CEOS-ARD for Synthetic Aperture Radar – 2024 Update

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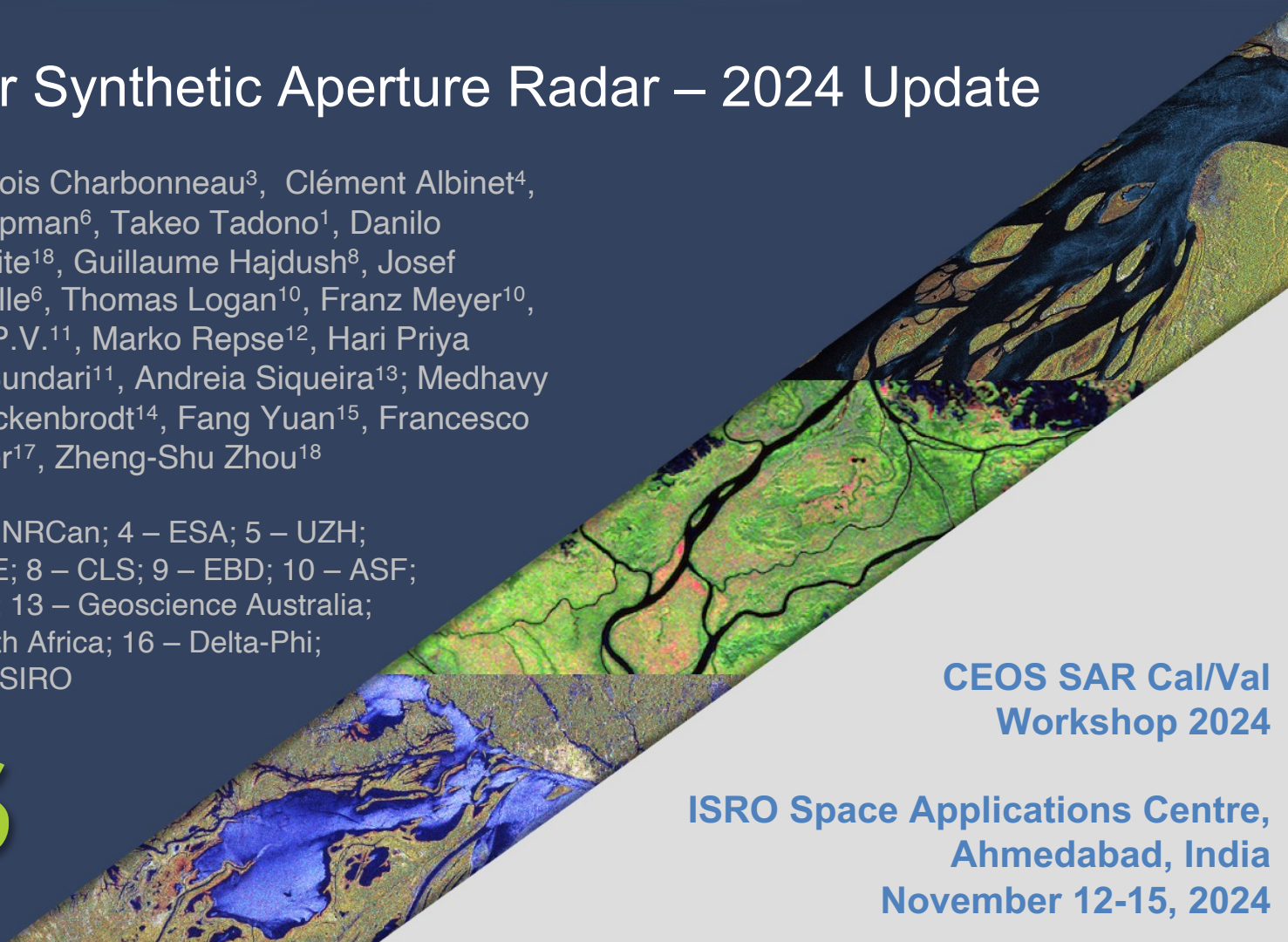
1 – JAXA; 2 – soloEO; 3 – NRCan; 4 – ESA; 5 – UZH;
6 – NASA JPL; 7 – CONAE; 8 – CLS; 9 – EBD; 10 – ASF;
11 – ISRO; 12 – Sinergise; 13 – Geoscience Australia;
14 – DLR; 15 – Digital Earth Africa; 16 – Delta-Phi;
17 – Stanford Univ; 18 – CSIRO



CEOS
Committee on
Earth Observation Satellites

CEOS SAR Cal/Val Workshop 2024

ISRO Space Applications Centre, Ahmedabad, India
November 12-15, 2024

CEOS-ARD for SAR
Current status

CEOS ARD specifications for Synthetic Aperture Radar (SAR) products:

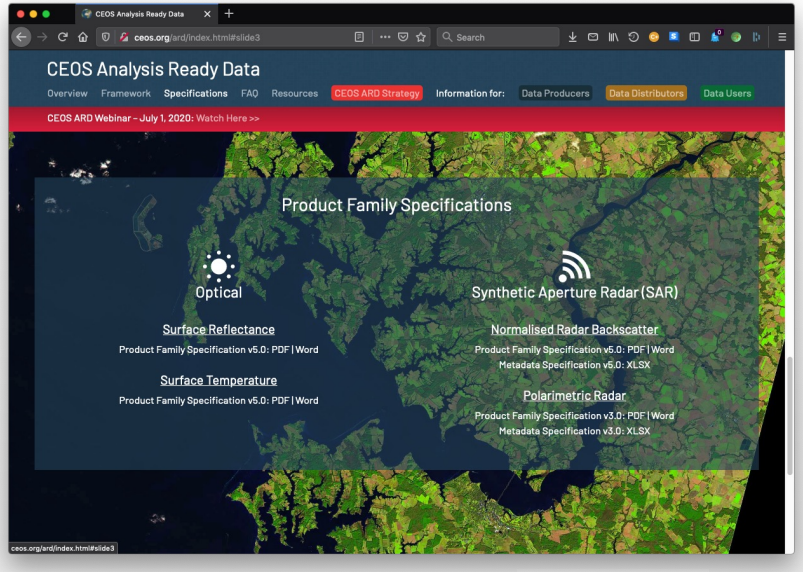
Endorsed and available at http://ceos.org/ard

CEOS-ARD for Synthetic Aperture Radar

- Normalised Radar Backscatter (NRB)
- Polarimetric Radar (POL)
- Ocean Radar Backscatter (ORB)
- Geocoded SLC (GSLC)

In the pipeline:

- Interferometric Radar (INSAR)
- Multi-source NRB
- NRB for VHR data (?)
- Lidar Terrain & Canopy Height



CEOS-ARD for SAR
Specifications for Data Providers

CEOS Committee on Earth Observation Satellites	Analysis Ready Data	Product Family Specification: Synthetic Aperture Radar

#	Parameter	CEOS-ARD product	Requirements
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. **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 **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. **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)

Extract from CEOS-ARD NRB specification document

CEOS-ARD specs

(a.k.a. Product Family Specifications – PFS)

- "Guidance document" for data providers:
  - Geometric corrections
  - Radiometric corrections
  - General meta (ancillary) data
  - Per-pixel (image) meta data
- Two levels of requirements
  - Threshold (mandatory) requirement
  - Goal (optional) requirement

CEOS-ARD for SAR Metadata

General Metadata – Metadata Specifications

#	Item	CEOS-ARD product	Threshold Requirements <parameters>	Goal Requirements <parameters>	itemAttribute	Type [and list of values]
1.1	Traceability		(Not Applicable in metadata file)			
1.2	Metadata machine readability		(Not Applicable in metadata file)			
1.3	Product type	[ALL]	<Product>		copyright=" "	String
			<ProductList>		count={"2", "3", ... ""}	Integer
			<ProductType>		"Normalised Radar Backscatter"	String
			<ProductType>		"Polarimetric Radar"	String
			<ProductType>		"Ocean Radar Backscatter"	String
			<ProductType>		"Geocoded Single-Look Complex"	String
1.4	Document Identifier	[ALL]	<DocumentIdentifier>		name="CEOS-ARD for Synthetic Aperture Radar"	String
					version="1.0"	String
					type="URL"	https://ceos.org/ard/files/PFS/SAR/v1.0/CEOS-ARD_PFS_Synthetic_Aperture_Radar_v1.0.pdf
1.5	Data collection time	[ALL]	<DataCollectionTime>			
			<NumberOfAcquisitions>			Integer
			<FirstAcquisitionDate>			utcDate String
			<LastAcquisitionDate>			utcDate String
1.6	Source Data Attributes					
			<SourceAttributes>		acqID = #	Sub-section header
1.6.1	Source Data Access	[ALL]	<SourceDataRepository>		type="DOI" or "URL"	String

s1_rtc_039039_N07E000_2021_12_02_metadata_v5.5.xml

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        <ProductDefinitionReference type="URL">https://sentinel.esa.int/documents/247904/1877131/Sentinel-1-Product-Definition<
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            <RadarCenterFrequency units="Hz">5.405000454334355E9</RadarCenterFrequency>
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Metadata Specifications

- Metadata specification developed to accompany each Radar PSF
- Consistent mapping of parameter names between PFS and metadata
- Specs for XML format but data provider may select other metadata formats (yaml, json, etc.)
- Currently non-mandatory (Goal req.), yet broad uptake by SAR agencies

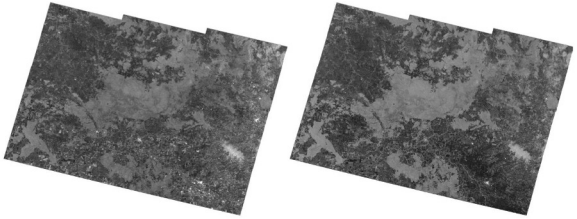
#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements
1.2	**Metadata Machine Readability**	Metadata is provided in a structure that enables a computer algorithm to be used to consistently and automatically identify and extract each component part for further use.	As threshold, but metadata is formatted in accordance with CARD4L NRB Metadata Specifications, v.5.5, or a community endorsed standard that facilitates machine-readability, such as ISO 19115-2

CEOS ANALYSIS READY DATA

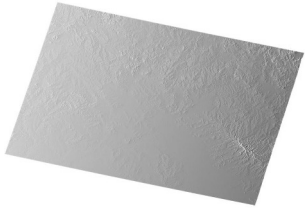
CEOS-ARD for SAR
General PFS structure

1. Radar Measurements

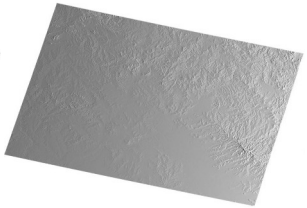
Radiometric and Geometric specs



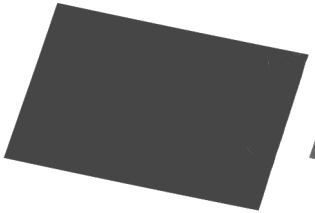
2. Per-Pixel Metadata (image data)



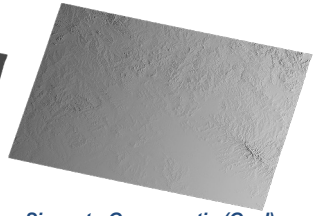
Local Inc Angle (Target)



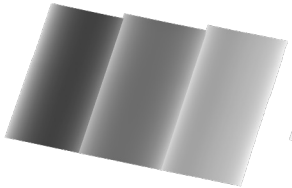
Scattering Area (Goal)



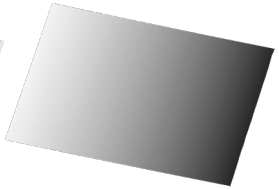
Data Mask (Target)



Sigma-to-Gamma ratio (Goal)



Noise Power (Goal)



Ellipsoid Inc Angle (Goal)

3. General Metadata

s1_rtc_039039_N07E000_2021_12_02_metadata_v5.5.xml

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    </DataCollectionTime>
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        <Satellite>Sentinel-1B</Satellite>
        <SatelliteReference type="URL">http://database.eohandbook.com/database/missionsummary.aspx?missionID=576</SatelliteReference>
        <ProductDefinitionReference type="URL">https://sentinel.esa.int/documents/247904/1877131/Sentinel-1-Product-Definition</Product
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        <SensorCalibration type="URL">https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-1-sar/sar-instrument/calibration
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Sentinel-1 (Copernicus)

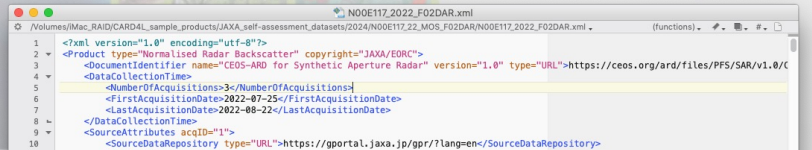
Processing:

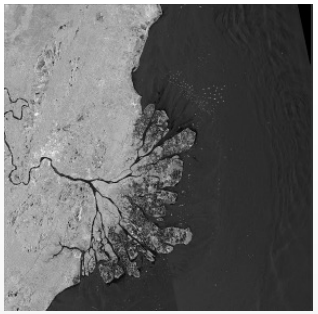
Z-S Zhou, CSIRO

CEOS-ARD for SAR
Normalised Radar Backscatter [NRB]

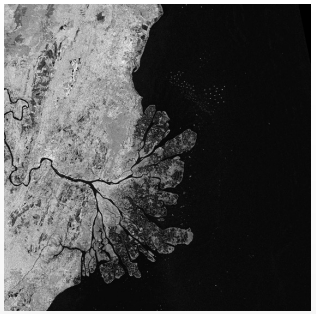
CEOS-ARD Normalised Radar Backscatter [NRB]

- Radar Measurement data:
  - Geometric Terrain Correction (ortho)
  - Radiometric Slope Correction
  - Backscatter expressed as gamma-nought, γ^0
- Per-pixel metadata:
  - Threshold (required):
    - Local Incidence Angle image
    - Mask image
    - Acquisition ID image (for composite products)
  - Goal (optional):
    - Scattering Area image
    - Gamma-to-Sigma ratio image
    - Ellipsoid Inc. Angle image
    - Noise power image (if applied)
    - Per-pixel DEM
- General metadata:
  - Detailed specs about source data and (CEOS-ARD) product (44 entries).
  - Metadata XML format spec provided (Target)

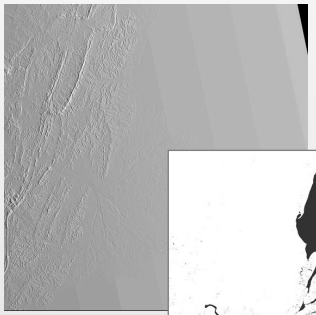




γ^0 *Backscatter (HH)*



γ^0 *Backscatter (HV)*



Local Inc. Angle

Acquisition ID

Data Mask

ALOS-2 PALSAR-2

(Global mosaic)

Processing: JAXA EORC

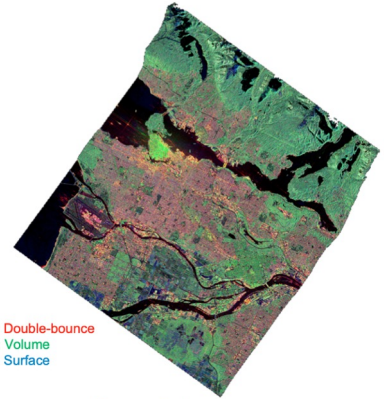
CEOS-ARD for SAR
Polarimetric Radar [POL]

CEOS-ARD Polarimetric Radar [POL]

General Metadata, Per-pixel Metadata, Geometric & Radiometric corrections near-identical to NRB

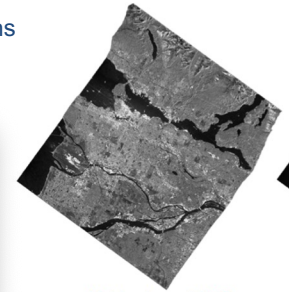
POL Measurement Data covers two product types:

- Polarimetric Decomposition
  - Data Providers to decide what decompositions to offer to users (e.g. Eigen value; Pauli, Freeman-D; Yamaguchi, etc.)
  - Polarimetric Covariance Matrix
    - Polarimetric phase and amplitude preserved
    - For polarimetric time-series and Pol-InSAR applications

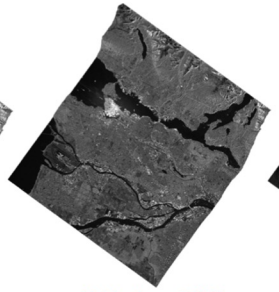


RADARSAT-2 (MDA)
Processing:
F. Charbonneau (NRCan)

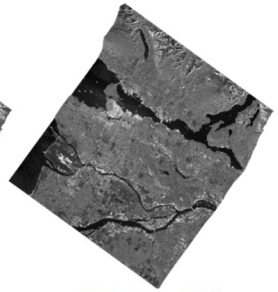
R: Double-bounce
G: Volume
B: Surface



Matrix element (1,1)
REAL
HH intensity

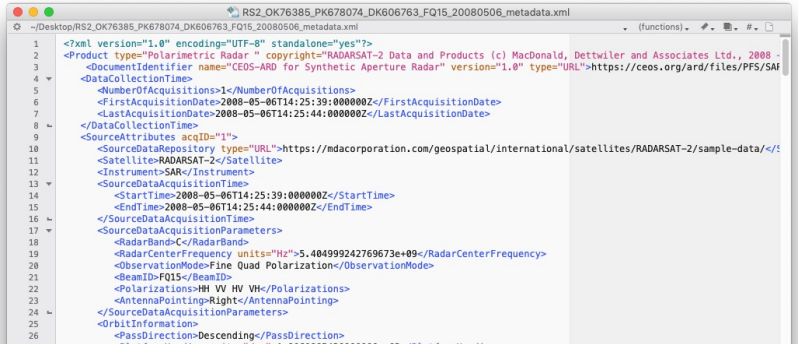


Matrix element (2,2)
REAL
HV intensity



Matrix element (3,3)
REAL
VV intensity

Matrix elements (1,2) (1,3) & (2,3)
COMPLEX (Re + Im): Polarimetric phase



RS2_OK76385_PK678074_DK606763_FQ15_20080506_metadata.xml

~/Desktop/RS2_OK76385_PK678074_DK606763_FQ15_20080506_metadata.xml

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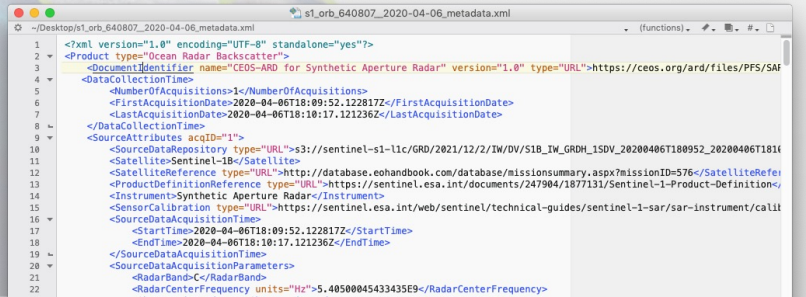
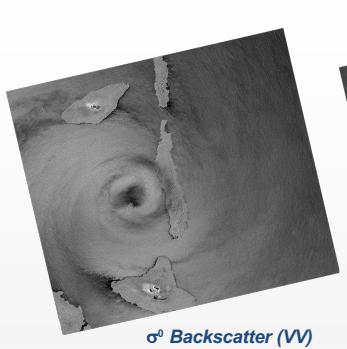
CEOS-ARD for SAR
Ocean Radar Backscatter [ORB]

CEOS-ARD Ocean Radar Backscatter [ORB]

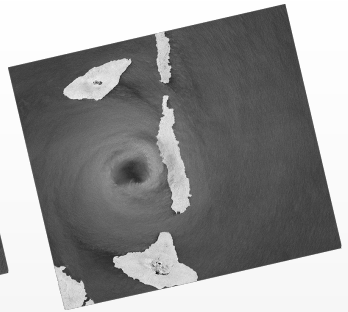
– Simplified version of the NRB product for ocean applications

- Radar Measurement data:
  - Geoid-corrected backscatter
  - Expressed as σ^0
- Per-pixel metadata:
  - Threshold (required):
    - Geoid Incidence Angle image
    - Mask image (including land mask)
    - Acquisition ID image (for composite products)
  - Goal (optional):
    - Noise power image (if applied)
    - Per-pixel Geoid
    - Look Direction image

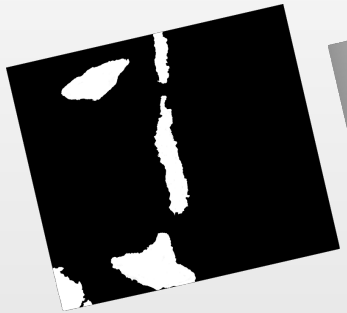




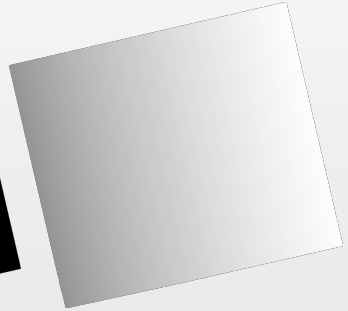
σ^0 Backscatter (VV)



σ^0 Backscatter (VH)



Data Mask image



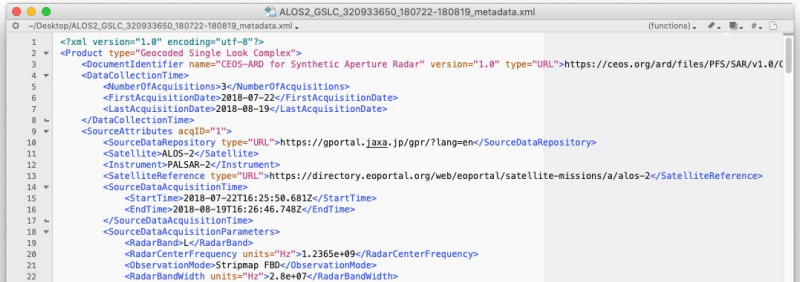
Geoid Inc. Angle image

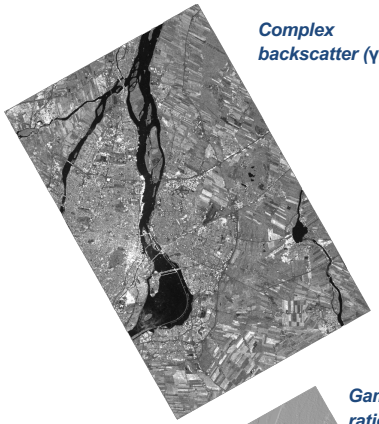
Sentinel-1 IWS
CEOS-ARD ORB (mock-up)
(Processing: soloEO)

CEOS-ARD for SAR
Geocoded SLC [GSLC]

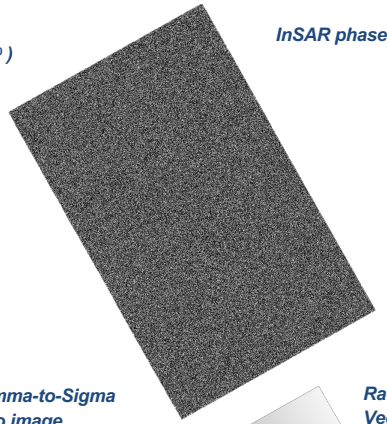
CEOS-ARD Geocoded Single-Look Complex [GSLC]

- Radar Measurement data:
  - Backscatter in complex format (I+Q) from which both **amplitude** and **phase** can be derived
  - Radiometry: Radiometric slope correction, expressed as γ^0
  - Geometry:
    - Ground-based map projection (i.e. not slant range)
    - Corrected relative to a common reference orbit → Co-registered GSLC images in a stack have same geometry → interferometric applications feasible by simple image math
- Per-pixel metadata (Threshold):
  - Local Incidence Angle image
  - Mask image
  - Acquisition ID image (for composite products)

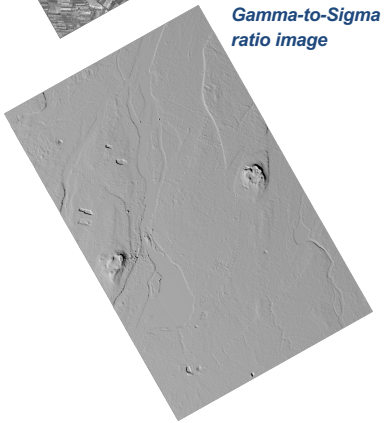




Complex backscatter (γ^0)



InSAR phase



Gamma-to-Sigma ratio image

Radar Unit Look Vector Grid image

RCM1 ©CSA Proc. F. Charbonneau, NRCan

CEOS-ARD for SAR
One PFS to Rule Them All

CEOS-ARD for Synthetic Aperture Radar PFS

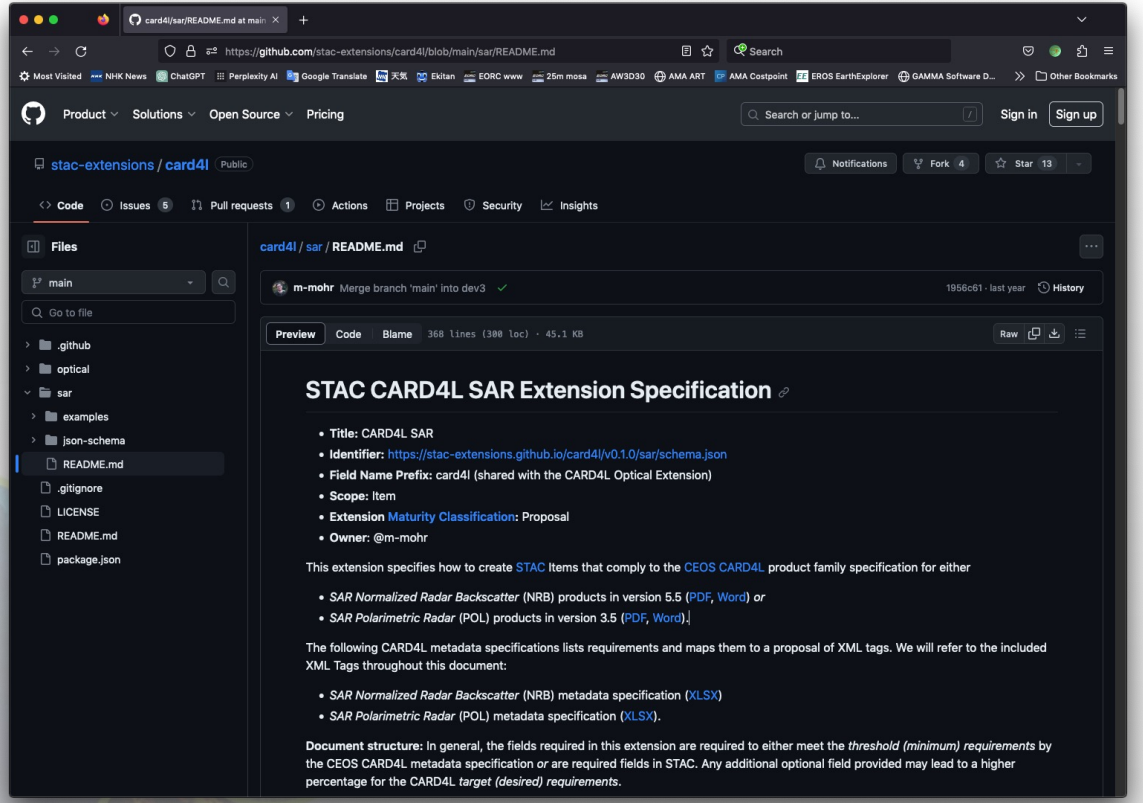
Single specification document for all CEOS-ARD SAR products:

– NRB, POL, ORB, GLSC

- Goals:
  - Ensuring consistent parameter names and specifications across all SAR PFSs
  - Simplifying revisions and change tracking
  - Maintains PFS clarity and readability while describing multiple products
  - No changes to (Threshold) specifications for endorsed PFSs

- The CEOS-ARD for SAR PFS was endorsed and released in October 2023.

STAC CEOS-ARD SAR Extension



STAC extensions

- Developed in 2021 for optical and SAR (NRB & POL) PFSs
- Name change: CARD4L → CEOS-ARD
- Major revision in 2025

CEOS-ARD for SAR Community Uptake

CEOS Analysis-Ready Datasets

The following table summarises all of the satellite EO datasets that have been assessed as CEOS Analysis Ready Data (CEOS-ARD). DOI links are provided for access, along with links to further information, sample products, and the completed CEOS-ARD self-assessment and peer review outcome documents.

Product	CEOS-ARD Type	PFS Version	Agency	Mission / Instrument(s)	Threshold Specification	Goal Specification	Access	Info	Self Assessment	Peer Review	Sample Products
ALOS-2 PALSAR-2 Global Mosaics (RTC)	SAR-NRB	v1.0	JAXA	ALOS-2 PALSAR-2	100%	Not assessed	Link	Link	DOC	PDF	Link
ALOS-2 PALSAR-2 25m & 50m ScanSAR NRB	SAR-NRB	v1.0	JAXA	ALOS-2 PALSAR-2	100%	Not assessed	Link	Link	DOC	25m, 50m	Link
NovaSAR-1 RTC	SAR-NRB	v5.5	CSIRO	NovaSAR-1	100%	Not assessed	Link	Link	ZIP	ZIP	See self-assessment docs
RISAT-1A (EOS-04) NRB	SAR-NRB	v1.0	ISRO	RISAT-1A (EOS-04)	100%	Not assessed	Link	Link	DOC	ZIP	TBA
Sentinel-1 RTC	SAR-NRB	v5.5	Sinergise & Digital Earth Africa	Sentinel-1 (A, B)	100%	Not assessed	Link	Link	PDF	PDF	Link
Opera RTC Sentinel-1	SAR-NRB	v5.5	NASA/JPL	Sentinel-1 (A, B)	TBA	TBA	ZIP	ZIP	TBA	22 Oct 2024	
Catalyst Sentinel-1 RTC	SAR-NRB	v1.1	Catalyst/PCI	Sentinel-1 (A, B)	TBA	TBA	DOC	PDF	TBA	17 Oct 2024	

Under peer review:

- ISRO (RISAR-1B/EOS-04 mosaics)
- NRCan (RCM NRB & POL)

In preparation:

- CONAE (SAOCOM-1A/B)
- ESA (S-1, ENVISAT, ERS, ROSE-L, BIOMASS)
- DLR (S-1)
- KARI (KOMPSAT-5)

CEOS-ARD SAR Team work topics

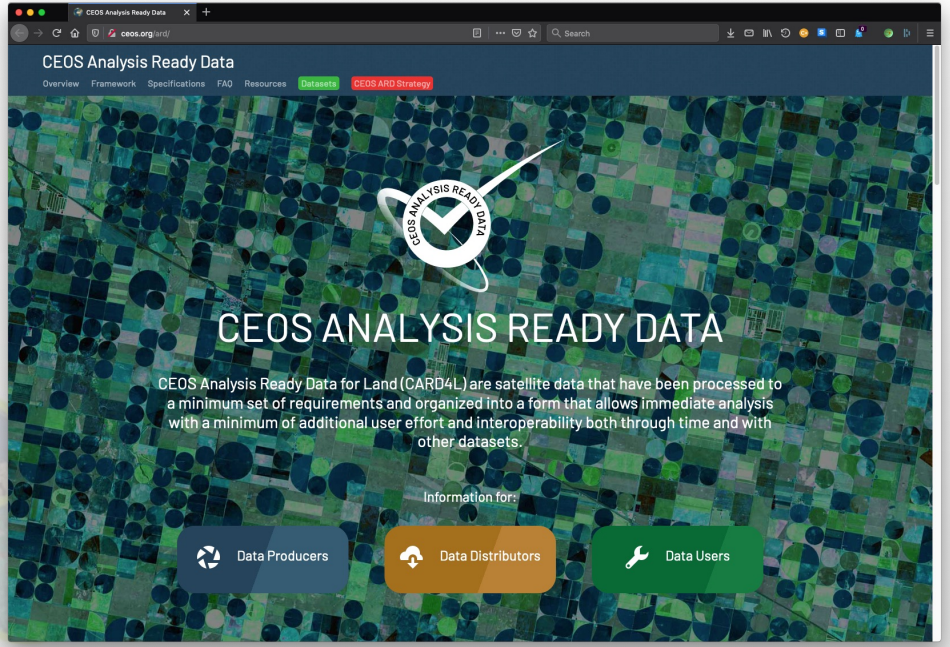
- **Interferometric Radar (INSAR) PFS**
  * Completion foreseen by Q1/2025
  * Input/comments from SAR community still possible and welcome

- **Multi-source NRB PFS**
  * Averaged composite products
    - Pixel values no longer unique to one source data take
    - Certain per-pixel metadata no longer defined (e.g. data mask; local inc angle, scattering area)

- **Special considerations for VHR (metre/sub-metre) SAR products:**
  * Is Radiometric Terrain Correction meaningful?
  * Mismatch between publicly available DEMs and VHR pixel spacing
  * Even with VHR DEMs, RTC designed for distributed target backscatter. May for certain targets introduce backscatter artefacts

  → Special NRB PFS required for VHR SAR?

धन्यवाद Thank you.



http://ceos.org/ard