Analysis Ready Data (ARD) for DESIS and EnMAP – Ensuring the Data Quality within the Ground Segments

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CEOS Analysis Ready Data for Land – CARD4L

*"CEOS Analysis Ready Data (CEOS-ARD) 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**."*
https://ceos.org/ard/

Current Product Family Specifications (PFS):

- **Surface Reflectances (CARD4L)**
- Aquatic Reflectances
- Surface Temperature

plus 2 radar PFS completed & multiple other in preparation

The CARD4L PFS includes requirements reg.

- General Metadata
- Per-pixel Metadata
- Radiometric and Atmospheric Corrections
- Geometric Corrections

Currently assessed (by Oct '22):

Product	CEOS-ARD Type	PFS Version	Agency	Mission(s)	Threshold Specification	Target Specification
EnMAP	Surface Reflectance	v5.0	DLR	EnMAP	100%	Not assessed
Landsat Collection 2	Surface Reflectance	v5.0	USGS	Landsat 4, 5, 7, 8, 9	100%	81%
Landsat Collection 2	Surface Temperature	v5.0	USGS	Landsat 4, 5, 7, 8, 9	100%	83%
Landsat Collection 2 U.S. ARD	Surface Reflectance	v5.0	USGS	Landsat 4, 5, 7, 8, 9	100%	Not assessed
Landsat Collection 2 U.S. ARD	Surface Temperature	v5.0	USGS	Landsat 4, 5, 7, 8, 9	100%	Not assessed
Sentinel-1 RTC	Normalised Radar Backscatter	v5.5	Sinergise & Digital Earth Africa	Sentinel-1 (A, B)	100%	Not assessed
Sentinel-2 Level-2A	Surface Reflectance	v5.0	ESA			

The EnMAP processing chain – highlights (I)

L0 (archived products):

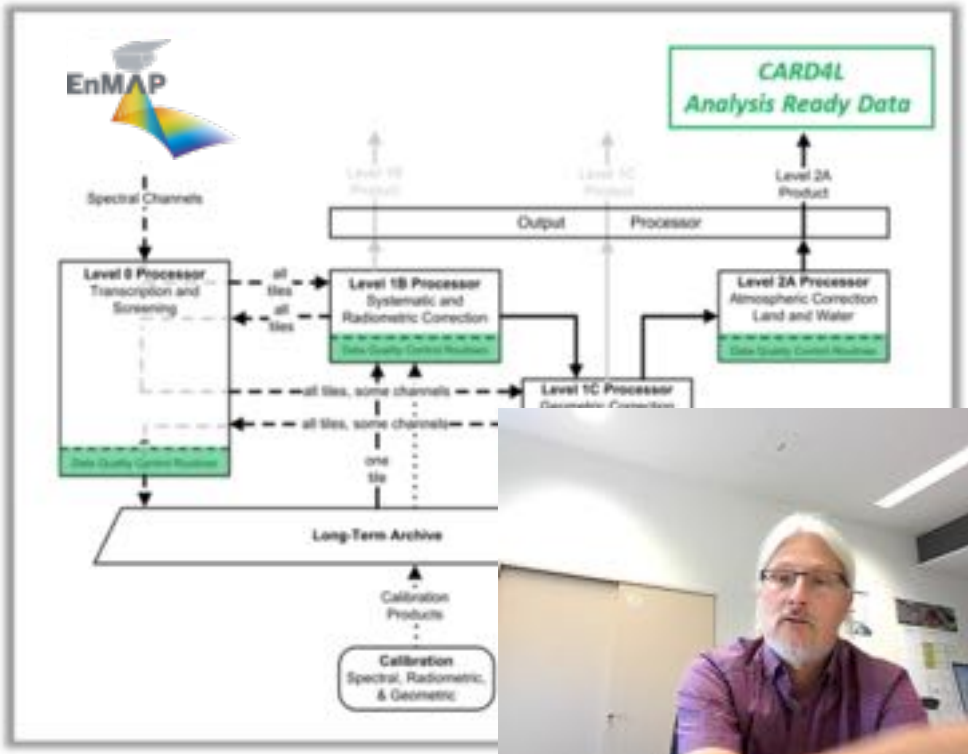
- Product includes full metadata as temporary processing of L1B, L1C & L2A

⇒ rich metadata incl. RPCs, spectral smile coefficients, AOT & WV information

⇒ all L1B, L1C, L2A processing on demand using latest cal. tables and processor versions

L1B (calibrated at-sensor radiances):

- Corrections applied: non-linearity, dark signal & offset, response non-uniformity, straylight
- Improved defective pixel interpolation and spectral smile correction (if required in the future): PACO inversion (conversion to BOA_ref, interpolation, re-conversion to TOA_rad)



The EnMAP processing chain – highlights (II)

L1C product:

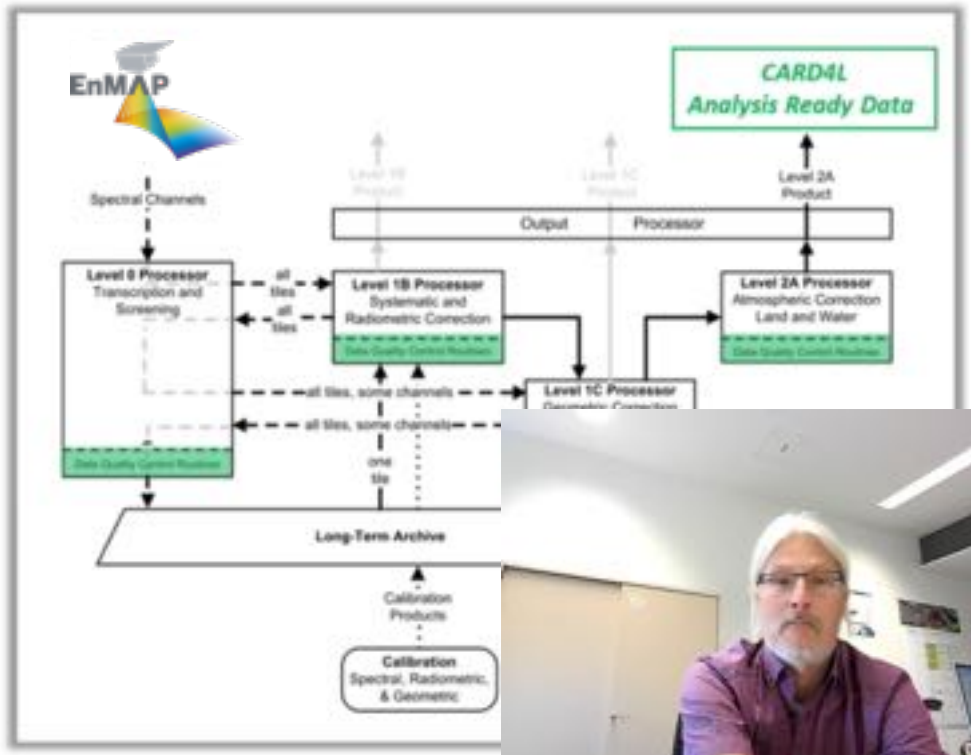
- Ortho-rectification using Copernicus DEM (GLO-30)
- LoS improvement by image-to-image matching using Sentinel-2 reference mosaic

⇒ per scene position accuracy measure using ICPs

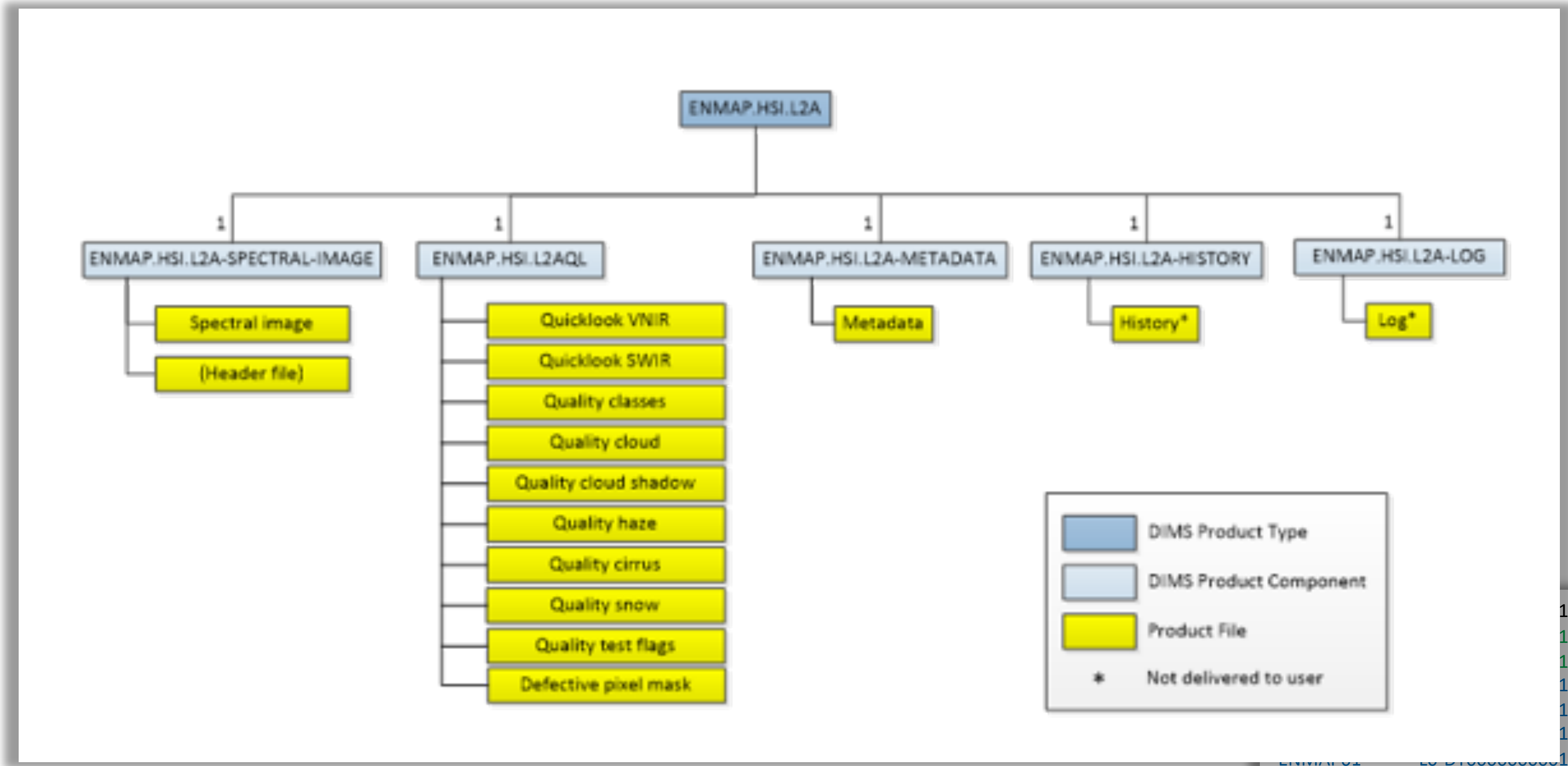
⇒ high relative consistency between EnMAP and S-2

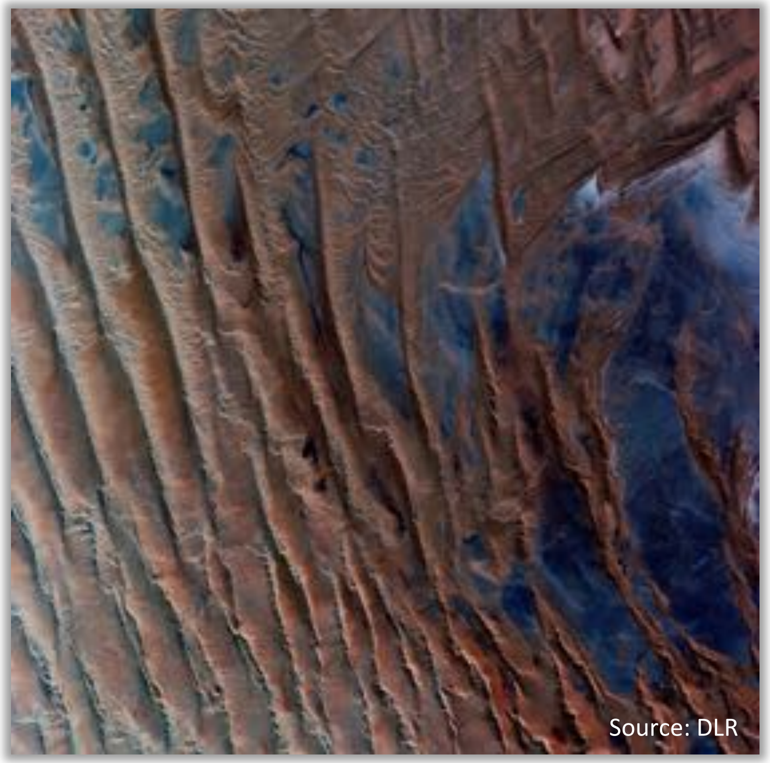
L2A products:

- **Land**: PACO using MODTRAN 5.4.0 &
  Fontenla 2011 solar irradiance model
  - BOA reflectance incl. terrain correction
  - De-hazing and cirrus correction
    (user selectable parameters)
  - ATCOR heritage, see validation in ACIX 1,2 & 3 (tbc)
- **Water**: MIP (by EOMAP), 2 products:
  - BOA water leaving reflectance
  - BOA subsurface reflectance



EnMAP – Data products and metadata





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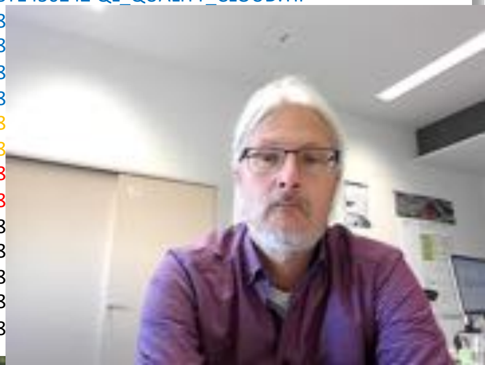


DLR

Mapping EnMAP to CARD4L (I)

- **L0+ processing metadata**
  - Screening and housekeeping parameters (e.g., temperatures)

- **L1B processing metadata**
  - Overall quality rating (nominal-reduced-low)
  - Radiometric quality rating (nominal-reduced-low)
  - Per mille values for saturation & crosstalk, defective pixels, striping and other artefacts
  - Absolute numbers of dead pixels
  - If required: indication flag for spectral smile
  - Summary of sensor & processor logs

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

Mapping EnMAP to CARD4L (II)

- **L1C processing metadata**
  - RMSE (x, y, xy) based on ICPs
  - RMSE & orthoResidual (x, y, xy) based on GCPs
  - Number of matching points (GCPs, ICPs)

- **L2A processing metadata**
  - Overall L2A quality rating (nominal-reduced-low)
  - Scene-averaged SZA, WV & AOT
  - Cover percentages for cloud, cloud-shadow, haze, cirrus, snow, water, terrain shadows, sun-glint
  - Information on processing (terrain correction & DDVs)

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

Mapping EnMAP to CARD4L (III)

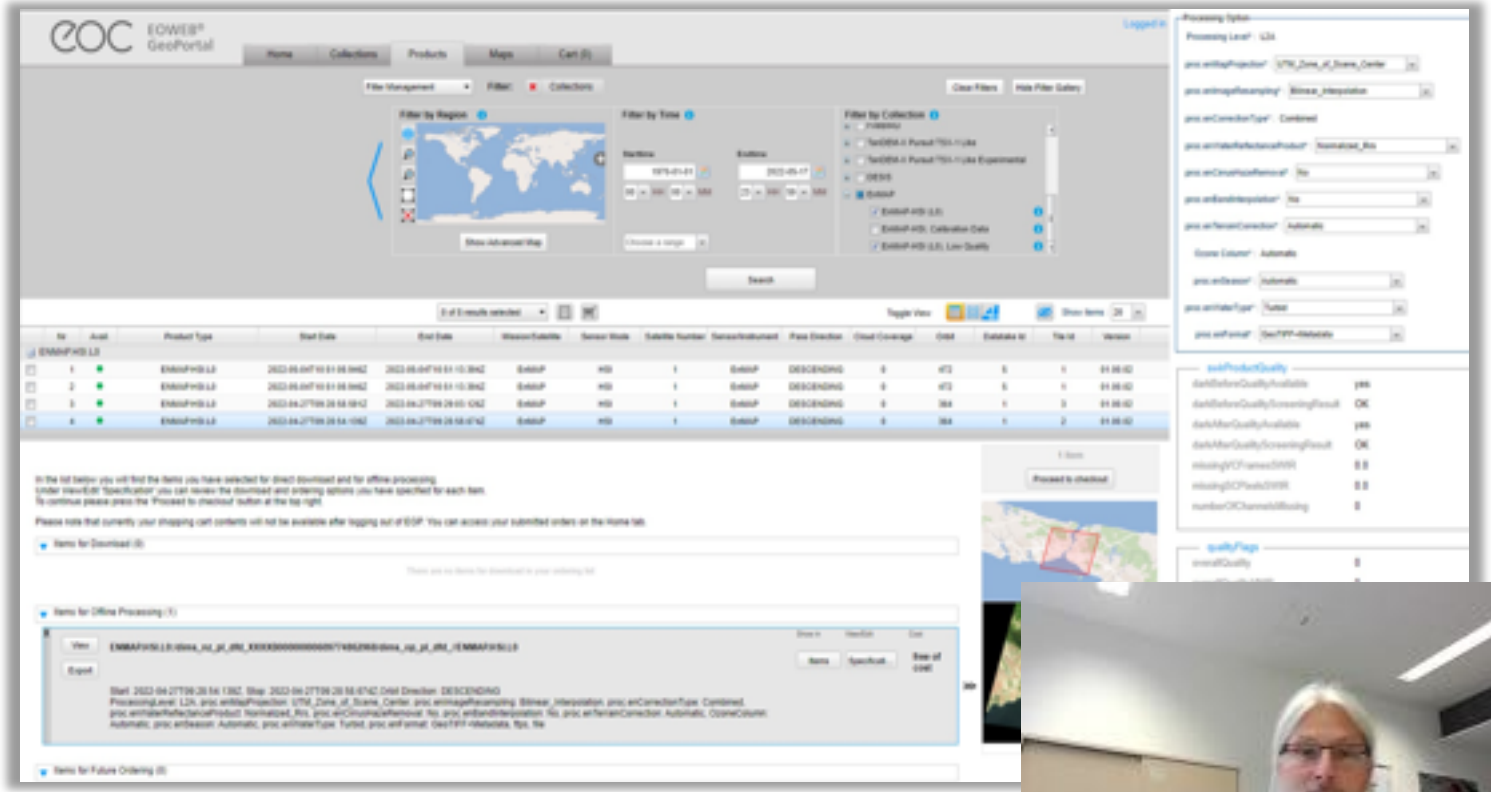
- **Per-pixel metadata (quality layers)**
  - Quicklook images for VNIR & SWIR, ortho-rectified
  - Per-pixel mask images: land, water, background, cloud, cloud-shadow, haze, cirrus, snow
  - Defective pixel mask (3-D cube of defects)
  - Aggregated quality flags: saturation, artefacts, interpolation and overall quality rating

- **ATBDs, Cal / Val reports & uncertainty studies**
  - To be published at www.enmap.org

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

Order & Processing Workflows

- Access via www.enmap.org
- EOWEB® GeoPortal provides catalogue search and retrieval functions for orders and archived data
- Provides access to all scene-specific Metadata (quicklooks, quality parameters etc.) of archived products
- Following OGC (Open Geospatial Consortium) standards:
  CSW (Catalog Service for the Web)
  WMS (Web Mapping Service)
  and ISO 19119 / 19115-2 INSPIRE conform



Outlook & Next Steps

- DESIS:
  - Preparation of CARD4L assessment

Under Development / Assessment

Product	CEOS-ARD Type	PFS Version	Agency	Mission(s)	Access (DOI)	Info
DESIS L2A	Surface Reflectance	v5.0	DLR	DESIS-on-ISS	TBA	TBA
Envisat ASAR	Normalised Radar Backscatter	v5.5	ESA	Envisat	TBA	TBA
Envisat MERIS	Surface Reflectance	v5.0	ESA	Envisat	TBA	TBA
ERS ATSR	Surface Reflectance	v5.0	ESA	ERS-1,-2	TBA	TBA

Currently assessed (by Oct ‘22):

- EnMAP
  - Preparation of L2A “Water Product” assessment reg. CEOS Aquatic Reflectance PSF

  - … and of course: Operational Phase

Supported by:

Federal Ministry
for Economic Affairs
and Climate Action

on the basis of a decision
by the German Bundestag

Thank you for your attention !

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EUFAR Metadata Standards
https://www.eufar.net/cms/metadata-standards/

IEEE P4001 "Standard for Characterization and Calibration of Ultraviolet through Shortwave Infrared (250 nm to 2500 nm) Hyperspectral Imaging Devices

EnMAP ARD paper incl. further details
Remote Sens. **2021**, *13*, 4536.
https://doi.org/10.3390/rs13224536

See also the related presentations by:
E. Carmona et al.
R. de los Reyes et al.
K. Alonso et al.
U. Heiden et al.