Committee on Earth Observation Satellites

Living Planet Symposium 2022
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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

Analysis Ready Data (ARD) & CEOS Analysis Ready Data (CARD)

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 SAR!)

CARD Radar products
Current status

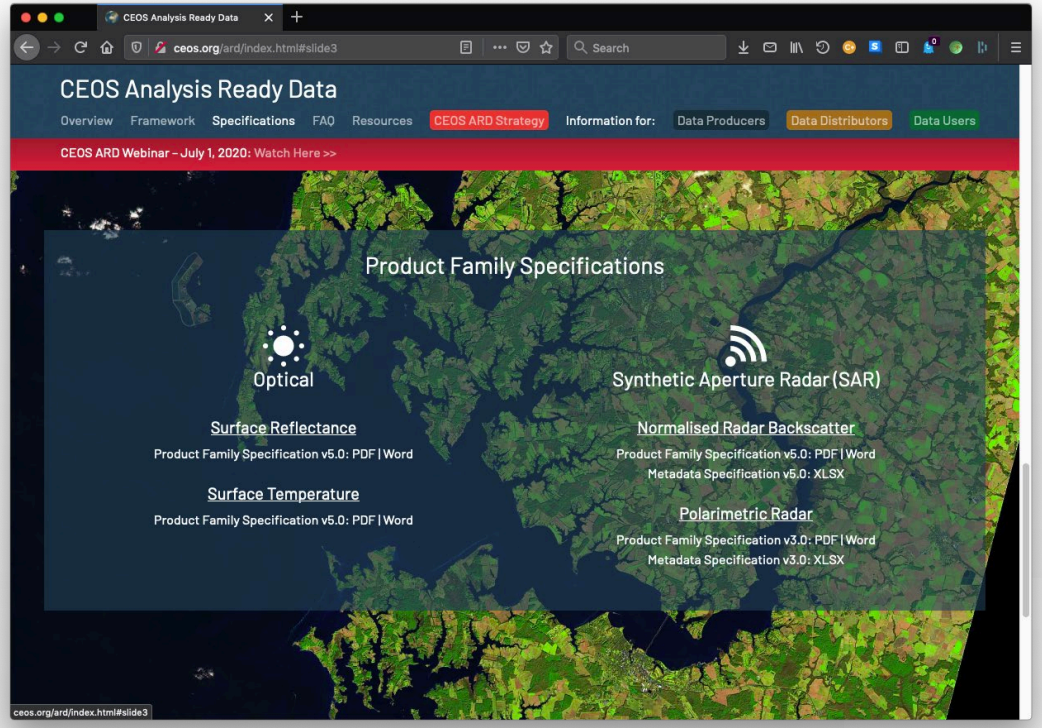
CEOS ARD specifications (CARD4L) for SAR products:

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



CEOS ARD – SAR
Specifications for Data Providers

Committee on Earth Observation Satellites	Analysis Ready Data *For Land (CARD4L)*	Product Family Specification: Normalised Radar Backscatter

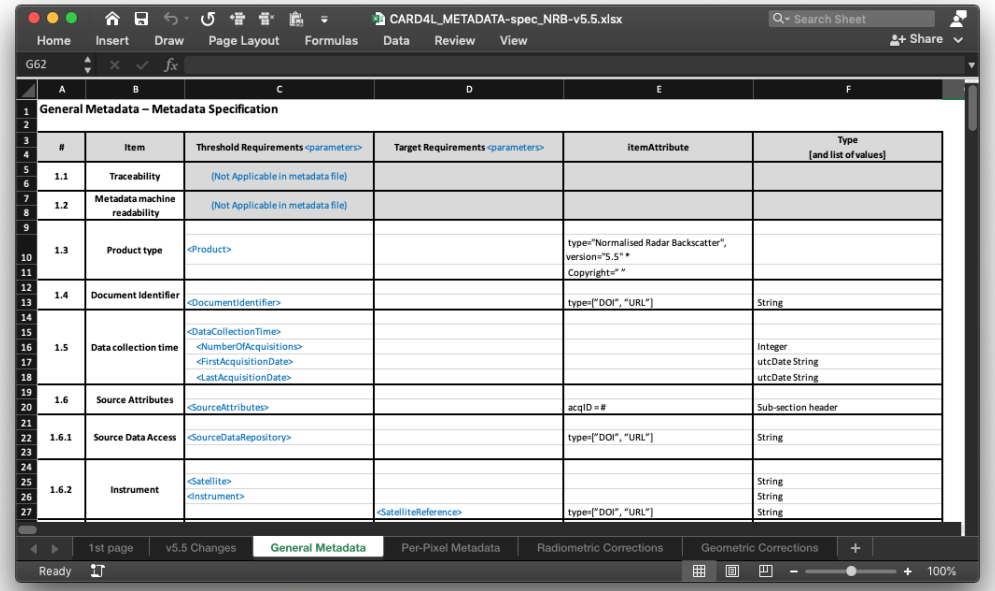
#	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements
1.6.4	**Source Data Acquisition Parameters**	Acquisition parameters related to the SAR antenna: - Radar band - Centre frequency Observation mode - Polarisation(s) - Antenna pointing [Right/Left] - Beam ID	As threshold.
1.6.5	**Source Data Orbit Information**	Information related to the platform orbit used for data processing: - Pass direction [asc/desc) - Orbit data source [e.g., predicted/definite/precise/ downlinked etc.]	As threshold, including also: - Platform heading angle - 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 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.

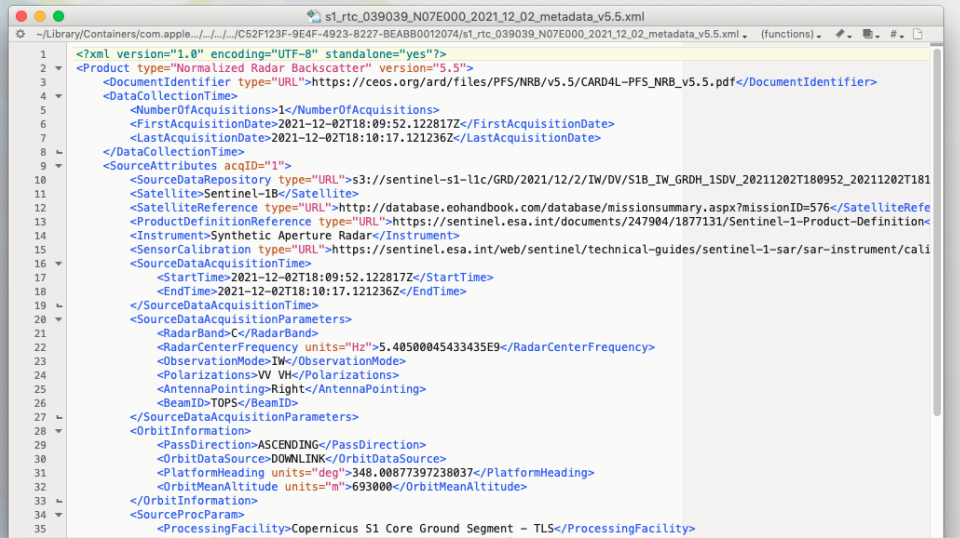
Extract from CARD4L NRB specification document

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

CARD Radar Metadata specs





Metadata Specifications

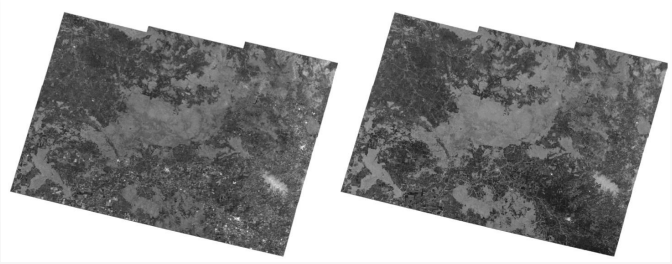
- Metadata specification developed to accompany each Radar PSF
- Consistent mapping of parameter names between PFS and metadata
- Specs for XML format but data provider may select other metadata formats (yaml, json, etc.)
- Non-mandatory (Target req.)

#	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

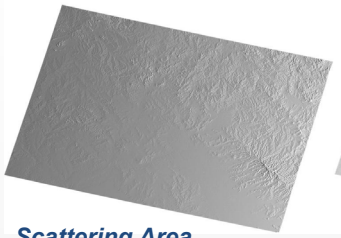
CARD Radar
General PFS structure

1. Radar Measurement

Geometric and Radiometric specs



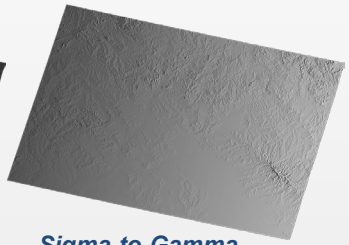
2. Per-Pixel Metadata (image data) (NRB example)



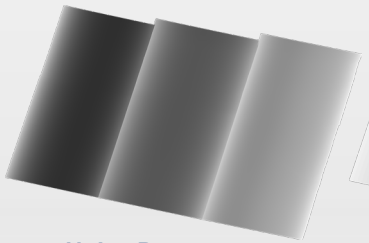
Scattering Area

Local Inc Angle

Data Mask



Sigma-to-Gamma



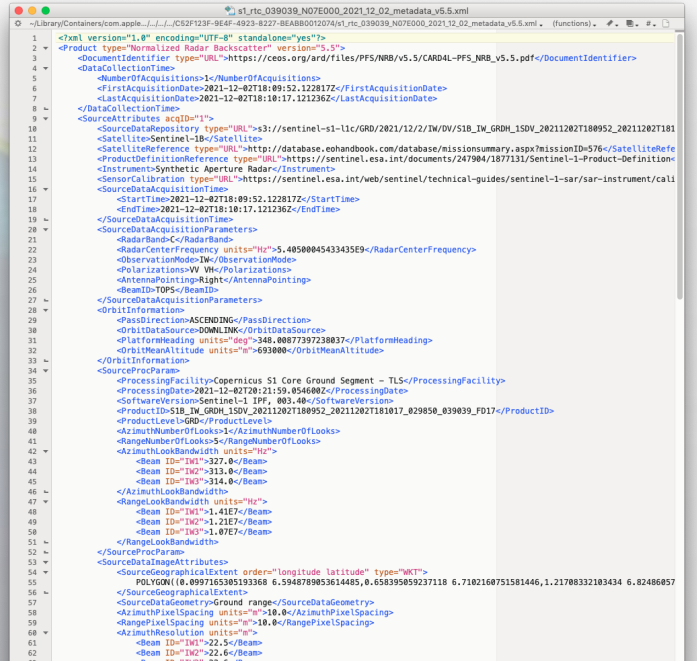
Noise Power

Ellipsoid Inc Angle

Acquisition ID

Per-pixel DEM

3. General Metadata



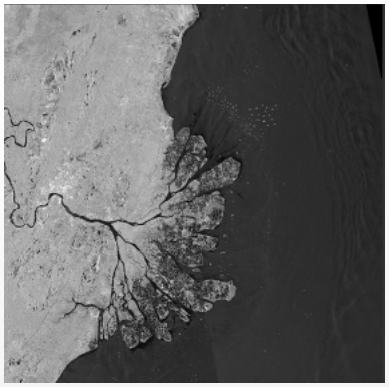
CARD4L NRB sample
(Processing: Z-S Zhou, CSIRO)

CEOS ARD – SAR
Normalised Radar Backscatter (NRB)

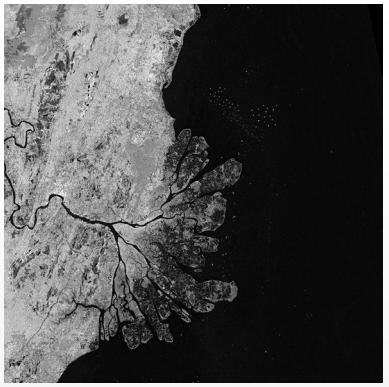
CARD NRB

- 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)

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



γ^0 *Backscatter (HH)*



γ^0 *Backscatter (HV)*

Local Inc. Angle

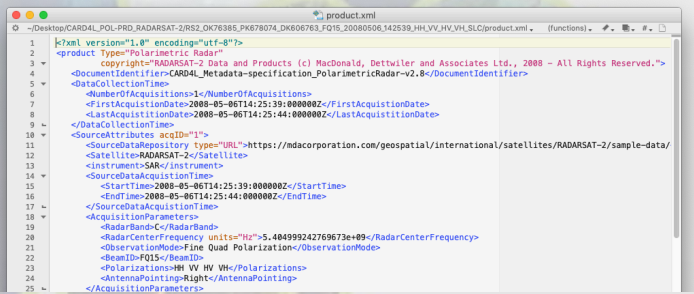
Acquisition ID

Data Mask

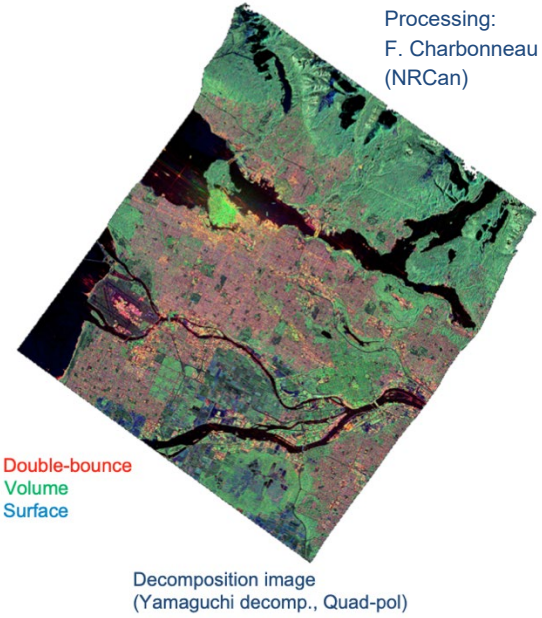
CEOS ARD – SAR
Polarimetric Radar (POL)

- 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

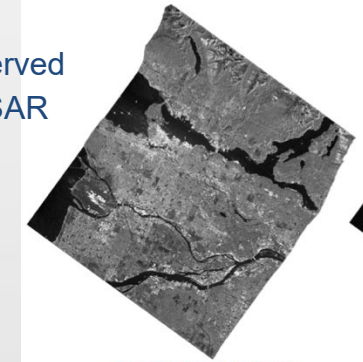
- POL Measurement Data covers two product types:
  - Polarimetric Decomposition
    - Data Providers to decide what decompositions to offer to users (e.g. Eigen value; Pauli, Freeman-D; Yamaguchi, etc.)
  - Polarimetric Covariance Matrix
    - Polarimetric phase and amplitude preserved
    - For polarimetric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



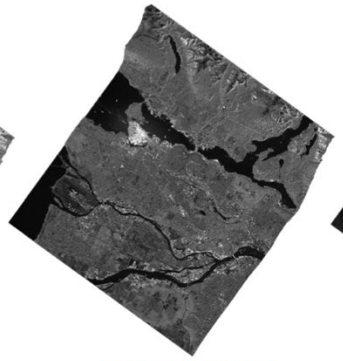
RADARSAT-2 (MDA)
Processing:
F. Charbonneau
(NRCan)



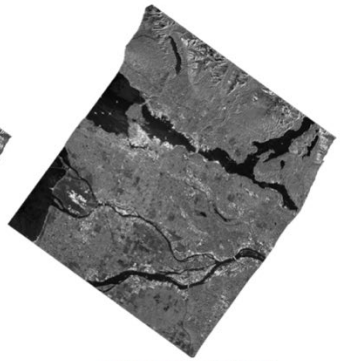
Decomposition image
(Yamaguchi decomp., Quad-pol)



Matrix element (1,1)
REAL
HH intensity



Matrix element (2,2)
REAL
HV intensity



Matrix element (3,3)
REAL
VV intensity

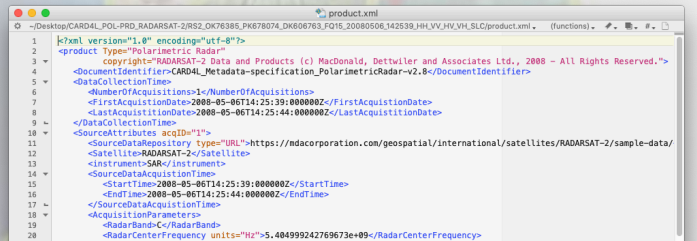
Matrix elements (1,2) (1,3) & (2,3)
COMPLEX (Re + Im): Polarimetric phase

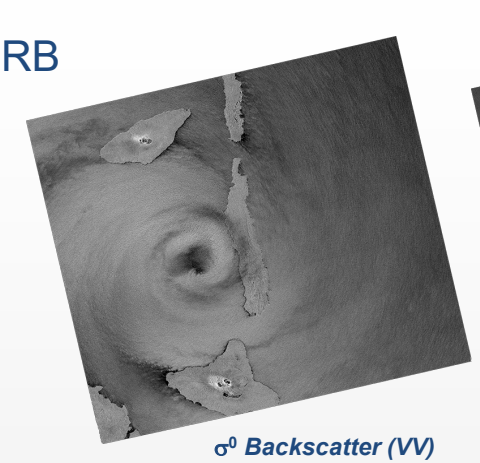
CEOS ARD – SAR
Ocean Radar Backscatter (ORB)

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

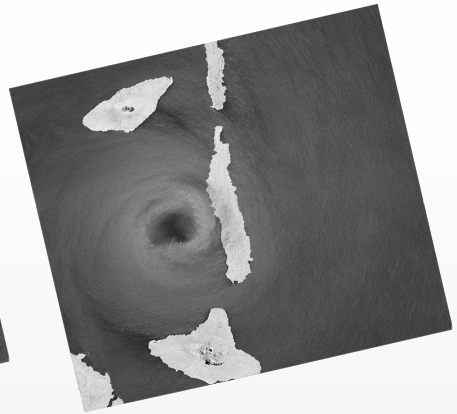
- Radar Measurement data:
  - Geoid-corrected backscatter
  - Expressed as σ^0
- Per-pixel metadata:
  - Threshold (required):
    - Geoid Incidence Angle image
    - Mask image (including land mask)
    - Acquisition ID image (for composite products)
  - Target (desired):
    - Noise power image (if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

- **The CARD ORB product specification is under development. Completion/release foreseen for Q3-Q4/2022.**



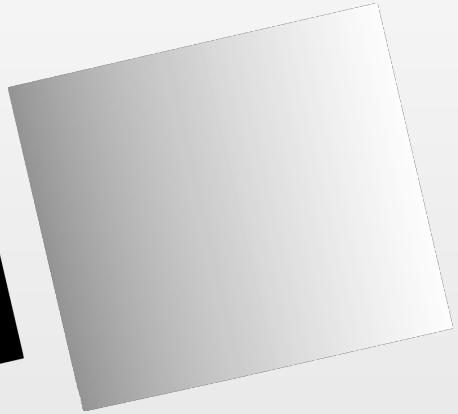


σ^0 *Backscatter (VV)*



σ^0 *Backscatter (VH)*

Data Mask image



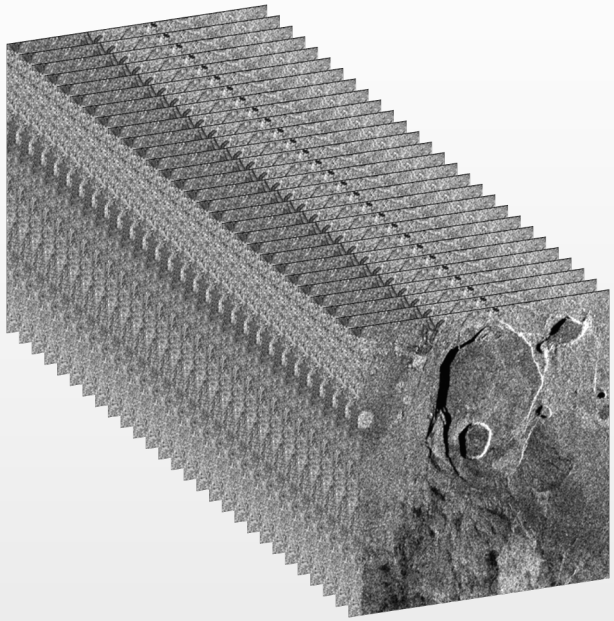
Geoid Inc. Angle image

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

CEOS ARD – SAR
Geocoded SLC (GSLC)

Geocoded Single-Look Complex (GSLC)

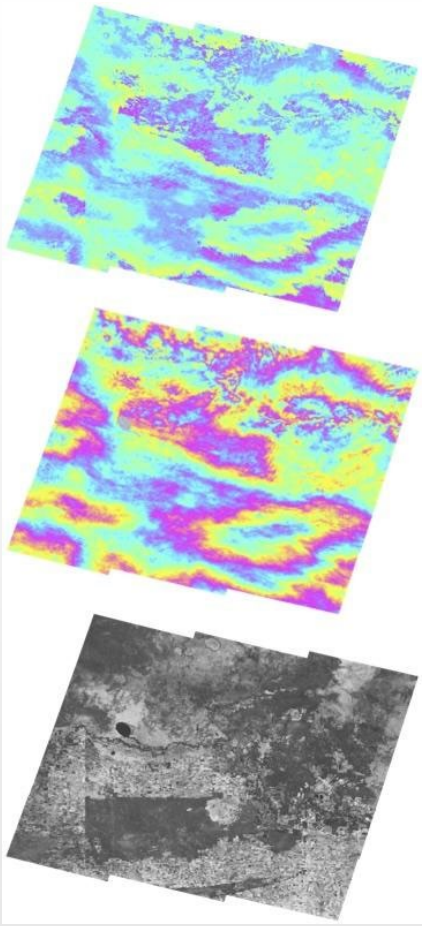
- The CARD GSLC product describes the complex radar reflectivity (amplitude & phase) at each point on the surface with all average propagational phases removed.
- GSLC data are presented in a common, often user-defined, ground based coordinate system (rather than in slant range), to facilitate use by 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)

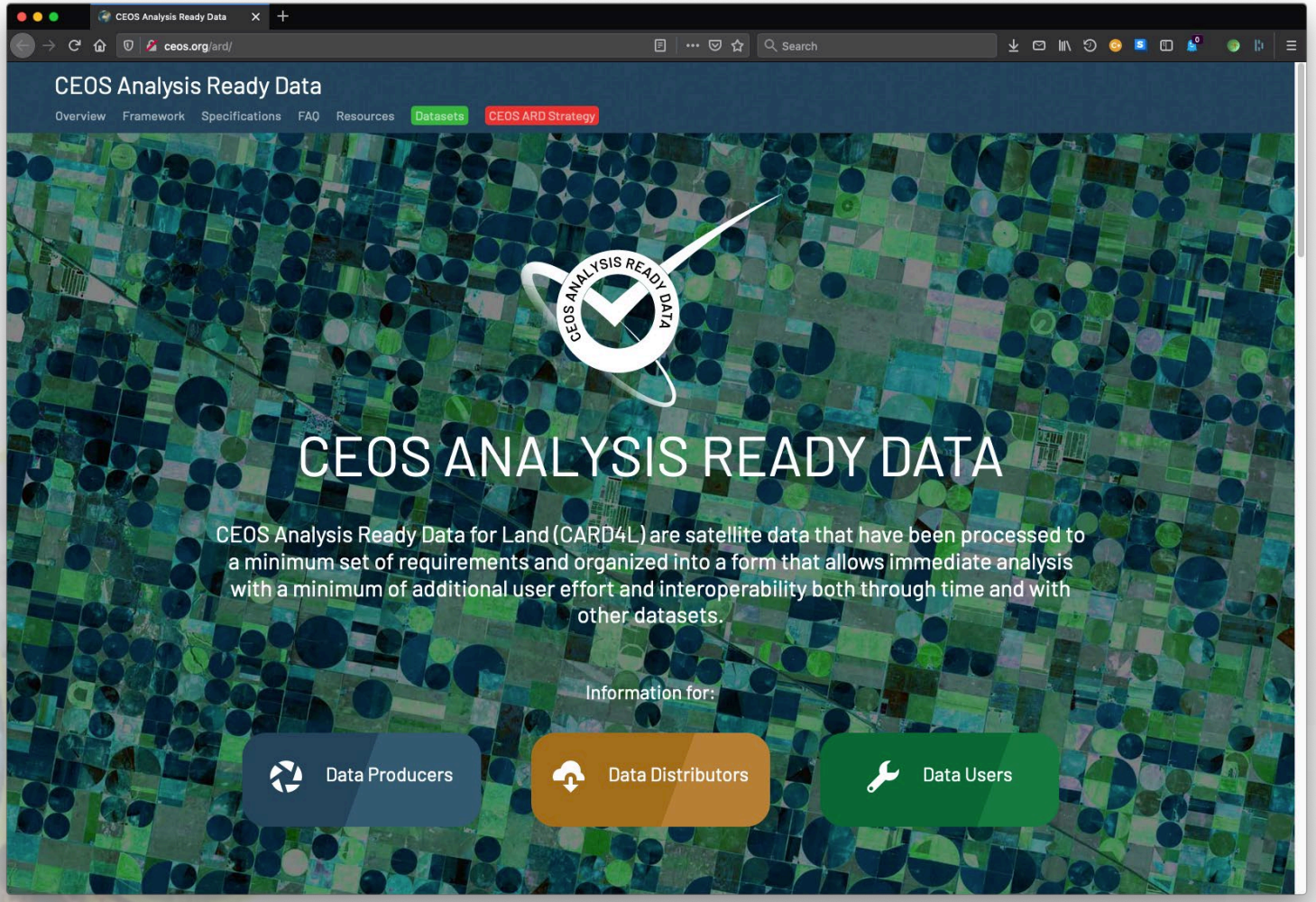
- A suite of three products generated from an InSAR pair, or a stack:
  - **Wrapped interferogram**: Image of differential phase signals between two SLC images
  - **Unwrapped interferogram**: Image of differential phase signals where the wrapped fringes are summed (“unwrapped”) to give a continuous 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 Radar Access

- 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/

CEOS ARD
Synthetic Aperture Radar

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