	CEOS Analysis Ready Data	**Product Family Specification:** **Ocean Radar Backscatter**

Document Status

For Adoption as: Product Family Specification, Ocean Radar Backscatter

This Specification should next be reviewed on: TBD

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Document History

Version	Date	Description of Changes	Authors
0.01	28.02.2022	Zero Draft based on the CARD4L NRB PFS v5.5 (by Rosenqvist, Albinet, Chapman, Charbonneau, Dadamia, Meyer, Miranda, Lavalle, Kellndorfer, Small, Repse, Thankappan, Tadono, Truckenbrodt, Yuan, Zhou, Zebker, Lewis, Killough, Siqueira)	Albinet, Truckenbrodt, Rosenqvist
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Description

Product Family Title: **Ocean Radar Backscatter (CARD-ORB)**

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

The CEOS ARD 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 2022) three [PENDING LSI-VC-12 endorsement] CEOS ARD SAR products endorsed by CEOS LSI-VC, and two under development:

- Normalised Radar Backscatter [endorsed]
- Polarimetric Radar [endorsed]
- Ocean Radar Backscatter [PENDING LSI-VC-12 endorsement]
- Geocoded Single-Look Complex [under development]
- Interferometric Products [under development]

The CARD Ocean Radar Backscatter (ORB) product specification described below has been subject to Geoid Correction and is provided in the sigma-0 (σ^0) backscatter convention, which is recommended for most ocean applications. As the ORB 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, unless specified in the metadata, speckle filtering has not been applied to the ORB 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

CARD	CEOS Analysis Ready Data
ORB	Ocean Radar Backscatter
NRB	Normalised Radar Backscatter
POL	Polarimetric Radar
GSLC	Geocoded Single-Look Complex
InSAR	Interferometric Radar
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 underline 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 CARD ORB Metadata Specifications, v.1.0, or a community endorsed standard that facilitates machine-readability, such as ISO 19115-2				
1.3	**Product type**	CEOS ARD product type name and (if required by the data provider) Copyright.	As threshold.				
1.4	**Document Identifier**	Reference to CARD Ocean 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 - 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	**Source 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. 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.	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
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	CARD Product Attributes	Sub-section containing information related to the CARD ORB product generation procedure and parameters					
1.7.1	Product Data Access	Processing parameters details of the CARD ORB product: - Processing facility - Processing date - Software version - Location from where the CARD ORB 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.				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
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	CARD ORB product processing parameters details: - Pixel (column) spacing - Line (row) spacing	As threshold.				
1.7.4	Product Number of Looks	Not required.	Equivalent Number of Looks (ENL)				
1.7.5	Product Resolution	Not required.	Average spatial resolution of the CEOS ORB product along: - Columns - Rows				

1.7.6	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
1.7.7	Product Bounding Box	Two opposite corners of the product file (bounding box) are identified, expressed in the coordinate reference system defined in 1.7.11.	As threshold.				
1.7.8	Product Image Extent	The geometry of the image footprint expressed in WGS84, in a standardised format (e.g., WKT).	As threshold.				
1.7.9	Product Image Size	Image attributes of the CARD ORB product: - Number of lines - Number of pixels/line - File header size (if applicable) - Number of no-data border pixels (if appl.)	As threshold.				
1.7.10	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
1.7.11	**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.				
1.7.12	**Look Direction Polynomials**	In case the per-pixel item 2.7 (Look Direction Image) is not provided, then a list of the polynomial coefficients a_i necessary to reconstruct the look direction angle*, together with an estimate of the accuracy, shall be provided. Example polynomial: $LookDir = a_1 Lat^2 + a_2 Lon^2 + a_3 LatLon + a_4 Lat + a_5 Lon + a_6$ Where: a_i = polynomial coefficients Lat = lattiude Lon = Longitude Lat and Lon are the related coordinates in the product map units ['m', 'deg', 'arcsec']	As threshold.				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
		* Note: The look direction angle represents the planar angle between north and each range direction. It is not constant in range, especially close to the poles.					

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 <u>discriminate between</u> (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 CARD ORB Metadata Specifications, v.1.0				
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. - Land - Saturation - Others				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
2.3	**Geoid Incident Angle Image**	Geoid-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.				
2.4	**Noise Power Image**	Not required.	Estimated noise equivalent σ^o (or β^0, 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				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
2.5	**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	As threshold.				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
2.6	**Per-pixel Geoid**	Not required.	Provide Geoid as used during the geometric and radiometric processing of the SAR data, resampled to an exact geometric match in extent and resolution with the CARD ORB image product. File format specifications/ contents provided in metadata: - Sample Type [Height] - Data Format - Data Type - Byte Order - Bits per sample - Ground Sampling Distance				
2.7	**Look Direction Image**	Not required.	Look Direction Image is provided. It is representing the planar angle between north and each range direction. It is not constant in range, especialy close to the poles. File format specifications/ contents provided in metadata: - Sample Type [Height] - Data Format - Data Type - Byte Order - Bits per sample				

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.

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
3.1	**Backscatter Measurements**	Geoid-corrected Sigma-Nought backscatter coefficient (σ^0) is provided for each available polarization. File format specifications/contents provided in metadata: - Measurement Type [Sigma-Nought] - Backscatter Expression Convention [linear amplitude or linear intensity*] - Backscatter Conversion Equation - Polarization [HH/HV/VV/VH] - Data Format [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	**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.				
3.3	**Radiometric Accuracy**	Not required.	Uncertainty (e.g., bounds on σ^0) information is provided as document referenced as URL or DOI. SI traceability is achieved.				
3.4	**Mean Wind-Normalised Backscatter Measurements**	Not required.	Mean wind-normalised (over ocean) backscatter coefficient is provided for each available polarization. It is calculated as the ratio between the backscatter intensity and a simulated backscatter intensity image generated using an ocean surface wind model. File format specifications/contents provided in metadata: - Measurement Type [Wind-Normalised				

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
			Backscatter] - Backscatter Expression Convention [intensity ratio] - Polarization [HH/HV/VV/VH] - Data Format [GeoTif/COG, ...] - Data Type [Byte/Int/Float, ...] - Byte order - Bits per sample *Reference wind model, wind speed and direction used for reference backscattering coefficient should be provided.*				

Geometric Corrections

Geometric corrections must place the measurement accurately on the surface of the Ocean (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	Geoid	a) During ortho-rectification, the data provider shall use the same Geoid that was used for the radiometric geoid flattening to ensure consistency of the data stack. b) Provide reference to the Geoid used for the radiometric geoid flattening c) Provide reference to Earth Gravitational Model (EGM) used for Geometric Correction	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 enable time-series analysis or interoperability between radar sensors.*	Output product sub-sample accuracy should be less than or equal to 3-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., 12.5 m, 25 m, 50 m, 100 m, 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

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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 CEOS ARD

What are CEOS Analysis Ready Data (CARD) products?

CEOS ARD products have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with a minimum of additional user effort. These products would be resampled onto a common geometric grid (for a given product) and would provide baseline data for further interoperability both through time and with other datasets.

CEOS ARD 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 CEOS ARD?

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

- The product has been assessed as meeting CEOS ARD 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 CEOS ARD 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.