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Overview of EnMAP processor and calibration activities

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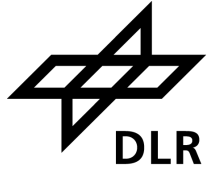
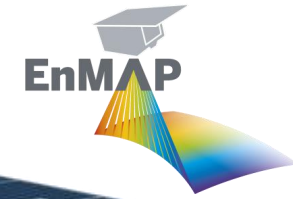


GFZ



EnMAP mission: requirements and fact sheet

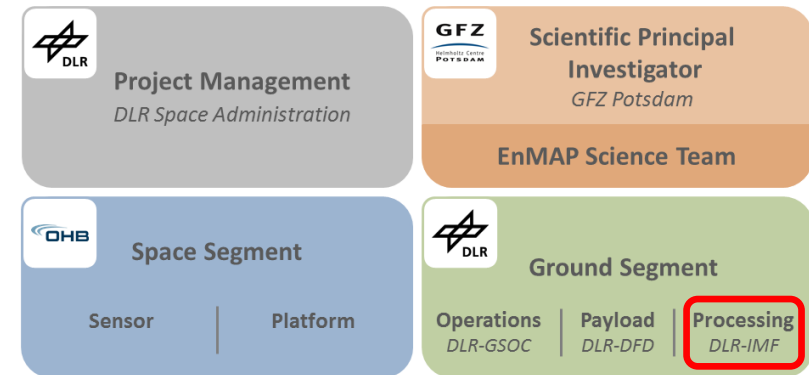
<https://www.enmap.org/>



EnMAP specification	VNIR	SWIR
Spectral range	420 – 1000 nm	900 – 2445 nm
Number of spectral bands	91	133
Spectral sampling distance	6.5 nm	10 nm
Spectral full width at half maximum	6 – 11 nm	7 – 11 nm
Spectral accuracy	0.5 nm	1 nm
Spectral stability	0.5 nm	
Spectral smile	<0.2 pix	
Signal-to-noise ratio	>500 (at 495 nm)	>150 (at 2200 nm)
Radiometric accuracy	<5%	
Radiometric stability	<2.5%	
Geometric accuracy	1 pix (30 m) with GCPs, otherwise 100 m	
VNIR/SWIR co-registration	0.2 pix	
L2AOT, WV, BOA (land, water)	see Storch et al 2023	
Orbit type, altitude and inclination	Sun-synchronous, 653 km, 97.96°	
Orbit period and repeat cycle	1.6 h, 398 revolutions in 27 days	
Local time descending node	11:00 h ± 18 min	
Revisit time	4 days (±30° off-nadir tilt) 21 days (±5° off-nadir tilt)	
Ground sampling distance	30 m (at nadir; sea level)	
Swath width	30 km (2.63° across track)	
Swath length	1000 km / orbit; 5000 km / day	
Product size	30 km x 30 km	

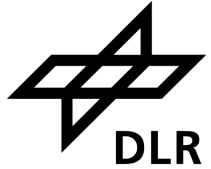
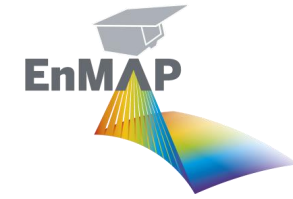


Source: DLR

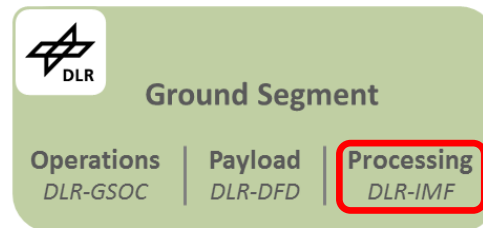


In-orbit calibration type	Mechanism	Frequency
Relative radiometric (lamp)	white spectralon	1x / week
Absolute radiometric (Sun)	Sun diffuser	1x / 2 months
Spectral	doped spectralon	1x / fortnight
Linearity	focal plane LEDs	1x / month
Deep space	dark sky	1x / month
Dark frames	closed shutter	before/after imaging

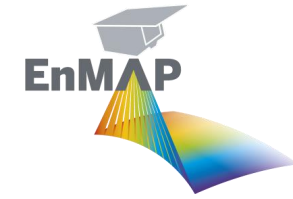
EnMAP processing and calibration



- In-flight calibration to update calibration tables
- Complex processing chain under continuous improvement to generate EnMAP products:
 - L0: raw data (internal only)
 - L1B: top-of-atmosphere radiances
 - L1C: orthorectified top-of-atmosphere radiances
 - L2A: orthorectified bottom-of-atmosphere reflectances (L2A land and L2A water)
- User products annotated with quality control and instrument monitoring information



EnMAP processing and calibration



Processor change log: https://www.enmap.org/data/doc/EnMAP_processor_changelog.pdf

- Overview of most important changes since launch
- Important go-to resource for users
- You can always reprocess your old data to benefit from improvements

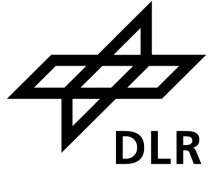
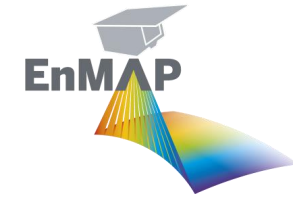
Selected highlights:

- Calibration: spectral and radiometric performance
- Processing and data quality: geometry, atmospheric correction
- Instrument monitoring: Moon observations

EnMAP processor change log

EnMAP processor version	Date	Description
01.00.01	08.04.2022	First processor version at launch.
01.01.00	11.07.2022	• Fixed matching for datatakes covering multiple UTM zones. • Fixed processing of scenes in antimeridian. • Fixed border effect due to adjacency correction in L2A land products. • Fixed bands filled with NaN in some L2A products.
01.01.01	10.08.2022	• Removed L2A quality rating from L0 overall quality rating.
01.01.09	30.09.2022	• Activated dehaze functionality in L2A processing.
01.01.11	24.11.2022	• Fixed units of L2A water products.
01.02.00	28.03.2023	• Improved co-registration accuracy. • Implemented interpolation of VNIR radiometric and RNU coefficients to reduce effect of VNIR degradation. • Implemented across-track destriping of L1B products. • Adapted spectral regions for interpolation in L2A processing. • Flag scenes with sun elevation angle of 0° or below (i.e., night scenes) as low quality.
01.03.00	02.05.2023	• Improved geolocation accuracy in along-track direction. • Prepared quality control configuration for update of EnMAP SWIR bands (active since 05.07.2023).
01.03.03	25.07.2023	• Filled gaps in DEM over Azerbaijan and Armenia. • Switched from MODIS to Copernicus for ozone and land surface temperature values used in L2A. • Fixed very high reflectances over snow in L2A products.
01.04.00	25.09.2023	• Re-activated adjacency correction over water in L2A water products (unintentionally de-activated in V01.01.11).
01.04.01	10.01.2024	• Fixed peaks in snow spectra at 590 nm and 647 nm in L2A products.
01.04.02	15.03.2024	• Fixed spectral noise in water spectra below 500 nm in L2A water products.
01.05.00	09.09.2024	• Writing new metadata entries viewingAzimuthAngle and viewingZenithAngle. • Fixed adjacency correction around clouds in L2A products. • Implemented SWIR dark signal correction at L1B level (active since 18.11.2024).
01.05.02	03.12.2024	• Taking the water vapor of adjacent tiles into account for the selection of radiative transfer LUTs. This should result in less inconsistencies between neighboring L2A tiles from the same datatake.

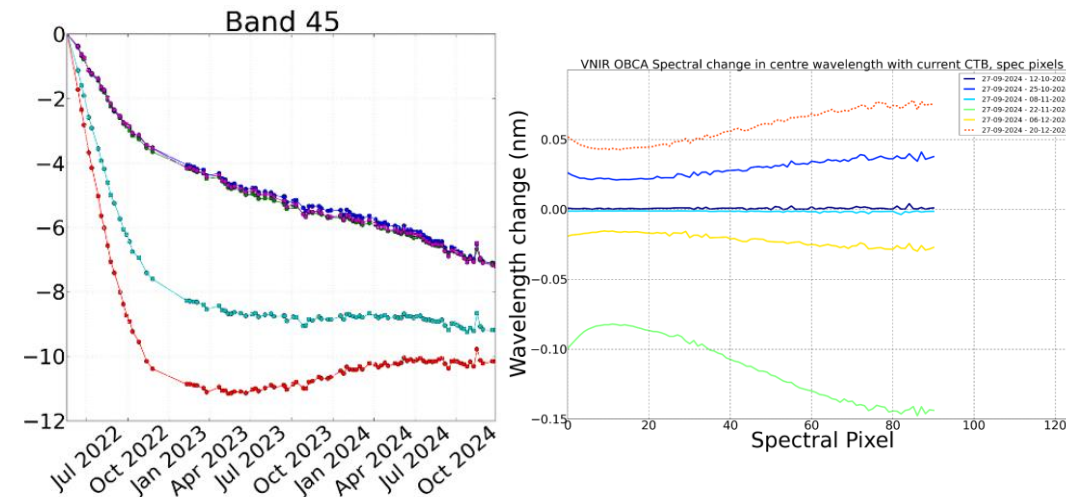
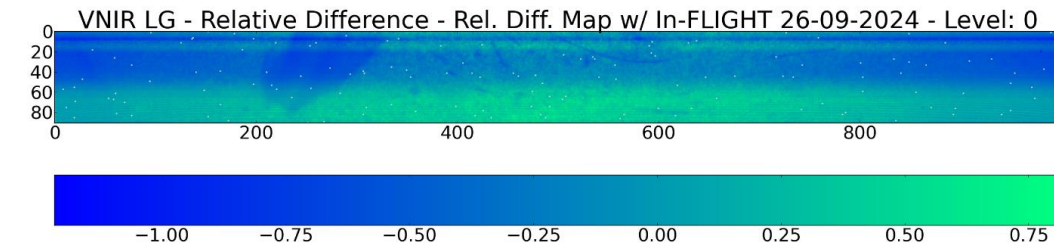
Spectral and radiometric performance



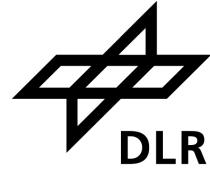
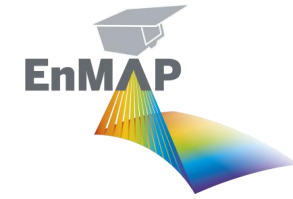
Highlight: Continuous monitoring of sensor performance with regular in-orbit calibration

Actions / results:

- Fast VNIR sensor degradation during first year slowed down by Mar 2023 but with differences across focal plane
- SWIR sensor very stable since launch
- Good spectral stability (<0.5 nm) for both VNIR and SWIR, last spectral update from Feb 2023
- Dark signal remarkably stable since launch
- VNIR/SWIR mismatch in overlapping spectral region under investigation (see next slide)



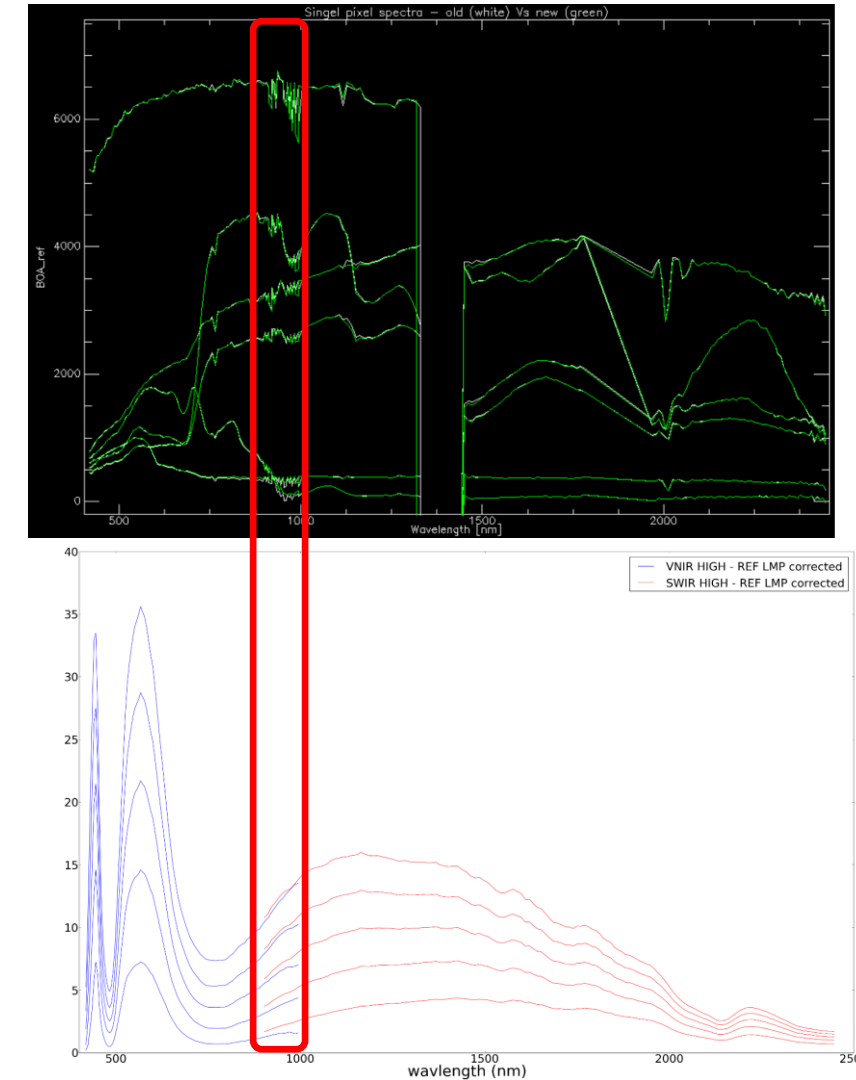
VNIR/SWIR mismatch in overlapping region



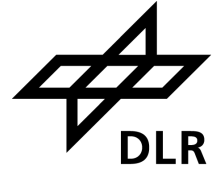
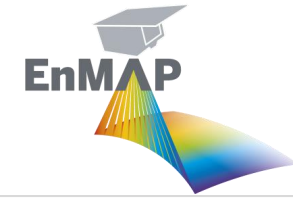
Highlight: Intercomparison between VNIR and SWIR to help fix calibration issues

Actions / results:

- Systematic differences between VNIR and SWIR radiances create zig-zag pattern in Earth L1C/L2A spectra at 900–1000 nm
- Effect also present in calibration data, but more obvious in Earth due to water absorption feature and interleaved VNIR/SWIR bands
- Root cause likely related to VNIR linearity at low signal levels
- In-depth analysis using Earth, Moon and in-orbit calibration data in progress with the final goal of developing correction



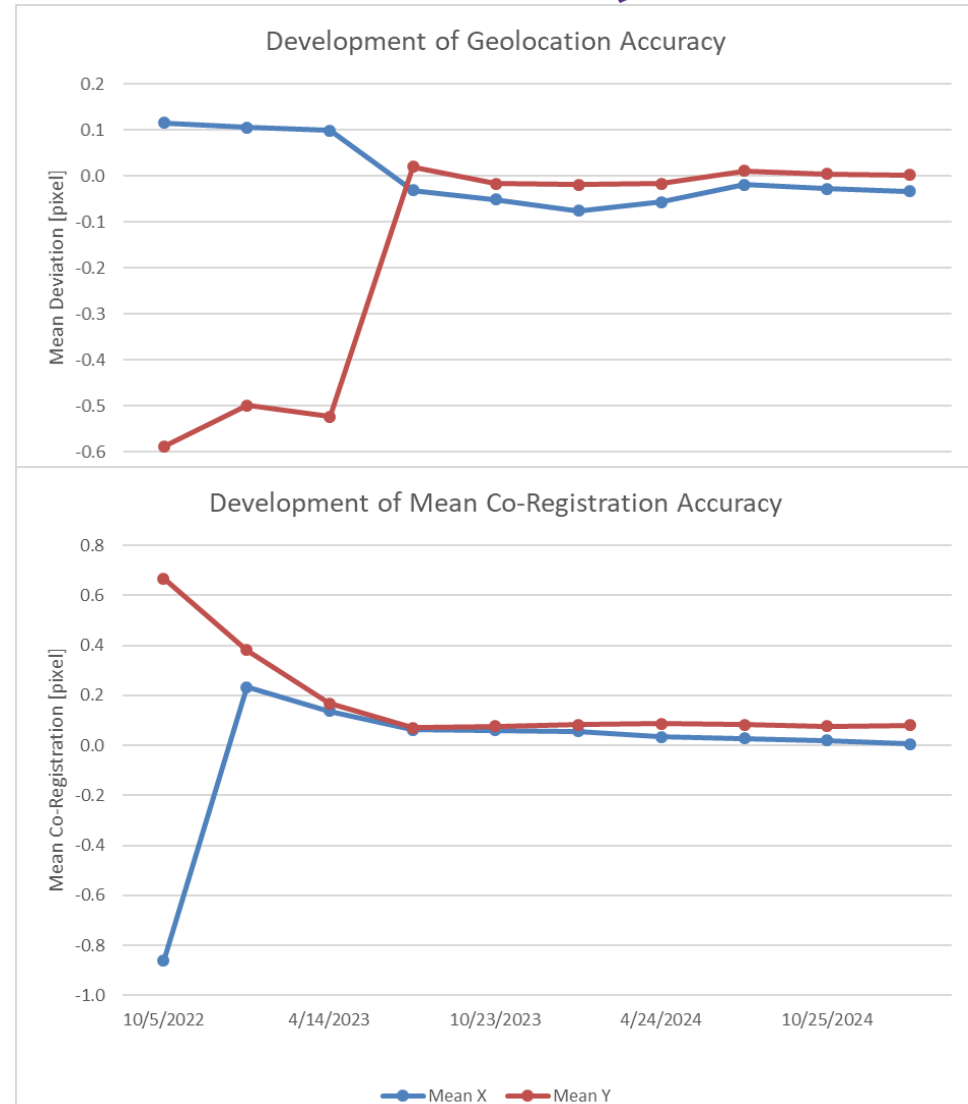
Geometrical performance



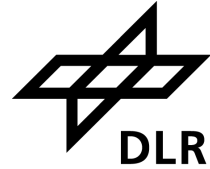
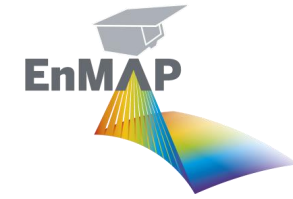
Highlight: Excellent geolocation and co-registration accuracies

Actions / results:

- Detailed analysis led to fix of attitude processing (Aug 2022)
- Boresight calibration (Sep 2022) and geometric calibrations (Nov 2022, Feb 2023) performed
- Bug fixes in processor versions V01.02.00 (Mar 2023) and V01.03.01 (May 2023)
- Excellent geometrical performance since May 2023:
 - Geolocation: RMSE ~ 0.4–0.5 px (req: 1 px)
 - Co-registration: RMSE ~ 0.1 px (req: 0.2 px)
- Reprocessing of past L0 products finished, users should make sure that „archivedVersion“ >= V01.03.01 to get best possible geometrical performance



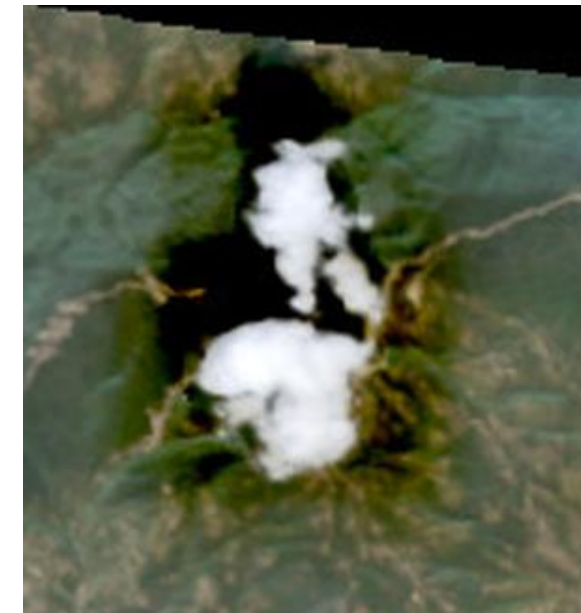
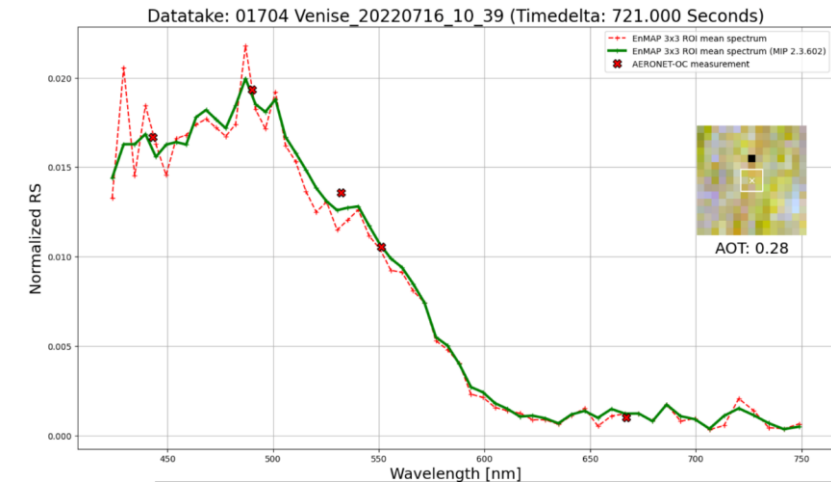
Atmospheric correction



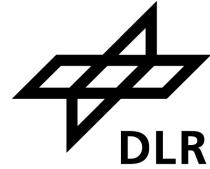
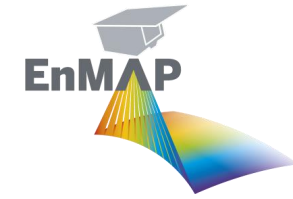
Highlight: Fixing of small inconsistencies in L2A products reported by users

Actions / results:

- Fixed high reflectance in blue (processor version V01.03.03, Jul 2023) and features at 590 nm and 647 nm (V01.04.01, Jan 2024) in snow spectra
- Re-activated adjacency correction (V01.04.00, Sep 2023) and fixed spectral noise below 500 nm (V01.04.02, Mar 2024) in water spectra
- Fixed adjacency correction artifacts around clouds (V01.05.00, Sep 2024) and reflectance differences between tiles (V01.05.02, Dec 2024) in land spectra
- Users may simply re-order their products from the catalog to benefit from improvements



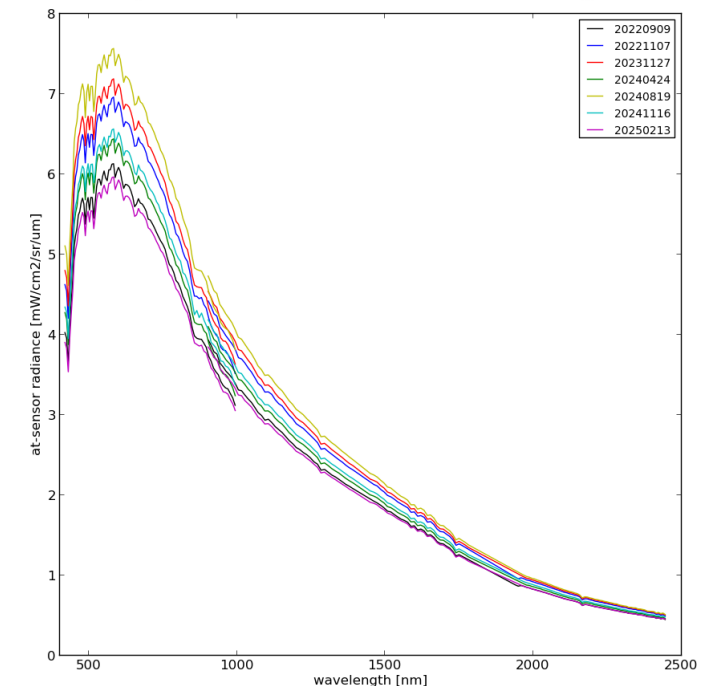
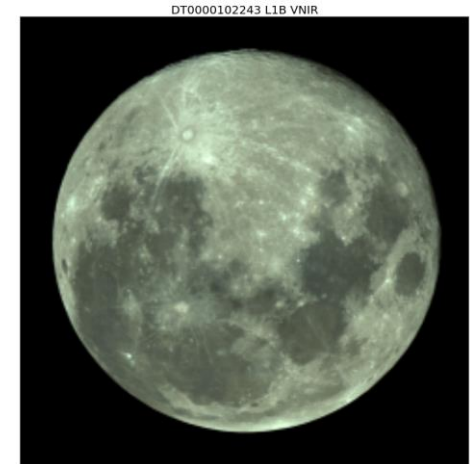
Moon observations



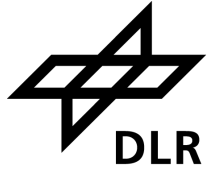
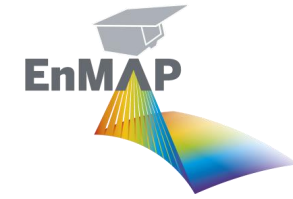
Highlight: Regular Moon observations for calibration purposes

Actions / results:

- Seven Moon observations acquired since launch and commitment to perform frequent observations
- Moon data used for analysis of straylight, dark signal and VNIR/SWIR mismatch
- Mid-term goal to use Moon data for alternative radiometric validation and Sun diffuser monitoring with help of lunar model experts
- Moon is complementary calibration target useful for monitoring and provides back-up to Sun calibrations if ever needed for a mission extension

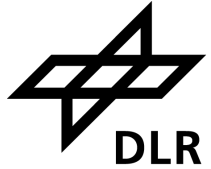
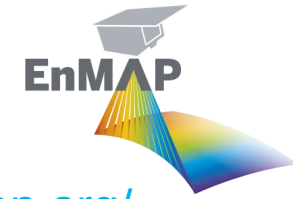


Outlook: 3 years in space



- After 3 years in space, EnMAP passed mid nominal life and enters mature phase with deep knowledge of instrument performance.
- EnMAP data products delivered to users meet all requirements and in some cases exceed expectations.
- Continuous improvements and user feedback ensure high quality of EnMAP data.
- All in-orbit calibration facilities and both VNIR and SWIR instruments working nominally and stable.
- We expect to operate EnMAP for many years and count with your user feedback!

A word to EnMAP users



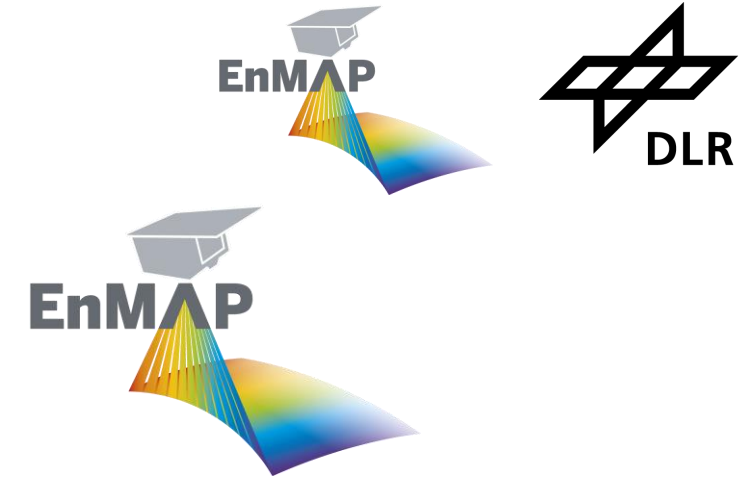
<https://www.enmap.org/>

- Lots of information can be found directly on the website:
 - Processor change log
 - Frequently Asked Questions (FAQ)
 - Product specification
 - ATBDs
 - Mission Quarterly Reports (MQR)
- Your feedback on EnMAP data is important and welcome.
- Thank you for helping improve EnMAP products!

The screenshot displays the EnMAP website interface. The top navigation bar includes 'Home', 'Data & Access', and 'Mission'. The 'Data & Access' section on the left lists 'Data Access Portal', 'SCREENCASTS' (with links for registration, proposals, planning, and data search), and 'RELATED DOCUMENTS'. The 'Mission' section on the right includes 'Organization', 'Space Segment', 'Ground Segment', 'Mission Exploitation Program', 'RELATED DOCUMENTS', 'GROUND TRACKS', and 'QUARTERLY REPORTS'. Red boxes highlight the following elements:

- Processor change log (under RELATED DOCUMENTS in Data & Access)
- FAQ (under RELATED DOCUMENTS in Data & Access)
- Level 1B, Level 1C, Level 2A Product Specification (under RELATED DOCUMENTS in Data & Access)
- Level 1B, Level 1C, Level 2A land, and Level 2A water (under ALGORITHM THEORETICAL BASELINE DOCUMENTS in Data & Access)
- 09 (01.07.2024-30.09.2024), 08 (01.04.2024-30.06.2024), 07 (01.01.2024-31.03.2024), 06 (01.10.2023-31.12.2023), and 05 (01.07.2023-30.09.2023) (under QUARTERLY REPORTS in Mission)

Acknowledgements



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Useful links:

- Tasking orders and catalog browsing:
<https://planning.enmap.org/>
- Mission quarterly reports:
<https://www.enmap.org/mission/>
- ICDs, ATBDs, FAQ, change log:
https://www.enmap.org/data_access/

<https://www.enmap.org/>

