115-2.
1.3	**Data Collection Time**	The start and stop time of data collection is identified in the metadata, expressed in date/time, to the second, with the time offset from UTC unambiguously identified.	Acquisition time for each pixel is identified (or can be reliably determined) in the metadata, expressed in date/time at UTC, to the second.
1.4	**Geographical Area**	The surface location to which the data relates is identified, typically as a series of four corner points, expressed in an accepted coordinate reference system (e.g.,WGS84).	The geographic area covered by the observations is identified specifically, such as through a set of coordinates of a closely bounding polygon. The location to which each pixel refers is identified (or can be reliably determined) expressed in projection coordinates with reference datum.
1.5	**Coordinate Reference System**	The metadata lists the coordinate reference system that has been used.	As threshold.
1.6	**Map Projection**	The metadata lists the map projection that has been used and any relevant parameters required in relation to use of data in that map projection.	As threshold.
1.7	**Geometric Correction**	The metadata describes the geodetic correction methods used, including reference database and ancillary data such as elevation model(s) and reference chip-sets. DOIs are	As threshold.

		used.	
1.8	**Geometric Accuracy**	A single-figure estimate of the Geometric accuracy is provided. The user is not necessarily provided with results of geometric correction processes pertaining to the dataset.	The metadata includes metrics describing the assessed geodetic accuracy of the data and the 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 as root mean square error (RMSE) or Circular Error Probability (e.g., CEP90, CEP95).
1.9	**Instrument**	The instrument used to collect the data is identified in the metadata.	As threshold, but including a reference to the relevant CEOS Missions, Instruments and Measurements Database record.
1.10	**Acquisition Parameters**	Acquisition parameters details: Look direction (L, R). - polarizations - resolution (range x azimuth) - Orbit direction of data-take (ascending or descending) - Satellite heading angle (at scene centre)	As threshold.
1.11	**Processing Parameters**	Processing parameters details: - pixel spacing (range x azimuth) Number of looks (range x azimuth)	As threshold.
1.12	**Sensor Calibration**	Sensor calibration details/list of scientific papers and articles websites describing the calibration approach/method used.	As threshold.
1.13	**Radiometric Accuracy**	Not required. The general metadata does not include specific information on the radiometric accuracy of the data. OR, A global uncertainty estimate is provided.	The metadata includes metrics describing the assessed absolute radiometric accuracy of the data, expressed as absolute radiometric uncertainty relative to a known reference standard (e.g., pseudo-invariant calibration sites). *Note: For example, this may come from comparison with rigorously collected in situ measurements.*
1.14	**Algorithms**	All algorithms and the sequence in which they were applied in the generation.	As threshold, but only algorithms that have been published in a peer-reviewed journal. *Note: It is possible that high quality corrections are applied through.*

#	Item	Threshold (Minimum Requirements)	Target (Desired) Requirements
1.15	**Ancillary Data**	The metadata identifies the sources of ancillary data used in the generation process, ideally expressed as DOIs. *Note: Ancillary data includes DEMs, etc. data sources.*	As threshold, but the ancillary data is also available for free online download, contemporaneously with the product.
1.16	**Processing Chain Provenance**	Not required.	The metadata includes a description of the processing chain used to generate the product, including the versions of the software used.
1.17	**Data Access**	The metadata identifies the location from where the product can be retrieved, expressed as a DOI. *Note: Manual and* offline *interaction action (e.g. log in) may be required.*	The metadata identifies an online location from where the data (including any available new records) can be consistently and reliably retrieved by a computer algorithm without any manual intervention being required. *Note: Some manual interaction action may be required <u>in the first instance</u> ('one off' basis) to establish ongoing access to the data.*
1.18	**Overall Data Quality**	Not applicable.	TBD. There is a perceived need for machine-readable metrics describing the overall quality of the data, however the specifications for these are yet to be determined. If there is not a clear case and clear specifications for such metadata, then "Overall data quality" will be removed.
1.19	**Performance Indicators**	Provide performance indicators on resolution, SLR, NESZ and ENL. Those are not to be estimated on each product, but estimated once and annotated on all products. That information should be provided for each polarization channel when available.	As threshold.
1.20	**Ionosphere indicator**	Not applicable	Flag indicating whether the backscatter imagery is "significantly impacted" by the ionosphere (0- no, 1 – yes). Significant impact would imply that the ionospheric impact on the backscatter exceeds the radiometric calibration requirement or goal for the imagery.

Pre-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
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 relevant international Standards (ISO 19115-2).
2.2	**No Data**	Pixels or grid cells that do not correspond to an observation ('empty pixels') are clearly flagged.	As threshold.
2.3	**Layover**	Layover flags or mask is provided.	As threshold.
2.4	**Shadow**	Shadow flags or mask is provided.	As threshold.
2.5	**Local Incidence Angle**	Local Incidence angle image is provided.	As threshold.
2.6	**Global Incidence Angle**	Global incidence angle is provided.	As threshold.
2.7	**Digital Elevation Model**	Digital Elevation Model used for Radiometric Terrain Correction.	As threshold.
2.8	**Noise Equivalent Sigma0**	Noise equivalent σ^o used for Noise Removal, if applied, for each channel.	Noise equivalent σ^o for each channel.

Radiometric Corrections

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
3.1	**Measurements**	Gamma-0 (γ^0) backscatter coefficient is provided for each polarisation (e.g. HH, HV, VV, VH). *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.

3.2	**Noise Removal**	Optional.	Thermal noise removal and image border noise removal (when applicable) to remove overall scene noise and scene edge artefacts, respectively.
3.3	**Terrain Corrections**	Adjustments are made for terrain by modelling the local illuminated reference area using the preferred choice of peer reviewed models to produce a radiometrically terrain corrected (RTC) γ^0. Metadata references: - a citable peer-reviewed algorithm - technical documentation regarding the implementation of that algorithm expressed as DOIs - the sources of ancillary data used to make corrections *Note 1: Examples of technical documentation include an Algorithm.* Theoretical Basis Document, product user guide, etc. *Note 2: Requirement for metadata are better placed in 1.13 and 1.14 (Radiometric accuracy and Algorithms).*	Require resolution of DEM no worse than (TBD) the SAR backscatter resolution when applying terrain corrections. Require validation that any change in DEM or landcover between the date of the DEM determination and the date of the SAR backscatter acquisition does result in violating the radiometric or geometric accuracy.
3.4	**Accuracy**	Uncertainty (e.g., bounds on γ^0) information is provided. SI traceability is achieved.	As threshold.

Note: Speckle filtering is not addressed here, as this process removes noise but alters the original backscatter values. Some users may desire this processing step, but it is not accepted as a common product for the majority of applications.

Geometric Corrections

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

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements
4.1	**Accuracy**	a) Sub-pixel accuracy is taken to be less than or equal to 0.2-pixel radial root mean square error (rRMSE) or equivalent in Circular Error Probability (CEP) relative to a defined reference. b) A given data provider shall use the same DEM (DEM of their choice) to ensure consistency of the data stack. c) A consistent gridding/sampling frame is used, including common cell size, origin, and nominal sample point location within the cell (centre, ll, ur). *Note 1. Relevant metadata must be provided under 1.7 and 1.8 (Geometric correction and Geometric accuracy).* *Note 2. Accurate geolocation is a prerequisite to radar processing to correct for terrain. To enable interoperability between radar sensors, absolute accuracy is required. Orbit ephemeris updates (precise ephemeris) are required prior to any orthorectification steps to ensure accuracy.*	a) Sub-pixel accuracy is achieved relative to an identified absolute independent terrestrial referencing system (such as a national map grid). b) A DEM with comparable or better resolution to the resolution of the output ARD imagery shall be used. c) A consistent gridding/sampling frame is necessary to meet this requirement. *Note 3. Relevant metadata must be provided under 1.7 and 1.8 (Geometric correction and Geometric accuracy).*

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 (hyperlink).

A product can continue to use CARD4L branding as long as its generation and distribution remain consistent with the peer-reviewed assessment.

What is the difference between Threshold and Target?

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

Products that meet target requirements will reduce the overall product uncertainties and enhance broad-scale applications. For example, the products may enhance interoperability or provide increased accuracy through additional corrections that are not reasonable at the *threshold* level.

Target requirements anticipate continuous improvement of methods and evolution of community expectations, which are both normal and inevitable in a developing field. Over time, *target* specifications may (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.

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) pp13–31.

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

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, vol. 3, no. 4, pp 657 – 671.

Small D., Miranda N., Meier E. [2009] (presentation), Local Incidence Angle Considered Harmful, *Proc. of CEOS SAR 2009 Workshop,* Pasadena, California, USA, Nov. 17-19, 2009.

D. Small, N. Miranda and E. Meier, "A revised radiometric normalisation standard for SAR," 2009 *IEEE International Geoscience and Remote Sensing Symposium*, Cape Town, 2009, pp. IV-566-IV-569.
doi: 10.1109/IGARSS.2009.5417439.