



Committee on Earth Observation Satellites

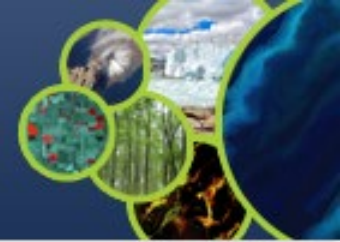
Living Planet Symposium 2022
23–27 May 2022 | Bonn

Guidelines for CEOS Analysis-Ready Data (CARD) Radar Product Specifications

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1 – soloEO; 2 – JAXA; 3 – NASA JPL; 4 – ESA; 5 – CONAE;
6 – NRCan; 7 – Geoscience Australia ; 8 – CLS group; 9 – EBD;
10 – ASF; 11 – EC/DG-DEFIS; 12 – sarmap; 13 – Sinergise;
14 – Univ. Zürich; 15 – FSU Jena; 16 – Stanford Univ; 17 – CSIRO





Why Analysis Ready Data?

- Recognition by satellite data providers of the need – and expectations – for EO products that do not require expert knowledge to ingest and analyse.
- EO user community:
 - Increase in non-expert users
 - Move from R&D towards operational applications with requirements for Big Data (e.g. time-series analysis over national-global scales, Data Cubes)
- Analysis Ready Data (ARD)
 - Term frequently used by satellite data providers today but common ARD standard lacking
 - No common standards → lost opportunity for interoperability
- **CEOS Analysis Ready Data (CARD)**
 - CEOS effort to develop a set of well-defined ARD specifications for key sensor types (optical, SAR, Lidar) which data providers – CEOS organisations and private sector – can opt to include in their suites of satellite data products offered to users.
 - Key driver – help broaden the EO user community (especially important for SARI!)





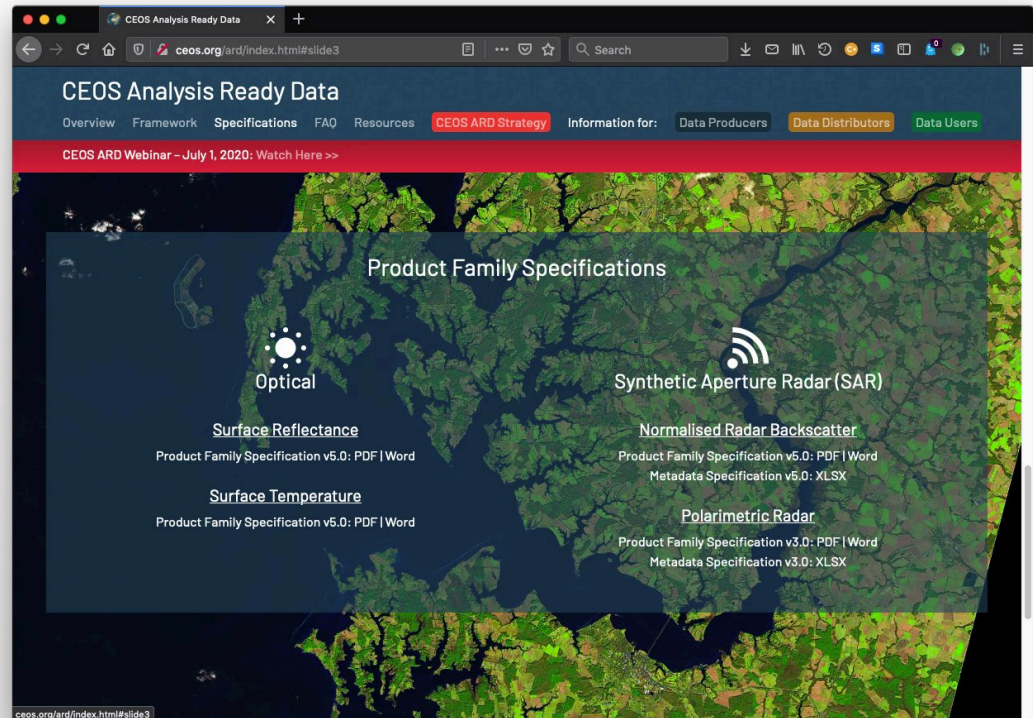
CEOS ARD specifications (CARD4L) for SAR products:

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


- Normalised Radar Backscatter (NRB)
- Polarimetric Radar (POL)
- Surface Reflectance (SR)
- Surface Temperature (ST)

In the pipeline:

- Ocean Radar Backscatter (ORB)
- Geocoded SLC (GSLC)
- Interferometric Radar (INSAR)
- Nightlight Radiance
- Aquatic Reflectance
- Lidar Terrain & Canopy Height





	Analysis Ready Data For Land (CARD4L)	Product Family Specification: Normalised Radar Backscatter
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CARD specs (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
 - Target (desired) requirement

#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements
1.6.4	Source Data Acquisition Parameters	Acquisition parameters related to the SAR antenna: <ul style="list-style-type: none"> - Radar band - Centre frequency - Observation mode - Polarisation(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: <ul style="list-style-type: none"> - Pass direction [asc/desc] - Orbit data source [e.g., predicted/definite/precise/ downlinked etc.] 	As threshold, including also: <ul style="list-style-type: none"> - Platform heading angle - Orbit data file containing state vectors (minimum of 5 state vectors, from 10% of scene length <i>before</i> start time to 10% of scene length <i>after</i> stop time) - Platform (mean) altitude
1.6.6	Source Data Processing Information	Processing parameters details of the source data: <ul style="list-style-type: none"> - 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) 	As threshold, plus additional relevant processing parameters, e.g., Range- and Azimuth Look Bandwidth and LUT applied.

CARD Radar Metadata specs



CARD4L_METADATA-spec_NRB-v5.5.xlsx

#	Item	Threshold Requirements <parameters>	Target 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	<Product>		type="Normalised Radar Backscatter", version="5.5" * Copyright"	
1.4	Document Identifier	<DocumentIdentifier>		type="DOI", "URL"	String
1.5	Data collection time	<DataCollectionTime> <NumberOfAcquisitions> <FirstAcquisitionDate> <LastAcquisitionDate>			Integer utcDate String utcDate String
1.6	Source Attributes	<SourceAttributes>		acqID = #	Sub-section header
1.6.1	Source Data Access	<SourceDataRepository>		type="DOI", "URL"	String
1.6.2	Instrument	<Satellite> <Instrument>	<SatelliteReference>	type="DOI", "URL"	String String String

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.)
- Non-mandatory (Target req.)

```

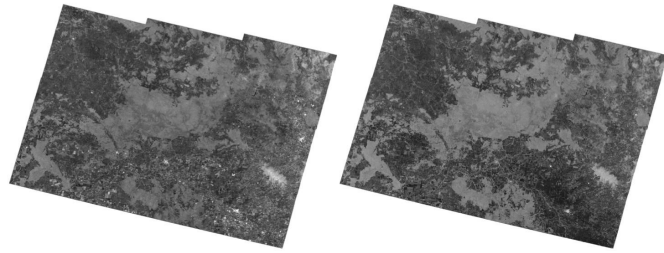
s1_rtc_039039_N07E000_2021_12_02_metadata_v5.5.xml
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<Product type="Normalised Radar Backscatter" version="5.5">
  <DocumentIdentifier type="URL">https://ceos.org/ard/files/PFS/NRB/v5.5/CARD4L-PFS_NRB_v5.5.pdf</DocumentIdentifier>
  <DataCollectionTime>
    <NumberOfAcquisitions>1</NumberOfAcquisitions>
    <FirstAcquisitionDate>2021-12-02T18:09:52.122817Z</FirstAcquisitionDate>
    <LastAcquisitionDate>2021-12-02T18:10:17.121236Z</LastAcquisitionDate>
  </DataCollectionTime>
  <SourceAttributes acqID="1">
    <SourceDataRepository type="URL">s3://sentinel-s1-l1c/GRD/2021/12/2/IW/DV/S1B_IW_GRDH_1SDV_20211202T180952_20211202T181
    <Satellite>Sentinel-1B</Satellite>
    <SatelliteReference type="URL">http://database.eohandbook.com/database/missionsummary.aspx?missionID=576</SatelliteRefe
    <ProductDefinitionReference type="URL">https://sentinel.esa.int/documents/247984/1877131/Sentinel-1-Product-Definition<
    <Instrument>Synthetic Aperture Radar</Instrument>
    <SensorCalibration type="URL">https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-1-sar/sar-instrument/cali
    <SourceDataAcquisitionTime>
      <StartTime>2021-12-02T18:09:52.122817Z</StartTime>
      <EndTime>2021-12-02T18:10:17.121236Z</EndTime>
    </SourceDataAcquisitionTime>
    <SourceDataAcquisitionParameters>
      <RadarBand>C</RadarBand>
      <RadarCenterFrequency units="Hz">5.49500045433435E9</RadarCenterFrequency>
      <ObservationMode>IW</ObservationMode>
      <Polarizations>VH</Polarizations>
      <AntennaPointing>Right</AntennaPointing>
      <BeamID>TOPS</BeamID>
    </SourceDataAcquisitionParameters>
    <OrbitInformation>
      <PassDirection>ASCENDING</PassDirection>
      <OrbitDataSource>DOMLINK</OrbitDataSource>
      <PlatformHeading units="deg">348.00877397238037</PlatformHeading>
      <OrbitMeanAltitude units="m">693000</OrbitMeanAltitude>
    </OrbitInformation>
    <SourceProcParam>
      <ProcessingFacility>Copernicus S1 Core Ground Segment - TLS</ProcessingFacility>
  </SourceAttributes>
</Product>
  
```

#	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, v5.5, or a community endorsed standard that facilitates machine-readability, such as ISO 19115-2





1. Radar Measurement Geometric and Radiometric specs



2. Per-Pixel Metadata (image data) (NRB example)

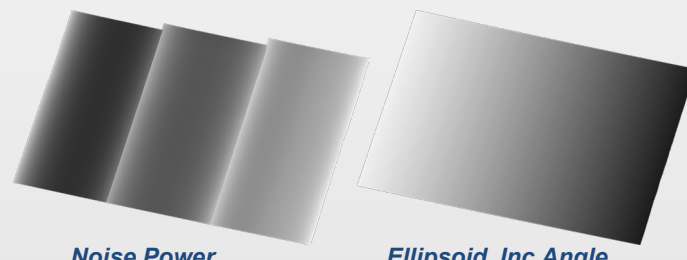
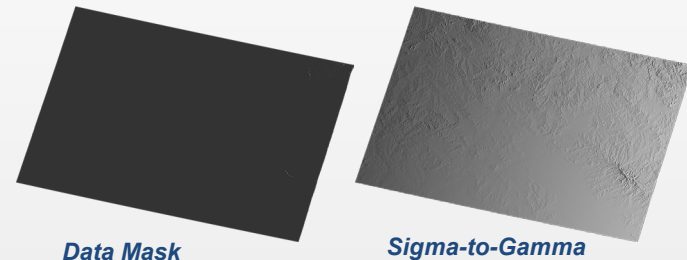


3. General Metadata

```

1 <?xml version="1.0" encoding="UTF-8" standalone="yes"?>
2 <Product type="Normalized Radar Backscatter" version="5.5">
3   <DocumentIdentifier type="URL"="https://ceos.org/ard/files/PFS/NRB/v5.5/CARD4L-PFS_NRB_v5.5.pdf" </DocumentIdentifier>
4   <DataCollectionTime>
5     <NumberOfAcquisitions>1</NumberOfAcquisitions>
6     <FirstAcquisitionDate>2021-12-02T18:09:52.122817Z</FirstAcquisitionDate>
7     <LastAcquisitionDate>2021-12-02T18:10:17.121236Z</LastAcquisitionDate>
8   </DataCollectionTime>
9   <SourceAttributes acquisition="1">
10     <SourceDataRepository type="URL"="s3://sentinel-s1-l1c/GRD/2021/12/2/TM/DV/S1B_TW_GRD_HLSV_20211202T180952_20211202T181017" </SourceDataRepository>
11     <SatelliteSentinel-1B</Satellite>
12     <SatelliteReference type="URL"="https://database.eohandbook.com/database/missionsummary.aspx?missionID=576" </SatelliteReference>
13     <ProductDefinitionReference type="URL"="https://sentinel.esa.int/documents/247984/1877131/Sentinel-1-Product-Definition" </ProductDefinitionReference>
14     <Instrument>Synthetic Aperture Radar</Instrument>
15     <SensorCalibration type="URL"="https://sentinel.esa.int/web/sentinel/technical-guides/sentinel-1-sar/sar-instrument/call" </SensorCalibration>
16     <SourceDataAcquisitionTime>
17       <StartTime>2021-12-02T18:09:52.122817Z</StartTime>
18       <EndTime>2021-12-02T18:10:17.121236Z</EndTime>
19     </SourceDataAcquisitionTime>
20     <SourceDataAcquisitionParameters>
21       <RadarBand>C</RadarBand>
22       <RadarCenterFrequency units="Hz">5.405080445334359</RadarCenterFrequency>
23       <ObservationMode>IW</ObservationMode>
24       <Polarizations>VV_VH</Polarizations>
25       <AntennaPointing>Right</AntennaPointing>
26       <BeamID>TOPS</BeamID>
27     </SourceDataAcquisitionParameters>
28     <OrbitInformation>
29       <PassDirection>ASCENDING</PassDirection>
30       <OrbitDataSource>DOWNLINK</OrbitDataSource>
31       <PlatformHeading units="deg">348.002739723837</PlatformHeading>
32       <OrbitMeanAltitude units="m">693000</OrbitMeanAltitude>
33     </OrbitInformation>
34     <SourceProcParam>
35       <ProcessingFacility>Copernicus S1 Core Ground Segment - TLS</ProcessingFacility>
36       <ProcessingDate>2021-12-02T20:21:59.054608Z</ProcessingDate>
37       <SoftwareVersion>Sentinel-1 L1E_003_48</SoftwareVersion>
38       <ProductID>S1B_TW_GRD_HLSV_20211202T180952_20211202T181017_029850_039039_F017</ProductID>
39       <ProductLevel>GRD</ProductLevel>
40       <AzimuthNumberOfLooks>1</AzimuthNumberOfLooks>
41       <RangeNumberOfLooks>5</RangeNumberOfLooks>
42       <AzimuthLookBandwidth units="Hz">
43         <Beam ID="IW1">327.0</Beam>
44         <Beam ID="IW2">313.0</Beam>
45         <Beam ID="IW3">314.0</Beam>
46       </AzimuthLookBandwidth>
47       <RangeLookBandwidth units="Hz">
48         <Beam ID="IW1">1.41E7</Beam>
49         <Beam ID="IW2">1.21E7</Beam>
50         <Beam ID="IW3">1.07E7</Beam>
51       </RangeLookBandwidth>
52     </SourceProcParam>
53     <SourceDataRangeAttributes>
54       <SourceGeographicalExtent order="longitude latitude" type="WKT">
55         POLYGON ((8.4097155305183358 6.5948789653614485, 6.6583958959237110 6.71802160751581446, 1.21788332103434 6.624860857
56       </SourceGeographicalExtent>
57       <SourceDataGeometry>Ground range</SourceDataGeometry>
58       <AzimuthPixelSpacing units="m">10.0</AzimuthPixelSpacing>
59       <RangePixelSpacing units="m">10.0</RangePixelSpacing>
60       <AzimuthResolution units="m">
61         <Beam ID="IW1">22.5</Beam>
62         <Beam ID="IW2">22.6</Beam>

```



Noise Power

Ellipsoid Inc Angle

Acquisition ID

Per-pixel DEM

CARD4L NRB sample
(Processing: Z-S Zhou, CSIRO)

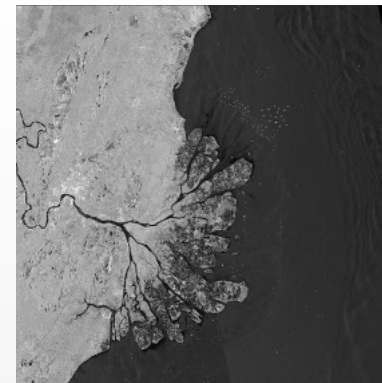




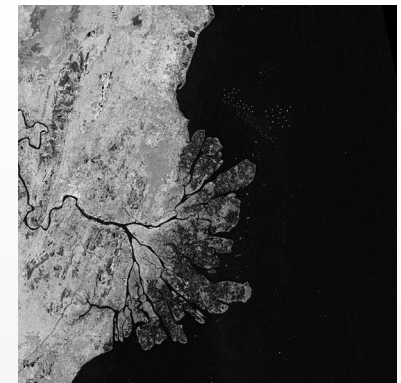
ALOS-2 PALSAR-2 (Global mosaic)
Processing: JAXA EORC

CARD NRB

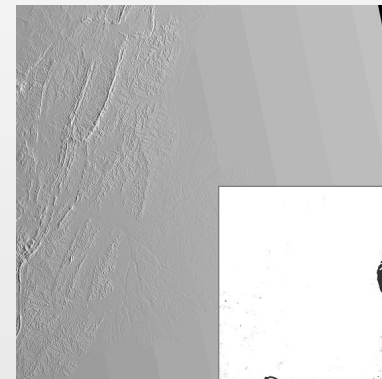
- Radar Measurement data:
 - Geometric Terrain Correction (ortho)
 - Radiometric Slope Correction
 - Backscatter expressed as gamma-nought, γ^0
- Per-pixel metadata:
 - Threshold (required):
 - Local Incidence Angle image
 - Mask image
 - Acquisition ID image (for composite products)
 - Target (desired):
 - 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 (CARD) product (44 entries).
 - Metadata XML format spec provided (Target)



γ^0 Backscatter (HH)



γ^0 Backscatter (HV)



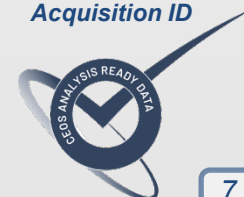
Local Inc. Angle



Acquisition ID



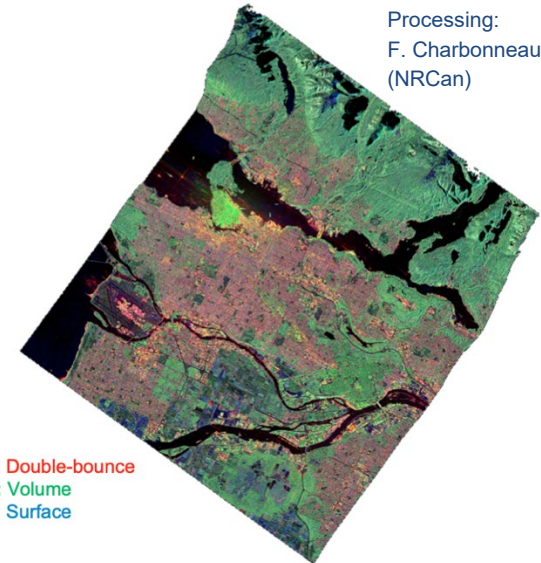
Data Mask





- **CARD POL** structure based on CARD Normalised Radar Backscatter
 - General Metadata, Per-pixel Metadata, Geometric & Radiometric corrections near-identical to NRB
 - Main difference in Measurement data
- 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)

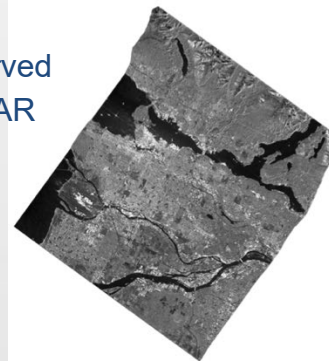


R: Double-bounce
G: Volume
B: Surface

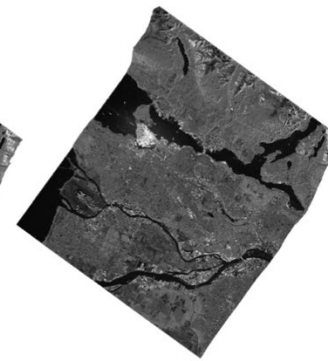
Decomposition image
(Yamaguchi decomp., Quad-pol)

```

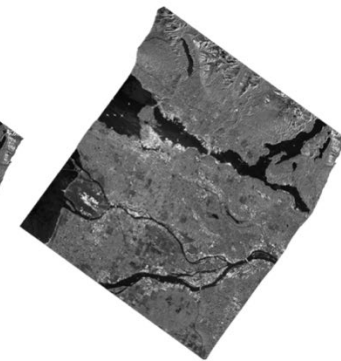
1  [?xml version="1.0" encoding="utf-8"?>
2  <product Type="Polarimetric Radar"
3  copyright="RADARSAT-2 Data and Products (c) MacDonald, Dettwiler and Associates Ltd., 2008 - All Rights Reserved.">
4  <documentIdentifier>CARD4L_Metadata-specification_PolarimetricRadar-v2.8</documentIdentifier>
5  <dataCollectionTime>
6  <NumberOfAcquisitions>1</NumberOfAcquisitions>
7  <FirstAcquisitionDate>2008-05-06T14:25:39:000000Z</FirstAcquisitionDate>
8  <LastAcquisitionDate>2008-05-06T14:25:44:000000Z</LastAcquisitionDate>
9  </DataCollectionTime>
10 <SourceContributors acqId="1">
11 <SourceDataRepository type="URL">https://mdacorporation.com/geospatial/international/satellites/RADARSAT-2/sample-data/
12 <Satellite>RADARSAT-2</Satellite>
13 <Instrument>SAR</Instrument>
14 <SourceDataAcquisitionTime>
15 <StartTime>2008-05-06T14:25:39:000000Z</StartTime>
16 <EndTime>2008-05-06T14:25:44:000000Z</EndTime>
17 </SourceDataAcquisitionTime>
18 <AcquisitionParameters>
19 <RadarBand>C</RadarBand>
20 <RadarCenterFrequency units="Hz">5.404999242769673e+09</RadarCenterFrequency>
21 <ObservationMode>Fine Quad Polarization</ObservationMode>
22 <BeamId>FQ15</BeamId>
23 <Polarizations>HH VV VH VV</Polarizations>
24 <AntennaPointing>Right</AntennaPointing>
25 </AcquisitionParameters>
    
```



Matrix element (1,1)
REAL
HH intensity



Matrix element (2,2)
REAL
HV intensity



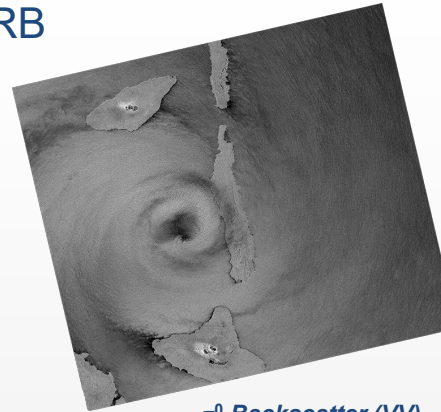
Matrix element (3,3)
REAL
VV intensity

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

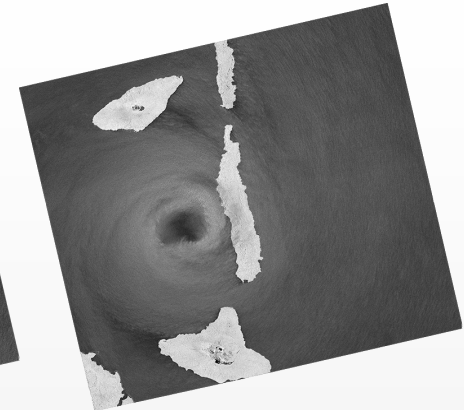


CARD ORB – Simplified version of the CARD NRB product for ocean applications

- 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)
 - Target (desired):
 - Noise power image (if applied)
 - Per-pixel Geoid
 - Look Direction image
- The **CARD ORB** product specification is under development. Completion/release foreseen for Q3-Q4/2022.



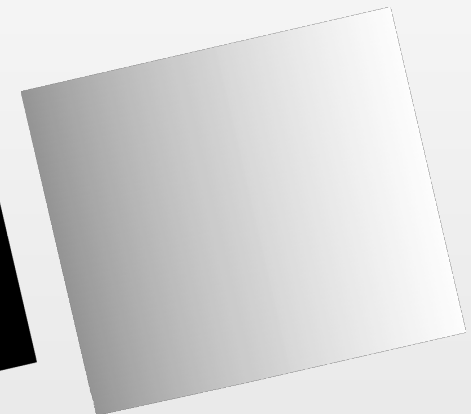
σ^0 Backscatter (VV)



σ^0 Backscatter (VH)



Data Mask image



Geoid Inc. Angle image

```

product.xml
1 |?xml version="1.0" encoding="utf-8"?
2 |<product type="Polarimetric Radar"
3 |  copyright="RADARSAT-2 Data and Products (c) MacDonald, Dettwiler and Associates Ltd., 2008 - All Rights Reserved."
4 |  <documentIdentifier>CARD4L_Metadata-specification_PolarimetricRadar-v2.8</documentIdentifier>
5 |  <dataCollectionTime>
6 |    <NumberOfAcquisitions>1</NumberOfAcquisitions>
7 |    <FirstAcquisitionDate>2008-05-06T14:25:39:000000Z</FirstAcquisitionDate>
8 |    <LastAcquisitionDate>2008-05-06T14:25:44:000000Z</LastAcquisitionDate>
9 |  </DataCollectionTime>
10 |  <SourceAttributes acqID="1">
11 |    <SourceDataRepository type="URL">https://ndacorporation.com/geospatial/International/satellites/RADARSAT-2/sample-data/
12 |    <Satellite>RADARSAT-2</Satellite>
13 |    <Instrument>SAR</Instrument>
14 |    <SourceDataAcquisitionTime>
15 |      <StartTime>2008-05-06T14:25:39:000000Z</StartTime>
16 |      <EndTime>2008-05-06T14:25:44:000000Z</EndTime>
17 |    </SourceDataAcquisitionTime>
18 |    <AcquisitionParameters>
19 |      <RadarBand>C</RadarBand>
20 |      <RadarCenterFrequency units="Hz">5.40499924769673e+09</RadarCenterFrequency>
    
```

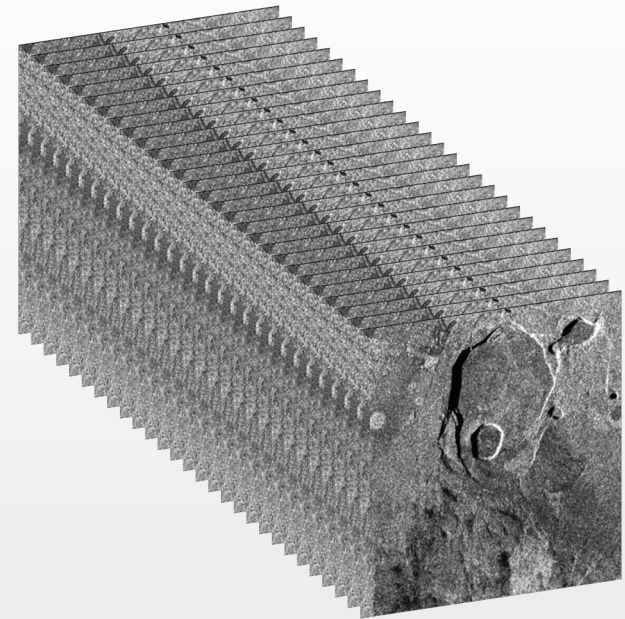
Sentinel-1 IWS
CARD ORB (mock-up)
(Processing: soloEO)





Geocoded Single-Look Complex (GSLC)

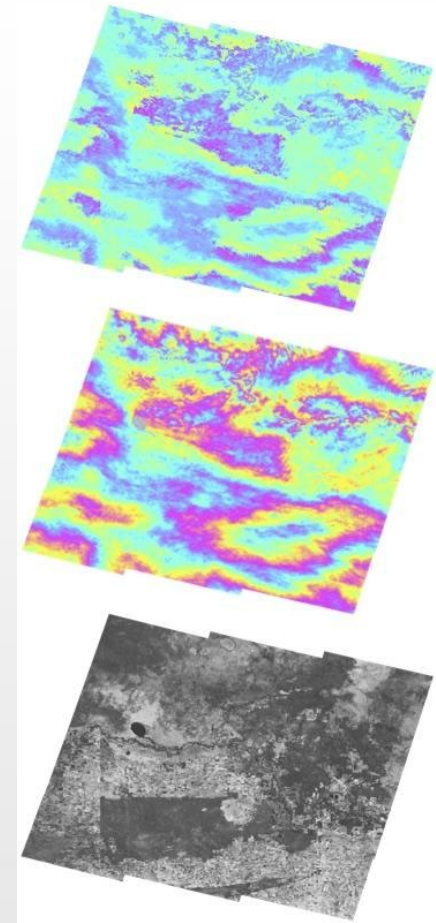
- The **CARD GSLC** product describes the complex radar reflectivity (amplitude & phase) at each point on the surface with all average propagational phases removed.
- GSLC data are presented in a common, often user-defined, ground based coordinate system (rather than in slant range), to facilitate use by non-radar-specialists.
- Same structure as the CARD4L NRB.
- The CARD4L GSLC product specification is under development. Completion/ & release foreseen in 2023



Stack of geocoded SLC images
(Zebker et al, 2018)

Interferometric Radar (INSAR)

- A suite of three products generated from an InSAR pair, or a stack:
 - **Wrapped interferogram:** Image of differential phase signals between two SLC images
 - **Unwrapped interferogram:** Image of differential phase signals where the wrapped fringes are summed (“unwrapped”) to give a continuous phase signal across the image
 - **Interferometric coherence:** Image of phase coherence between the two images.
- The **CARD INSAR** product specification is under development. Completion/release foreseen in 2023.



Sentinel 1 interferometric products
(Geoscience Australia team)



- CEOS ARD specifications for **Normalised Radar Backscatter** and **Polarimetric Radar** endorsed by CEOS. Latest updates: Dec 2021
- Further SAR CARD products under development (ORB, GSLC, INSAR)
- Public open **CARD NRB products** (NRB compliance presently under assessment by CEOS WG CalVal) :
 - ALOS-2 PALSAR-2 (Global mosaic products) – JAXA
https://www.eorc.jaxa.jp/ALOS/en/dataset/fnf_e.htm
 - Sentinel-1 (Digital Earth Africa) – Sinergise (CARD4L approved last week!)
<https://registry.opendata.aws/deafrica-sentinel-1/>
- Public open **CARD POL sample product** available at:
 - RADARSAT-2 – NRCan
<ftp://ftp.ccrs.nrcan.gc.ca/ad/Charbonneau/CARD4L/>



More information at <http://ceos.org/ard>

CEOS Analysis Ready Data

Overview Framework Specifications FAQ Resources **Datasets** CEOS ARD Strategy

CEOS ANALYSIS READY DATA

CEOS Analysis Ready Data for Land (CARD4L) are satellite data that 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 and interoperability both through time and with other datasets.

Information for:

- Data Producers
- Data Distributors
- Data Users