|  |  |  |
| --- | --- | --- |
|  | **Analysis Ready Data** | **Product Family Specification:****Synthetic Aperture Radar** |

**Toronto, October 3, 2024**

**CATALYST self-assessment for CEOS-ARD SAR v1.1 compliance.**

**CEOS-ARD SAR product type: Normalised Radar Backscatter**

**Sensor: Sentinel-1**

Zipped archive with sample CEOS-ARD NRB product: [CATALYST Sentinel-1 RTC CEOS Submission](https://pcigeomatics-my.sharepoint.com/%3Af%3A/g/personal/williams_catalyst_earth/EqRnDtrwf-FJkvaqSgvdYzABLarPP_Rx_RrqxaOyuFVSZg?e=SyAyEf)

**Dataset 1: S1A\_IW\_GRDH\_1SDV\_20240710T001801\_20240710T001826\_054691\_06A88A**

**VV backscatter image:**

S1A\_IW\_GRDH\_1SDV\_20240710T001801\_20240710T001826\_054691\_06A88A\_rtc\_vv.rtc.tif

**VH backscatter image:**

S1A\_IW\_GRDH\_1SDV\_20240710T001801\_20240710T001826\_054691\_06A88A\_rtc\_vh.rtc.tif

**Data Mask image:**

S1A\_IW\_GRDH\_1SDV\_20240710T001801\_20240710T001826\_054691\_06A88A\_rtc\_mask.rtc.tif

**Local Incidence Angle image:**

S1A\_IW\_GRDH\_1SDV\_20240710T001801\_20240710T001826\_054691\_06A88A\_rtc\_linc.rtc.tif

**XML metadata in CEOS-ARD SAR format:**

S1A\_IW\_GRDH\_1SDV\_20240710T001801\_20240710T001826\_054691\_06A88A\_rtc\_meta.rtc.tif

**Dataset 2: S1A\_IW\_GRDH\_1SDV\_20230603T230045\_20230603T230110\_048828\_05DF3F**

**VV backscatter image:**

S1A\_IW\_GRDH\_1SDV\_20230603T230045\_20230603T230110\_048828\_05DF3F\_rtc\_vv.rtc.tif

**VH backscatter image:**

S1A\_IW\_GRDH\_1SDV\_20230603T230045\_20230603T230110\_048828\_05DF3F\_rtc\_vh.rtc.tif

**Data Mask image:**

S1A\_IW\_GRDH\_1SDV\_20230603T230045\_20230603T230110\_048828\_05DF3F\_rtc\_mask.rtc.tif

**Local Incidence Angle image:**

S1A\_IW\_GRDH\_1SDV\_20230603T230045\_20230603T230110\_048828\_05DF3F\_rtc\_linc.rtc.tif

**XML metadata in CEOS-ARD SAR format:**

S1A\_IW\_GRDH\_1SDV\_20230603T230045\_20230603T230110\_048828\_05DF3F\_rtc\_meta.rtc.tif

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# Requirements

# General Metadata

| **#** | **Parameter** | **CEOS-ARD product** | **Requirements** | **Self-Assessment** |
| --- | --- | --- | --- | --- |
| **1.1** | **Traceability** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements**Data must be traceable to SI reference standard. *Note 1: Relationship to 3.5. 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** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Metadata is provided in a structure that enables a computer algorithm to be used to consistently and automatically identify and extract each component/variable/layer for further use. | Achieved level: THRESHOLD (GOAL)Metadata in separate metadata file in XML format, formatted in accordance with “CEOS-ARD\_ Metadata-spec\_Synthetic\_ Aperture\_Radar\_v1.1.xlsx”> |
| **Goal (Desired) Requirements**As threshold, but metadata is formatted in accordance with CEOS-ARD SAR Metadata Specifications, v.1.1, or in a community endorsed standard that facilitates machine-readability, such as ISO 19115-2, Climate and Forecast (CF) convention, the Attribute Convention for Data Discovery (ACDD), etc. |
| **1.3** | **Product Type** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**CEOS-ARD product type name – or names in case of compliance with more than one product type – and, if required by the data provider, copyright. | Achieved level: THRESHOLD<Product> in XML metadata file |
| **Goal (Desired) Requirements**As threshold. |
| **1.4** | **Document Identifier** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Reference to CEOS-ARD for Synthetic Aperture Radar PFS document as URL. | Achieved level: THRESHOLD<DocumentIdentifier> |
| **Goal (Desired) Requirements**As threshold. |
| **1.5** | **Data Collection Time** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Number of source data acquisitions of the data collection is identified. The start and stop UTC time of data collection is identified in the metadata, expressed in date/time. In case of composite products, the dates/times of the first and last data takes and the per-pixel metadata 2.8 (Acquisition ID Image) is provided with the product. | Achieved level: THRESHOLD<DataCollectionTime><NumberOfAcquisitions> <FirstAcquistionDate><LastAcquistionDate |
| **Goal (Desired) Requirements**As threshold. |
| **1.6** | **Source Data Attributes** |  | Subsection describing (detailing) each SAR acquisition used to generate the ARD product.*Note: Source data attribute information are described for each acquisition and sequentially identified as acqID= 1, 2, 3, …* | Achieved level: THRESHOLD<SourceAttributes> Single source product: acqID=1 |

| **#** | **Parameter** | **CEOS-ARD product** | **Requirements** | **Self-Assessment** |
| --- | --- | --- | --- | --- |
| **1.6.1** | **Source Data Access** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**The metadata identifies the location from where the source data can be retrieved, expressed as a URL or DOI. | Achieved level: THRESHOLD<SourceDataRepository> provided as URL  |
| **Goal (Desired) Requirements**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** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**The instrument used to collect the data is identified in the metadata:* Satellite name
* Instrument name
 | Achieved level: THRESHOLD (GOAL)<Satellite><SatelliteReference><Instrument> |
| **Goal (Desired) Requirements**As threshold, but including a reference to the relevant CEOS Missions, Instruments and Measurements Database record. |
| **1.6.3** | **Source Data Acquisition****Time** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**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. | Achieved level: THRESHOLD<SourceDataAcquisitionTime> <StartTime> <EndTime> |
| **Goal (Desired) Requirements**As threshold. |
| **1.6.4** | **Source Data Acquisition Parameters** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Acquisition parameters related to the SAR antenna:* Radar band
* Centre frequency
* Observation mode (i.e., Beam mode name)
* Polarization(s) (listed as in original product)
* Antenna pointing [Right/Left]
* Beam ID (i.e., Beam mode Mnemonic)
 | Achieved level: THRESHOLD<SourceDataAcquisitionParameters> <RadarBand> <RadarCenterFrequency> <ObservationMode> <Polarizations> <AntennaPointing> <BeamID>  |
| **Goal (Desired) Requirements**As threshold. |
| **1.6.5** | **Source Data Orbit Information** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Information related to the platform orbit used for data processing: * Pass direction [asc/desc] \*
* Orbit data source [e.g., predicted/ definite/ precise/ downlinked, etc.]

*\* For source data crossing the North or South Pole, it is recommended to produce two distinct CEOS-ARD products and to use the appropriate “Pass direction” in each.* | Achieved level: THRESHOLD<OrbitInformation> <PassDirection>  <OrbitDataSource> |
| **Goal (Desired) Requirements**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 Parameters** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Processing parameters details of the source data:* Processing facility
* Processing date
* Software version
* Product level
* Product ID (file name)
* Azimuth number of looks
* Range number of looks (separate values for each beam, as necessary)
 | Achieved level: THRESHOLD<SourceProcParam> <ProcessingFacility> <ProcessingDate> <SoftwareVersion>  <ProductID>  <ProductLevel>  <AzimuthNumberOfLooks> <RangeNumberOfLooks> |
| **Goal (Desired) Requirements**As threshold, plus additional relevant processing parameters, e.g., range- and azimuth look bandwidth and LUT applied. |
| **1.6.7** | **Source Data Image Attributes** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**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
 | Achieved level: THRESHOLD<SourceDataImageAttributes>  <SourceDataGeometry> <AzimuthPixelSpacing> <RangePixelSpacing>  <AzimuthResolution> <RangeResolution> <IncAngleNearRange> <IncAngleFarRange> |
| **Goal (Desired) Requirements**Geometry of the image footprint expressed in WGS84 in a standardised format (e.g., WKT). |
| **1.6.8** | **Sensor Calibration** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements**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** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Provide performance indicators on data intensity noise level (NE$σ^{0}$ and/or NE$β^{0}$ and/or NE$γ^{0}$ (noise equivalent Sigma- and/or Beta- and/or Gamma-Nought)). 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. | Achieved level: THRESHOLD<PerformanceIndicators><NoiseEquivalentIntensity> <Estimates>Provided as maximum Noise Equivalent Sigma-0 expressed in dB. <NoiseReference> provides the URL to the reference document (page 19, table 5.1) |
| **Goal (Desired) Requirements**Provide additional relevant performance indicators (e.g., ENL, PSLR, ISLR, and performance reference DOI or URL). |
| **1.6.10** | **Source Data Polarimetric Calibration Matrices** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements**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** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements**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** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements**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** | **CEOS-ARD Product Attributes** |  | Subsection containing information related to the CEOS-ARD product generation procedure and geographic parameters. | <CEOS-ARDProductAttributes> |
| **1.7.1** | **Product Data Access** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Processing parameters details of the CEOS-ARD product:* Processing facility
* Processing date
* Software version
* Location from where CEOS-ARD product can be retrieved, expressed as a URL or DOI.
 | Achieved level: THRESHOLD<DataAccess> <ProcessingFacility> <ProcessingTime> <SoftwareVersion> <Repository> |
| **Goal (Desired) Requirements**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** | **Auxiliary Data** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLD (GAOL)<AuxiliaryData>DEM reference provided |
| **Goal (Desired) Requirements**The metadata identifies the sources of auxiliary data used in the generation process, ideally expressed as DOIs.*Note: Auxiliary data includes DEMs, etc., and any additional data sources used in the generation of the product.* |
| **1.7.3** | **Product Sample Spacing** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**CEOS-ARD product processing parameters details:* Pixel (column) spacing
* Line (row) spacing
 | Achieved level: THRESHOLD<ProductSampleSpacing> < ProductColumnSpacing> < ProductRowSpacing> |
| **Goal (Desired) Requirements**As threshold. |
| **1.7.4** | **Product Equivalent Number of Looks** | [NRB][POL][ORB] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLD (GOAL)<ProductENL> |
| **Goal (Desired) Requirements**Equivalent Number of Looks (ENL) |
| **1.7.5** | **Product Resolution** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements**Average spatial resolution of the CEOS-ARD product along:* Columns
* Rows
 |
| **1.7.6** | **Product****Filtering** | [NRB][POL][ORB] | **Threshold (Minimum) Requirements**Flag if speckle filter has been applied [True/False]. Metadata should include:* Reference to algorithm as DOI or URL
* Input filtering parameters
	+ Type
	+ Window size in pixel units
	+ Any other parameters defining the speckle filter used

Mandatory for [POL]: Advanced polarimetric filter preserving covariance matrix properties should be applied. | Achieved level: THRESHOLD<Filtering> <FilterApplied>Flag set to False |
| **Goal (Desired) Requirements**As threshold. |
| **1.7.7** | **Product Bounding Box** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Two opposite corners of the product file (bounding box, including any zero-fill values) are identified, expressed in the coordinate reference system defined in 1.7.11.Four corners of the product file are recommended for scenes crossing the Antemeridian, or the North or the South Pole.  | Achieved level: THRESHOLD<ProductBoundingBox> <Northing> and <Easting> provided for UL and LR corners |
| **Goal (Desired) Requirements**As threshold. |
| **1.7.8** | **Product Geographical Extent** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**The geometry of the SAR image footprint expressed in WGS84, in a standardised format (e.g., WKT Polygon). | Achieved level: THRESHOLD<ProductGeographicalExtent> expressed in WKT format |
| **Goal (Desired) Requirements**As threshold. |
| **1.7.9** | **Product Image Size** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Image attributes of the CEOS-ARD product:* Number of lines
* Number of pixels per line
* File header size (if applicable)
* Number of no-data border pixels (if appl.)
 | Achieved level: THRESHOLD<ProductImageSize> <NumberLines> <NumPixelsPerLine>  |
| **Goal (Desired) Requirements**As threshold. |
| **1.7.10** | **Product** **Pixel Coordinate Convention** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**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]. | Achieved level: THRESHOLD<PixelCoordinateConvention>  |
| **Goal (Desired) Requirements**As threshold. |
| **1.7.11** | **Product Coordinate Reference System** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**The metadata lists the map projection (or geographical coordinates, if applicable) that was used and any relevant parameters required to geolocate data in that map projection, expressed in a standardised format (e.g., WKT). Indicate EPSG code, if defined for the CRS. | Achieved level: THRESHOLD<CoordinateReferenceSystem>Provided in WKT format. EPSG also provided |
| **Goal (Desired) Requirements**As threshold. |
| **1.7.12** | **Look Direction Polynomials** | [ORB] | **Threshold (Minimum) Requirements**In case the per-pixel item 2.11 (Look Direction Image) is not provided, then a list of the polynomial coefficients ai necessary to reconstruct the look direction angle\*, together with an estimate of the added error from use of polynomial vs. per-pixel more accurate values, shall be provided. Example polynomial:LookDir = a1Lat2 + a2Lon2 + a3LatLon + a4Lat + a5Lon + a6where:ai = polynomial coefficientsLat = latitude Lon = longitudeLat and Lon are the related coordinates in the product map units [‘m’, ‘deg’, ‘arcsec’]*\* 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.* | **Self-Assessment**Not applicable for NRB |
| **Goal (Desired) Requirements**As threshold. |
| **1.7.13** | **Radar Unit Look Vector** | [GSLC] | **Threshold (Minimum) Requirements**3-D components radar unit look vector, specified at centre of scene, in an Earth-Centred Earth-Fixed (ECEF) coordinate system (also called Earth Centred Rotating - ECR) is provided. It consists of unit vectors from antenna to surface pixel (i.e., positive Z component). Only required if per-pixel metadata 2.12 (Radar Unit Look Vector Grid Image) is not provided. | Not applicable for NRB |
| **Goal (Desired) Requirements**As threshold. |
| **1.7.14** | **Slant Range Sensor to Surface**  | [GSLC] | **Threshold (Minimum) Requirements**Slant range distance from the sensor to the surface, specified at centre of scene.Only required if per-pixel metadata 2.13 (Slant Range Sensor to Surface Image) is not provided. | Not applicable for NRB |
| **Goal (Desired) Requirements**As threshold. |
| **1.7.15** | **Reference Orbit** | [NRB][POL][GSLC] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements****Usage:** For **[NRB] & [POL]** only when per-pixel metadata 3.7 (Flattened phase) is provided. For **[GSLC]** when a reference orbit is used instead of a virtual orbit (see Annex A 1.2).Provide the absolute orbit number used as reference for topographic phase flattening. In case a virtual orbit has been used, provide orbit parameters or orbit state vectors as DOI or URL.Provide scene-centred perpendicular baseline for the for the source data relative to the reference orbit used (for approximate use only). |

# Per-Pixel Metadata

| **#** | **Parameter** | **CEOS-ARD product** | **Requirements** | **Self-Assessment** |
| --- | --- | --- | --- | --- |
| **2.1** | **Metadata Machine Readability** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Metadata is provided in a structure that enables a computer algorithm to be used to consistently and automatically identify and extract each component/variable/layer for further use. | Achieved level: THRESHOLD (GOAL)Metadata in separate metadata file in XML format, formatted in accordance with “CEOS-ARD\_ Metadata-spec\_Synthetic\_ Aperture\_Radar\_v1.1.xlsx” |
| **Goal (Desired) Requirements**As threshold, but metadata is formatted in accordance with CEOS-ARD SAR Metadata Specifications, v.1.1, or in a community endorsed standard that facilitates machine-readability, such as ISO 19115-2, Climate and Forecast (CF) convention, the Attribute Convention for Data Discovery (ACDD), etc. |
| **2.2** | **Data Mask Image** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Mask image indicating:* Valid data
* Invalid data
* No data

File format specifications/ contents provided in metadata:* Sample Type [Mask]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Int, ...]
* Bits per Sample
* Byte Order
* Bit Value Representation
 | Achieved level:<DataMask> <FileName>  <SampleType> <DataFormat> <DataType> <BitsPerSample>  <ByteOrder> <BitValues> <NoData> <ValidData> <InvalidData> |
| **Goal (Desired) Requirements**As threshold, including additional bit value representations, e.g.:* Layover (masked as invalid data in threshold)
* Radar shadow (masked as invalid data in threshold)
* Ocean water
* Land (recommended for [ORB])
* RTC applied (e.g., for maritime scenes with land samples for which RTC has been applied)
* DEM gap filling (i.e., interpolated DEM over gaps)
 |
| **2.3** | **Scattering Area Image** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements****Usage:** Recommended for scenes that include land areas.DEM-based scattering area image used for Gamma-Nought terrain normalisation is provided. This quantifies the local scattering area used to normalise for radiometric distortions induced by terrain to the measured $β^{0} $backscatter. The terrain-flattened $γ\_{T}^{0}$ is best understood as $β^{0}$ divided by the local scattering area.File format specifications/ contents provided in metadata:* Sample Type [Scattering Area]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Int/Float, ...]
* Bits per Sample
* Byte Order
 |
| **2.4** | **Local Incident Angle Image** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**DEM-based Local Incident angle image is provided.File format specifications/ contents provided in metadata:* Sample Type [Angle]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Int/Float, ...]
* Bits per Sample
* Byte Order

*Note: For maritime [ORB] scenes when no land areas are covered, a geoid model could be used for the calculation of the local incident angle* | Achieved level: THRESHOLD< LocalIncAngle> <FileName>  <SampleType> <DataFormat> <DataType> <BitsPerSample>  <ByteOrder>  |
| **Goal (Desired) Requirements**As threshold. |
| **2.5** | **Ellipsoidal Incident Angle Image** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements**Ellipsoidal incident angle is provided.File format specifications/ contents provided in metadata:* Sample Type [Angle]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Int/Float, ...]
* Bits per Sample
* Byte Order
* Reference Ellipsoid Name

*Note: For maritime [ORB] scenes when no land areas are covered, the ellipsoidal incident angle is nearly identical to the geoid based local incident angle.* |

| **#** | **Parameter** | **CEOS-ARD product** | **Requirements** | **Self-Assessment** |
| --- | --- | --- | --- | --- |
| **2.6** | **Noise Power Image** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements**Estimated Noise Equivalent $σ^{0}$ (or $β^{0}$ or $γ^{0}$, as applicable) used for noise removal, if applied, for each channel. NE$σ^{0}$ and NE$γ^{0}$ are both based on a simplified ellipsoid Earth model.File format specifications/ contents provided in metadata:* Sample Type [Gamma-Nought, Sigma-Nought, Beta-Nought]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Int/Float, ...]
* Bits per Sample
* Byte Order
 |
| **2.7** | **Gamma-to- Sigma Ratio Image** | [NRB][POL][GSLC] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements**Ratio of the integrated area in the Gamma projection over the integrated area in the Sigma projection (ground). Multiplying RTC $γ\_{T}^{0}$ by this ratio results in an estimate of RTC $σ\_{T}^{0}$.File format specifications/ contents provided in metadata:* Sample Type [Ratio]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Int/Float, ...]
* Bits per Sample
* Byte Order
 |
| **2.8** | **Acquisition ID Image** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements****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 (integer or fractional) 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, Time, ID]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Int/Float, ...]
* Bits per sample
* Byte Order
 | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements**In case of image composites, the sources for each pixel are uniquely identified. |

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| **#** | **Parameter** | **CEOS-ARD product** | **Requirements** | **Self-Assessment** |
| **2.9** | **Per-pixel DEM** | [NRB][POL][GSLC] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements**Provide DEM or DSM as used during the geometric and radiometric processing of the SAR data, resampled to an exact geometric match in extent and resolution with the CEOS-ARD SAR image product. Can also be provided with [ORB] products containing land areas.File format specifications/ contents provided in metadata:* Sample Type [Height]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Int/Float, ...]
* Bits per Sample
* Byte Order
 |
| **2.10** | **Per-pixelGeoid** | [ORB] | **Threshold (Minimum) Requirements**Not required. | Not applicable for NRB |
| **Goal (Desired) Requirements**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 CEOS-ARD ORB image product.File format specifications/ contents provided in metadata:* Sample Type [Height]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Int/Float, ...]
* Bits per Sample
* Byte Order
* Ground Sampling Distance
 |
| **#** | **Parameter** | **CEOS-ARD product** | **Requirements** | **Self-Assessment** |
| **2.11** | **LookDirectionImage** | [ORB] | **Threshold (Minimum) Requirements**Not required. | Not applicable for NRB |
| **Goal (Desired) Requirements**Look Direction Image is provided. It represents the planar angle between north and each range direction.File format specifications/ contents provided in metadata:* Sample Type [Angle]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Int/Float, ...]
* Bits per Sample
* Byte Order
 |
| **2.12** | **Radar Unit Look Vector Grid Image** | [GSLC] | **Threshold (Minimum) Requirements**Not required. | Not applicable for NRB |
| **Goal (Desired) Requirements**3-D components radar unit look vector, specified at each pixel in an Earth-Centred Earth-Fixed (ECEF) coordinate system (also called Earth Centred Rotating – ECR) is provided. It consists of unit vectors from the antenna to the surface pixel (i.e., positive Z component). File format specifications/ contents provided in metadata:* Sample Type [3D unit vector]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Float, ...]
* Bits per Sample
* Byte Order
 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **#** | **Parameter** | **CEOS-ARD product** | **Requirements** | **Self-Assessment** |
| **2.13** | **Slant Range Sensor to Surface Image** | [GSLC] | **Threshold (Minimum) Requirements**Not required. | Not applicable for NRB |
| **Goal (Desired) Requirements**Slant range distance from the sensor to the surface, specified at each pixel in an Earth-Centred Earth-Fixed (ECEF) coordinate system (also called Earth Centred Rotating – ECR) is provided. File format specifications/ contents provided in metadata:* Sample Type [Distance]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Float, ...]
* Bits per Sample
* Byte Order
 |
| **2.14** | **InSAR Phase Uncertainty Image** | [GSLC] | **Threshold (Minimum) Requirements**Not required. | Not applicable for NRB |
| **Goal (Desired)l Requirements**Estimate of uncertainty in InSAR phase is provided, such as finite signal to noise ratio, quantization noise, or DEM error. Identification of which error sources are included will be provided as DOI/URL reference or brief description. It represents statistical variation from known noise sources only. File format specifications/ contents provided in metadata:* Sample Type [Angle]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Float, ...]
* Bits per Sample
* Byte Order
 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **#** | **Parameter** | **CEOS-ARD product** | **Requirements** | **Self-Assessment** |
| **2.15** | **Atmospheric Phase Correction Image** | [GSLC] | **Threshold (Minimum) Requirements**Not required. | Not applicable for NRB |
| **Goal (Desired) Requirements**Phase correction value at each pixel, if applied. DOI/URL reference to algorithm or brief description is provided.File format specifications/ contents provided in metadata:* Sample Type [Angle]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Float, ...]
* Bits per Sample
* Byte Order
 |
| **2.16** | **Ionospheric Phase Correction Image** | [GSLC] | **Threshold (Minimum) Requirements**Not required. | Not applicable for NRB |
| **Goal (Desired) Requirements**Phase correction value at each pixel, if applied. DOI/URL reference to algorithm or brief description is provided.File format specifications/ contents provided in metadata:* Sample Type [Angle]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Float, ...]
* Bits per Sample
* Byte Order
 |

##

# Radiometrically Corrected Measurements

| **#** | **Parameter** | **CEOS-ARD product** | **Requirements** | **Self-Assessment** |
| --- | --- | --- | --- | --- |
| **3.1** | **BackscatterMeasurements** | [NRB] | **Threshold (Minimum) Requirements [NRB]**“Terrain-flattened” Radiometrically Terrain Corrected (RTC) Gamma-Nought backscatter coefficient ($γ\_{T}^{0}$) is provided for each polarization.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 [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Int/Float, ...]
* Bits per Sample
* Byte Order

*\*Note: Transformation to the logarithm decibel scale is not required or desired as this step can be completed by the user if necessary.* | Achieved level: THRESHOLD<BackscatterMeasurementData> <BackscatterMeasurement> <BackscatterConvention> <BackscatterConversionEq> <Polarization> <FileName>  <DataFormat> <DataType> <BitsPerSample>  <ByteOrder> Provided for each polarisation. |
| **Goal (Desired) Requirements**As threshold. |
| **3.2** | **Scaling Conversion** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**If applicable, indicate the equation to convert pixel linear amplitude/power to logarithmic decibel scale, including, if applicable, the associated calibration (dB offset) factor, and/or the equation used to convert compressed data (int8/int16/float16) to float32. | Achieved level: THRESHOLD<BackscatterConvention> included above as part of (3.1) <BackscatterMeasurementData> |
| **Goal (Desired) Requirements**As threshold, but use of float32. |
| **3.3** | **Noise Removal** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Flag if noise removal\* has been applied (Y/N). Metadata should include the noise removal algorithm and reference to the algorithm as URL or DOI.*\*Note: Thermal noise removal and image border noise removal to remove overall scene noise and scene edge artefacts, respectively.* | Achieved level: THRESHOLD<NoiseRemoval> <NoiseRemovalApplied>Flag set to False |
| **Goal (Desired) Requirements**As threshold. |
| **3.4** | **Radiometric Terrain Correction Algorithm** | [NRB][POL][GSLC] | **Threshold (Minimum) Requirements**Adjustments were made for terrain by modelling the local contributing scattering area using the preferred choice of a published peer-reviewed algorithm to produce radiometrically terrain corrected (RTC) $γ\_{T}^{0}$ backscatter estimates. Metadata references, e.g.:* a citable peer-reviewed algorithm
* technical documentation regarding the algorithm used to generate the backscatter estimates is expressed as URLs or DOIs
* the sources of auxiliary data used to make corrections

**Goal** for [GSLC] product type*Note: Examples of technical documentation include an Algorithm, Theoretical Basis Document, product user guide, etc.* | Achieved level: THRESHOLD<RadiometricTerrainCorrections> <RTCAlgorithm>DOI to peer-reviewed publication provided. |
| **Goal (Desired) Requirements****Goal** for [GSLC] product typeRequire resolution of DEM better than the output product resolution when applying terrain corrections. |
| **3.5** | **RadiometricAccuracy** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements**Uncertainty (e.g., bounds on $γ^{0}$ or $σ^{0}$) information is provided as document referenced as URL or DOI. SI traceability is achieved. |
| **3.6** | **Mean Wind- Normalised Backscatter Measurements** | [ORB] | **Threshold (Minimum) Requirements**Not required. | Not applicable for NRB |
| **Goal (Desired) Requirements****Usage:** Only for Maritime sceneMean 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 such as, e.g., Quilfen et al. (1998) or Vachon and Dobson (2000) for VV and HH polarization respectively.File format specifications/ contents provided in metadata:* Measurement Type [Wind-Normalised Backscatter]

Backscatter Expression Convention [intensity ratio]* Polarization [HH/HV/VV/VH]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Int/Float, ...]
* Bits per Sample
* Byte Order

*Note: Reference wind model, wind speed and direction used for reference backscattering coefficient should be provided*. |
| **3.7** | **Flattened Phase** | [NRB][POL] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements****Usage: Alternative to [GSLC] product for [NRB] and [POL] products**The Flattened Phase is the interferometric phase for which the topographic phase contribution is removed. It is derived from the range-Doppler SLC product using a DEM and the orbital state vectors with respect to a reference orbit (see Annex A1.2). The use of the Flattened Phase with the **[NRB]** or **[POL]** intensity (3.1 Backscatter measurement) provides the [GSLC] equivalent, as follows:  **GSLC** = sqrt(**NRB**) x exp(j FlattenPhase)File format specifications/ contents provided in metadata:* Measurement Type [Flattened Phase]
* Reference Polarization [HH/HV/VV/VH]
* Data Format [GeoTIFF/HDF5/NetCDF, …]
* Data Type [Int/Float, ...]
* Bits per Sample
* Byte Order

In case of polarimetric data, indicate the reference polarization. |

##

# Geometric Corrections

| **#** | **Parameter** | **CEOS-ARD product** | **Requirements** | **Self-Assessment** |
| --- | --- | --- | --- | --- |
| **4.1** | **Geometric Correction Algorithm** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements**Metadata references, e.g.:* A metadata citable peer-reviewed algorithm,
* Technical documentation regarding the implementation of that algorithm expressed as URLs or DOIs
* The sources of auxiliary data used to make corrections.
* Resampling method used for geometric processing of the source data.

*Note: Examples of technical documentation can include e.g., an Algorithm Theoretical Basis Document (ATBD), a product user guide*. |
| **4.2** | **DigitalElevation****Model** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements****Usage:** For products including land areas.1. 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.
2. Provide reference to Digital Elevation Model used for geometric terrain correction.
3. Provide reference to Earth Gravitational Model (EGM) used for geometric correction
 | Achieved level: THRESHOLD<DigitalElevationModel> <DEMReference> <EGMReference>Provided as URLs <DEMType> <DEMResamplingMethod> <DEMOversamplingFactor> and <EGMType> <EGMResamplingMethod> provided in addition |
| **Goal (Desired) Requirements**1. A DEM with comparable or better resolution to the resolution of the output CEOS-ARD product shall be used if available. Else, the upsampled DEM is identified.
2. Resampling method used for preparation of the DEM.
3. Method used for resampling the EGM.
 |
| **4.3** | **Geometric Accuracy** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Accurate geolocation is a prerequisite to radar processing to correct for terrain and to enable interoperability between radar sensors. The absolute geolocation error (ALE) for a sensor is typically assessed through analysis of Single Look Complex (SLC) imagery and measured along the slant range and azimuth directions (case A: SLC ALE). The end-to-end “ARD” ALE of the final CEOS-ARD product could be measured directly in the final image product in the chosen map projection, i.e., in the map coordinate directions: e.g., Northing and Easting (case B: ARD ALE). Providing accuracy estimates based on measurements following at least one scheme (A or B or both) meets the threshold requirement. Estimates of the ALE is provided as a bias and a standard deviation, with (Case A) SLC ALE expressed in slant range and azimuth, and (Case B) ARD ALE expressed in map projection dimensions.*Note 1: This assessment is often made through comparison of measured corner reflector positions with their projected location in the imagery. In some cases, other mission calibration/validation results may be used.* *Note 2: The ALE is not typically assessed for every processed image, but through an ALE assessment by the data processing team characterizing all or (usually a subset) of the generated products.*  | Achieved level: THRESHOLD (GOAL)<GeoCorrAccuracy> <ALESource> <LineBias> <LineSTDev> <SampleBias> <SampleSTDev> <GeoAccuracyReference> provided as URL (page 38, Table 12 in reference doc) |
| **Goal (Desired) Requirements**Output product sub-sample accuracy should be less than or equal to 0.1 (slant range) pixel radial root mean square error (rRMSE).Provide documentation of estimates of ALE as DOI or URL.  |
| **4.4** | **Geometric Refined Accuracy** | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**Not required. | Achieved level: THRESHOLDNOT REQUIRED |
| **Goal (Desired) Requirements**Values provided under 4.3 Geometric accuracy are provided by the SAR mission Cal/Val team. CEOS-ARD processing steps could include method refining the geometric accuracy, such as cross-correlation of the SAR data in slant range with a SAR scene simulated from a DSM or DEM. Methodology used (name and reference), quality flag, geometric standard deviation values should be provided. |
| **4.5** | **Gridding Convention**  | [NRB][POL][ORB][GSLC] | **Threshold (Minimum) Requirements**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.* | Achieved level: THRESHOLD<GriddingConvention> Note that S1 does not use a gridding convention, our data aligns to the nominal Mission Datatake ID convention that is used by ESA. More information can be found in Table 1 of <https://sentiwiki.copernicus.eu/web/s1-products>  |
| **Goal (Desired) Requirements**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** | **Goal** |
| **1** | **CEOS-ARD product** | **General Metadata** |  |  |
| 1.1 | [ALL] | Traceability | Not req. |  |
| 1.2 | [ALL] | Metadata Machine Readability | YES | (YES) |
| 1.3 | [ALL] | Product Type | YES |  |
| 1.4 | [ALL] | Document Identifier | YES |  |
| 1.5 | [ALL] | Data Collection Time | YES |  |
| **1.6** |  | **Source Data Attributes** | YES |  |
| 1.6.1 | [ALL] | Source Data Access | YES |  |
| 1.6.2 | [ALL] | Instrument | YES | (YES) |
| 1.6.3 | [ALL] | Source Data Acquisition Time | YES |  |
| 1.6.4 | [ALL] | Source Data Acquisition Parameters | YES |  |
| 1.6.5 | [ALL] | Source Data Orbit Information | YES |  |
| 1.6.6 | [ALL] | Source Data Processing Parameters | YES |  |
| 1.6.7 | [ALL] | Source Data Image Attributes | YES |  |
| 1.6.8 | [ALL] | Sensor Calibration | Not req. |  |
| 1.6.9 | [ALL] | Performance Indicators | YES |  |
| 1.6.10 | [ALL] | Source Data Polarimetric Calibration Matrices | Not req. |  |
| 1.6.11 | [ALL] | Mean Faraday Rotation Angle | Not req. |  |
| 1.6.12 | [ALL] | Ionosphere indicator | Not req. |  |
| **1.7** |  | **CEOS-ARD Product Attributes** |  |  |
| 1.7.1 | [ALL] | Product Data Access | YES |  |
| 1.7.2 | [ALL] | Auxiliary Data | YES | (YES) |
| 1.7.3 | [ALL] | Product Sample Spacing | YES |  |
| 1.7.4 | [NRB][POL][ORB] | Product Equivalent Number of Looks | YES |  |
| 1.7.5 | [ALL] | Product Resolution | Not req. |  |
| 1.7.6 | [NRB][POL][ORB] | Product Filtering | YES |  |
| 1.7.7 | [ALL] | Product Bounding Box | YES |  |
| 1.7.8 | [ALL] | Product Geographical Extent | YES |  |
| 1.7.9 | [ALL] | Product Image Size | YES |  |
| 1.7.10 | [ALL] | Product Pixel Coordinate Convention | YES |  |
| 1.7.11 | [ALL] | Product Coordinate Reference System | YES |  |
| 1.7.12 | [ORB] | Look Direction Polynomials | N/A for NRB |  |
| 1.7.13 | [GSLC] | Radar Unit Look Vector | N/A for NRB |  |
| 1.7.14 | [GSLC] | Slant Range Sensor to Surface | N/A for NRB |  |
| 1.7.15 | [NRB][POL][GSLC] | Reference Orbit | Not req. |  |
|  |  |  | **Threshold** | **Goal** |
| **2** | **CEOS-ARD product** | **Per-Pixel Metadata** |  |  |
| 2.1 | [ALL] | Metadata Machine Readability | YES | (YES) |
| 2.2 | [ALL] | Data Mask Image | YES |  |
| 2.3 | [ALL] | Scattering Area Image | Not required |  |
| 2.4 | [ALL] | Local Incident Angle Image | YES |  |
| 2.5 | [ALL] | Ellipsoidal Incident Angle Image | Not req. |  |
| 2.6 | [ALL] | Noise Power Image | Not req. |  |
| 2.7 | [NRB][POL][GSLC] | Gamma-to-Sigma Ratio Image | Not req. |  |
| 2.8 | [ALL] | Acquisition ID Image | Not req. |  |
| 2.9 | [NRB][POL][GSLC] | Per-pixel DEM | Not req. |  |
| 2.10 | [ORB] | Per-pixel Geoid | N/A for NRB |  |
| 2.11 | [ORB] | Look Direction Image | N/A for NRB |  |
| 2.12 | [GSLC] | Radar Unit Look Vector Grid Image | N/A for NRB |  |
| 2.13 | [GSLC] | Slant Range Sensor to Surface Image | N/A for NRB |  |
| 2.14 | [GSLC] | InSAR Phase Uncertainty Image | N/A for NRB |  |
| 2.15 | [GSLC] | Atmospheric Phase Correction Image | N/A for NRB |  |
| 2.16 | [GSLC] | Ionospheric Phase Correction Image | N/A for NRB |  |
|  |  |  | **Threshold** | **Goal** |
| **3** | **CEOS-ARD product** | **Radiometrically Corrected Measurements** |  |  |
| 3.1 | [ALL] | Backscatter Measurements | YES |  |
| 3.2 | [ALL] | Scaling Conversion  | YES |  |
| 3.3 | [ALL] | Noise Removal | YES |  |
| 3.4 | [NRB][POL][GSLC] | Radiometric Terrain Correction Algorithms | YES |  |
| 3.5 | [ALL] | Radiometric Accuracy | Not req. |  |
| 3.6 | [ORB] | Mean Wind-Normalised Backscatter Measurements | N/A for NRB |  |
| 3.7 | [NRB][POL] | Flattened Phase | Not req. |  |
|  |  |  | **Threshold** | **Goal** |
| **4** | **CEOS-ARD product** | **Geometric Corrections** |  |  |
| 4.1 | [ALL] | Geometric Correction Algorithms | Not req. |  |
| 4.2 | [ALL] | Digital Elevation Model | YES |  |
| 4.3 | [ALL] | Geometric Accuracy | YES |  |
| 4.4 | [ALL] | Geometric Refined Accuracy | Not req. |  |
| 4.5 | [ALL] | Gridding Convention | YES |  |