CEOS Analysis Ready Data (CEOS ARD)

by Steve Labahn (USGS) on behalf of
CEOS – Land Surface Imaging Virtual Constellation (LSI-VC)

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Agenda
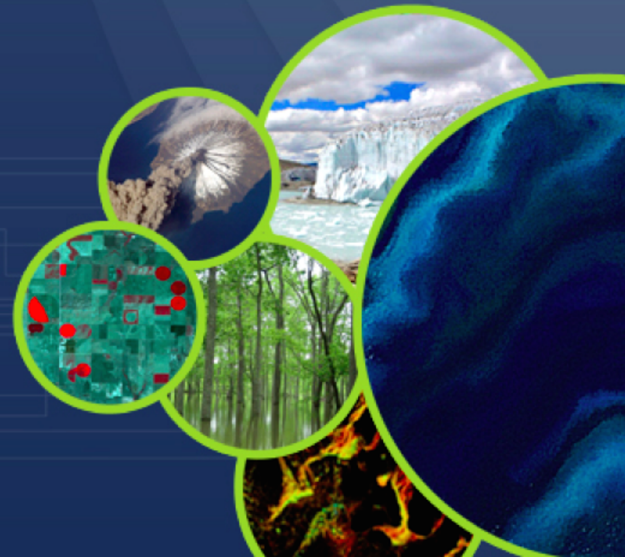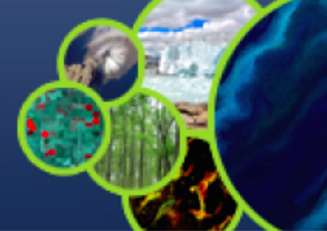
- **CEOS & LSI-VC Overviews**

- **CEOS "ARD" & "Interoperability" Definitions**

- **CEOS ARD for Land (CARD4L) Framework**

- **CARD4L Specifications & Compliance Review Process**

- **Next Steps**

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CEOS ensures international coordination of civil space-based Earth observation programs and promotes exchange of data to optimize societal benefit and inform decision making for securing a prosperous and sustainable future for humankind.

Established under the auspices of the G-7 Economic Summit of Industrialized Nations (1984).

Operates through the best efforts & voluntary contributions of Members (space agencies) & Associates (UN Agencies, Phase A programs, or supporting ground facility programs).

Delivers on high priority objectives in support of the Group on Earth Observation (GEO) Tasks as the space component of the Global Earth Observation System of Systems (GEOSS).

http://ceos.org/

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.

The CEOS Land Surface Imaging Virtual Constellation (LSI-VC) served as the forum for developing the CEOS Analysis-Ready Data definition. CARD4L underpins a large amount of the future data architectures work being progressed within CEOS. The CARD4L definition was endorsed by the CEOS Plenary in 2016.

The CEOS Land Surface Imaging Virtual Constellation (LSI-VC) has over 20 members representing 12 agencies (CNES, CSA, CSIRO, DLR, EC, ESA, GA, ISRO, JAXA, NASA, NOAA, USGS).

http://ceos.org/ard

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CEOS Analysis Ready Data: Processed and Organized for Immediate Analysis

CEOS ARD

CEOS Analysis Ready Data 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.

CEOS Analysis Ready Data Product Family Specifications detail specific 'Threshold' and 'Target' requirements for:

• General Metadata
• Per-pixel Metadata
• Radiometric and Atmospheric Corrections
• Geometric Corrections
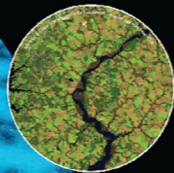
Initial Product Family Specifications included Surface Reflectance, Surface Temperature, and Radar Backscatter. Further Specifications are in active development.

Systematic and regular provision of CEOS Analysis Ready Data will greatly reduce the data processing burden on global satellite data users.

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ARD & Interoperability Definitions
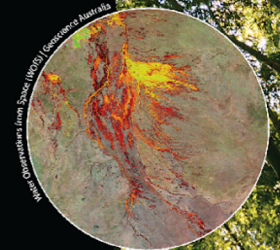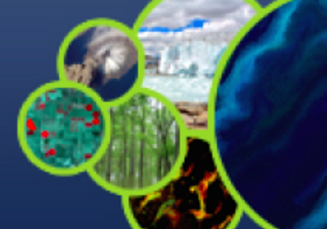
In the context of Earth remote sensing, the terms *Analysis Ready Data (ARD)*, *interoperability*, and *harmonisation* are often used and, to a large extent, used inconsistently

As it relates to Earth Observation products, *interoperability* represents a continuum of potential compatibility for products to work in numerous information technology systems and with other like-prepared data products

- Ultimate product interoperability (i.e., a fully harmonised dataset) is achieved when products have a fully consistent spectral, radiometric, geometric, metadata, and file format implementation where applications can interact fully with the data interchangeably, automatically, and without modification

Specifically, 5 terms have been defined:

- Analysis Ready Data (ARD)
- CEOS ARD for Land (CARD4L) Products
- Interoperable Products
- Harmonised Products
- Fused Products

Raw Imagery — CARD4L — Fully Harmonised Dataset — Fused Dataset

Little/No Interoperability — Increasing Interoperability
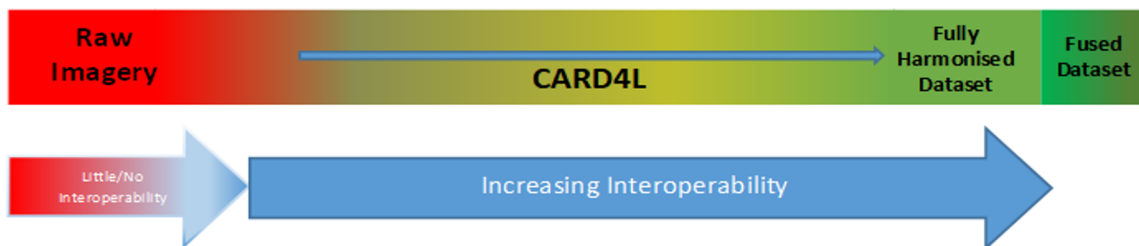
CEOS Interoperability Terminology Report:
http://ceos.org/document_management/Meetings/Plenary/34/Documents/CEOS_Interoperability_Terminology_Report.pdf
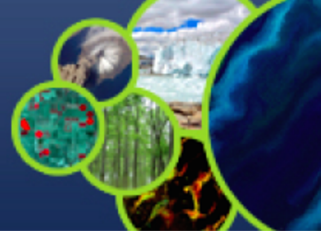
CEOS Analysis Ready Data for Land (CARD4L) are satellite data that have been processed to a minimum set of requirements and organized into a form that allows immediate analysis with a minimum of additional user effort and interoperability both through time and with other datasets.

CARD4L offers numerous benefits for data producers, data distributors, and data users. More info: http://ceos.org/ard/

Data Producers	Data Distributors	Data Users
Increase Uptake	Platform Appeal	Save Time and Effort
Increase Impact	Consistent, High-	Capitalize on Experts
Stay Relevant	Quality Data Sets	Minimize Costs
Increase Efficiency		Consistent, High-
Enable Interoperability		Quality Data Sets

What CARD4L Is… and Isn't

- **What it is:**
  - Focuses on geophysical measurements (Level-2 products, surface reflectance, surface temperature, normalized radar backscatter, polarimetric radar, etc.)
  - Ensures that new users (e.g., applications scientists) are able to use these datasets with ease and confidence, including all the necessary metadata (provenance, quality flags). Reduces end user post-processing and data preparation (~80% target)
  - Original development driven by the needs of moderate resolution observations (10-100m), but it is intended to address both higher and lower resolution data as well
  - Intended to be at least one common product establishing minimum level of interoperability for time series analysis and data cube type of implementations
  - Developed in consultation with science experts including academia and commercial (not just internal to CEOS)
  - Intended to provide a framework for interoperability that is built-in to product definition prior to product development
  - Recognition for having a quality product as well as a framework to support ongoing quality improvements
- **What it isn't:**
  - Not intended to limit/preclude space agencies from developing additional products
  - Not intended to meet all user needs
  - Does not include lower-level (Level-0 or Level-1) or higher-level (Level-3 or Level-4) products
  - Does not dictate product packaging (e.g., tiling), format (e.g., GeoTIFF, COG, HDF), or a single metadata standard (e.g., ISO 19115-2, STAC)
  - Not a 'standard'… but LSI-VC is working with standards bodies (OGC, IEEE, ISO)
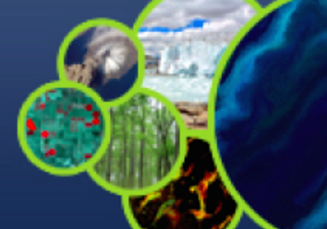
1) CARD4L Definition

2) Product Family Specifications (PFS)
• Optical Surface Reflectance (CARD4L-SR), v5.0
• Optical Surface Temperature (CARD4L-ST), v5.0
• Normalized Radar Backscatter (CARD4L-NRB), v5.0
• Polarimetric Radar (CARD4L-POL), v3.0
* Additional radar PFSs are under consideration
* LiDAR PFS is under consideration
* Aquatic Reflectance PFS in-work
* Nighttime Light Radiance PFS in-work

3) Product Alignment Assessment
• Providers self-assessment
• Peer-review assessment

CARD4L-compliant stamp!

CARD4L DEFINITION
Satellite data that have been processed to a minimum set of requirements

CARD4L Developed and Endorsed by LSI-VC / User Consultation

CARD4L PRODUCT FAMILY SPECIFICATION
(e.g. Surface Reflectance, Surface Temperature)
Threshold and Target:
• General Metadata
• Per-pixel Metadata
• Radiometric and atmospheric corrections
• Geometric corrections

PRODUCT ALIGNMENT ASSESSMENT
(e.g. Surface Reflectance, Surface Temperature)
Assesses how well the specific product complies with each of the metadata & calibration criteria in PFS.
Includes description of 'how' it complies.

PAA Developed by Agency Seeking CARD4L Brand
Peer Review in collaboration with LSI-VC with WGCV

CARD4L *TARGET* ✓   **CARD4L** *THRESHOLD* ✓

CEOS ANALYSIS READY DATA

- **2 Requirement Levels**
  - Threshold – Minimum requirements that must be met for CARD4L-compliance
  - Target – Desired requirements to be met for greater interoperability

  Note: Over time, *Target* specifications may evolve to become *Threshold* requirements (thru annual review process)

- **4 Categories/Sections**
  - General Metadata
  - Per-pixel Metadata
  - Radiometric and Atmospheric Corrections
  - Geometric Corrections

Example – Surface Reflectance
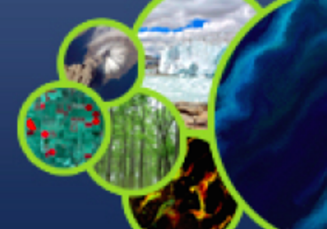
Requirements

General Metadata

These are metadata records describing a distributed collection of pixels. The collection of pixels referred to must be contiguous in space and time. General metadata should allow the user to assess the underlined overall suitability of the dataset, and must meet the following requirements:

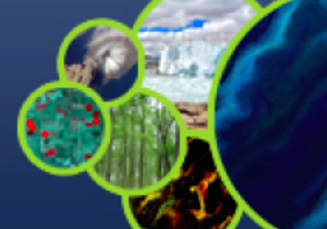| #	Item	Threshold (Minimum) Requirements	Target (Desired) Requirements	Threshold Self-Assessment	Target Self-Assessment	Self-Assessment Explanation/ Justification	Recommended Requirement Modification
1.1	Traceability	Not required.	Data must be traceable to SI reference standard. *Note 1: Relationship to 3.2. Traceability requires an estimate of measurement uncertainty. Note 2: Information on traceability should be available in the metadata as a single DOI landing page.*				
1.2	Metadata Machine Readability	Metadata is provided in a structure that enables a computer algorithm to be used consistently and to automatically identify and extract each component part for further use.	As threshold, but metadata should be provided in a community endorsed standard that facilitates machine-readability, such as ISO 19115-2.				
1.3	Data Collection Time	The data collection time is identified in the metadata, expressed in date/time, to the second, with the time offset from UTC unambiguously identified.	Acquisition time for each pixel is identified (or can be reliably determined) in the metadata, expressed in date/time at UTC, to the second.				
1.4	Geographical Area	The surface location to which the data relates is identified, typically as a	The geographic area covered by the observations is identified specifically, such as				

- **General Metadata (example)**
  - Threshold and Target Requirements
  - Data provider Self-Assessment columns for both threshold and target requirements
  - Option to provide feedback on any recommended requirements modifications intended to mature the requirements over time
- **This continues for:**
  - Per-Pixel Metadata
  - Radiometric and Atmospheric Corrections
  - Geometric Corrections

http://ceos.org/ard/files/PFS/SR/v5.0/CARD4L_Product_Family_Specification_Surface_Reflectance-v5.0.pdf
http://ceos.org/ard/files/PFS/SR/v5.0/CARD4L_Product_Family_Specification_Surface_Reflectance-v5.0.docx

Summary Self-Assessment Table

	Threshold	Target
1. General Metadata		
1.1 Traceability		
1.2 Metadata Machine Readability		
1.3 Data Collection Time		
1.4 Geographical Area		
1.5 Coordinate Reference System		
1.6 Map Projection		
1.7 Geometric Correction Methods		
1.8 Geometric Accuracy of the Data		
1.9 Instrument		
1.10 Spectral Bands		
1.11 Sensor Calibration		
1.12 Radiometric Accuracy		
1.13 Algorithms		
1.14 Auxiliary Data		
1.15 Processing Chain Provenance		
1.16 Data Access		
1.17 Overall Data Quality		
2. Per-Pixel Metadata		
2.1 Metadata Machine Readability		
2.2 No Data		
2.3 Incomplete Testing		
2.4 Saturation		
2.5 Cloud		
2.6 Cloud Shadow		
2.7 Land/Water Mask		
2.8 Snow/Ice Mask		
2.9 Terrain Shadow Mask		
2.10 Terrain Occlusion		
2.11 Solar and Viewing Geometry		
2.12 Terrain Illumination Correction		
2.13 Aerosol Optical Depth Parameters		
3. Radiometric and Atmospheric Corrections		
3.1 Measurement		
3.2 Measurement Uncertainty		
3.3 Measurement Normalisation		
3.4 Directional Atmospheric Scattering		
3.5 Water Vapour Corrections		
3.6 Ozone Corrections		
4. Geometric Corrections		
4.1 Geometric Correction		

- **Summary Self-Assessment Table**
  - To provide a quick snapshot of the self-assessment at both Threshold and Target requirement levels

- **Also included:**
  - Guidance
  - Introduction to CARD4L
  - Procedural Examples
  - Specific Examples
  - Reference Papers

http://ceos.org/ard/files/PFS/SR/v5.0/CARD4L_Product_Family_Specification_Surface_Reflectance-v5.0.pdf
http://ceos.org/ard/files/PFS/SR/v5.0/CARD4L_Product_Family_Specification_Surface_Reflectance-v5.0.docx

Landsat Collection 2

Landsat Collection 2 Level-1 and Level-2 surface reflectance and surface temperature scene-based products are available.
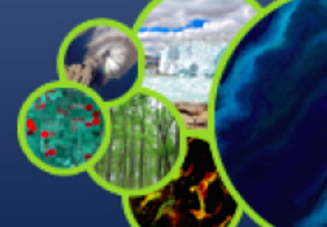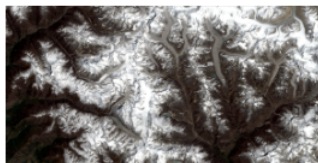
Level-1
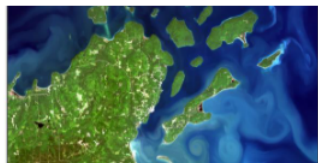
Technical Information for Collection 2 Level-1.

Learn More

Level-2

Technical Information for Collection 2 Level-2.

Learn More

Collection 1 vs Collection 2

Quick Reference Guide for Changes Between Collection 1 & Collection 2.

Learn More

Return to Landsat Collections Overview

Access Landsat Collection 1 Information

Landsat Collection 2 marks the second major reprocessing effort on the Landsat archive by the USGS that results in several data product improvements that harness recent advancements in data processing, algorithm development, and data access and distribution capabilities.

A primary characteristic of Collection 2 is the substantial improvement in the absolute geolocation accuracy of the global ground reference dataset - which improves interoperability of the Landsat archive through time. Collection 2 also includes updated global digital elevation modeling sources and calibration and validation updates.

Collection 2 includes Landsat Level-1 data for all sensors since 1972, as well as global Level-2 surface reflectance and surface temperature scene-based products from 1982 to present (excluding Landsat 1-5 Multispectral Scanner (MSS)) within defined constraints.

Collection 1 based products, including: Landsat 8 Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+) Collection 1 Level-1, U.S. Landsat ARD and Level-3 Science Products data processing and downloads <u>will remain available for at least one year after Collection 2 is publicly released</u>.

Visit this <u>Landsat Data Access</u> web page to discover how to search and download all Landsat products from USGS data portals.

The USGS are the first recipients of the Committee on Earth Observation Satellites (CEOS) endorsement for Analysis Ready Data for Land (CARD4L)-compliant products for Landsat Collection 2 Level-2 products. This internationally recognized certification ensures that Landsat Collection 2 Level-2 products are more interoperable with other Earth observing platforms, such as Europe's Sentinel-2 satellite, as they too work towards CARD4L-compliant products.

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https://www.usgs.gov/core-science-systems/nli/landsat/landsat-collection-2

CEOS Analysis-Ready Datasets

The following table summarises all of the satellite EO datasets that have been assessed as CEOS Analysis Ready Data for Land (CARD4L). DOI links are provided for access, along with links to further information, sample products, and the completed CARD4L self-assessment and peer review outcome documents.

Product	CARD4L Type	PFS Version	Agency	Mission(s)	Threshold Specification	Target Specification	Access (DOI)	Info	Self Assessment	Peer Review	Sample Products
Landsat Collection 2	Surface Reflectance	v4.1	USGS	Landsat 8, 7, 5, 4	● 100%	🌙 81%	Landsat 4-5, 7, 8	Link	PDF	PDF	Link
Landsat Collection 2	Surface Temperature	v4.2	USGS	Landsat 8, 7, 5, 4	● 100%	� 93%	Landsat 4-5, 7, 8	Link	PDF	PDF	Link

Under Development / Assessment

Product	CARD4L Type	PFS Version	Agency	Mission(s)	Access (DOI)	Info	Self Assessment	Peer Review	Sample Products
Landsat Collection 2	Surface Reflectance	v5.0	USGS	Landsat 8, 7, 5, 4	Landsat 4-5, 7, 8	Link	PDF	TBA	Link
Landsat Collection 2	Surface Temperature	v5.0	USGS	Landsat 8, 7, 5, 4	Landsat 4-5, 7, 8	Link	PDF	TBA	Link
Sentinel-2 Level-2A	Surface Reflectance	v5.0	ESA	Sentinel-2A, 2B	Link	Link	TBA	TBA	TBA
Sentinel-2 Level-2A (E84)	Surface Reflectance	v5.0	Element 84	Sentinel-2A, 2B	TBA	TBA	TBA	TBA	TBA
EnMAP	Surface Reflectance	v5.0	DLR	EnMAP	TBA	Link	TBA	TBA	Link

https://ceos.org/ard/index.html#slide4

Next Steps
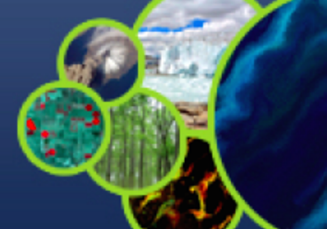
CEOS now has a broad ARD Strategy that it is executing, including:

- Specification Improvements
  - Annual review with input from others → broad input is welcome
  - Engagement with OGC
  - Beyond land – ocean and atmosphere communities
  - Guidance materials (working with IVOS and WGISS) to improve interoperability
- Assured Production & Access
  - USGS are producing data to the CARD specifications, and others are in-work
  - Data are moving into cloud platforms and cloud-effective formats (COG, STAC)
- Pilots & Feedback
  - Africa Pilot (www.digitalearthafrica.org), with Sinergise and Element-84
  - COAST
  - OGC Disasters Pilot
- Communication & Promotion
  - Webinars, conferences, and workshop participation (ARD20, JACIE, VH-RODA, ESIP, …)

Questions?

Committee on Earth Observation Satellites

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