Status of EnMAP processor and calibration activities

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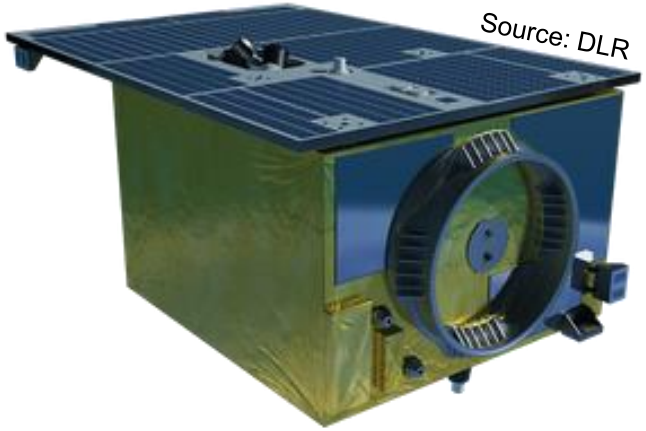
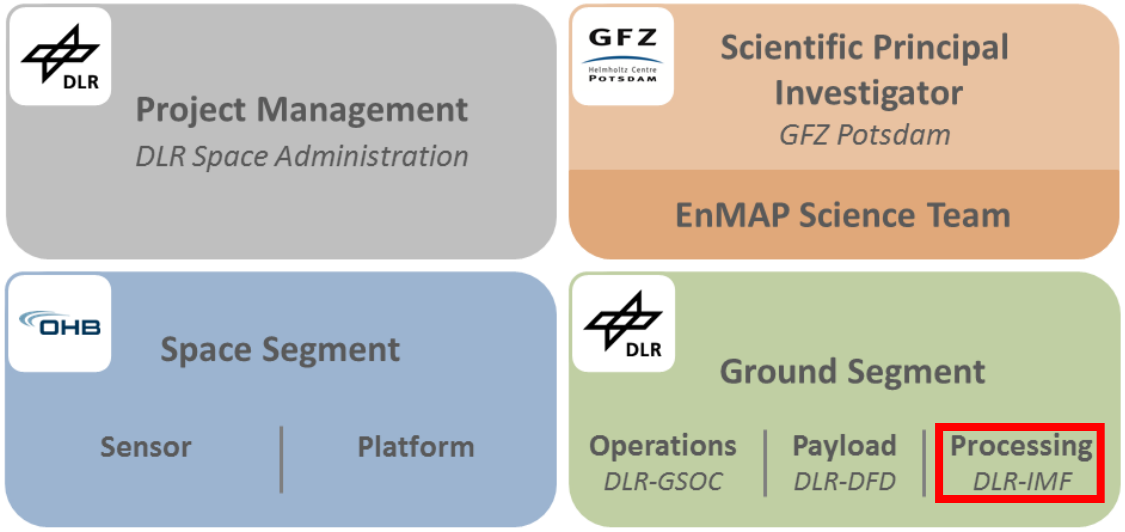
EnMAP mission: processing and calibration

https://www.enmap.org/





GS / processing and calibration:

- processor development
- in-flight calibration*
- data quality control
- instrument monitoring

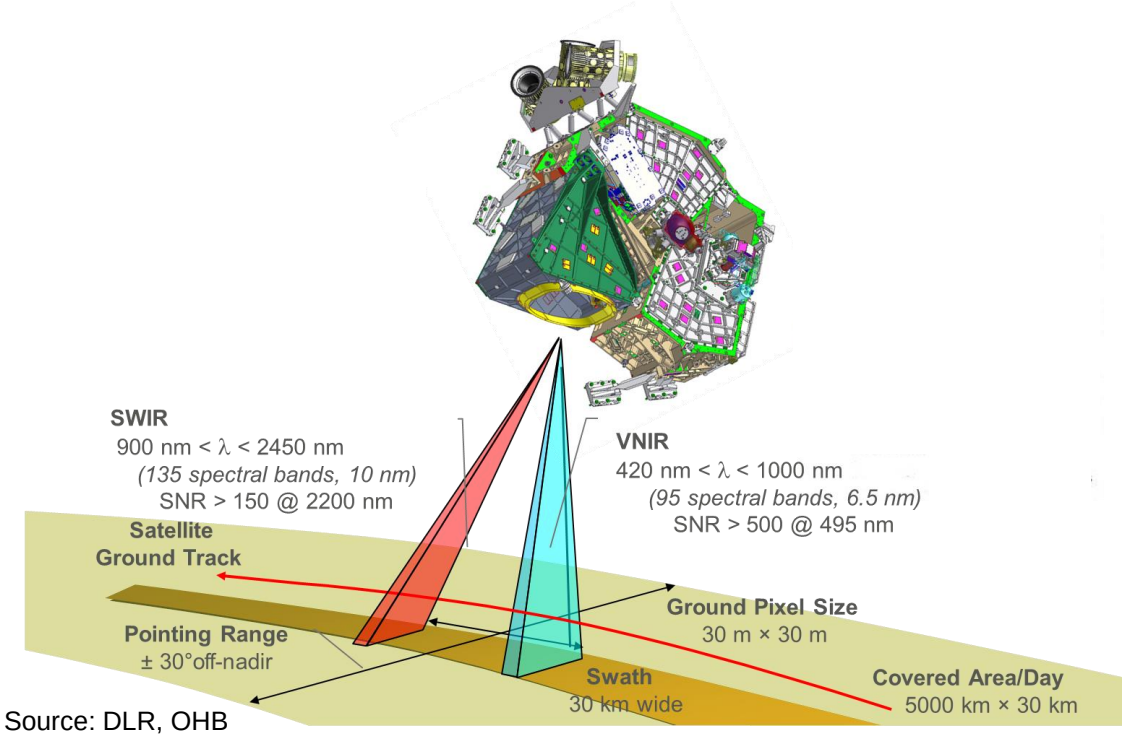
* see next talk by David Marshall Ingram

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 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	
L2A AOT, 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	

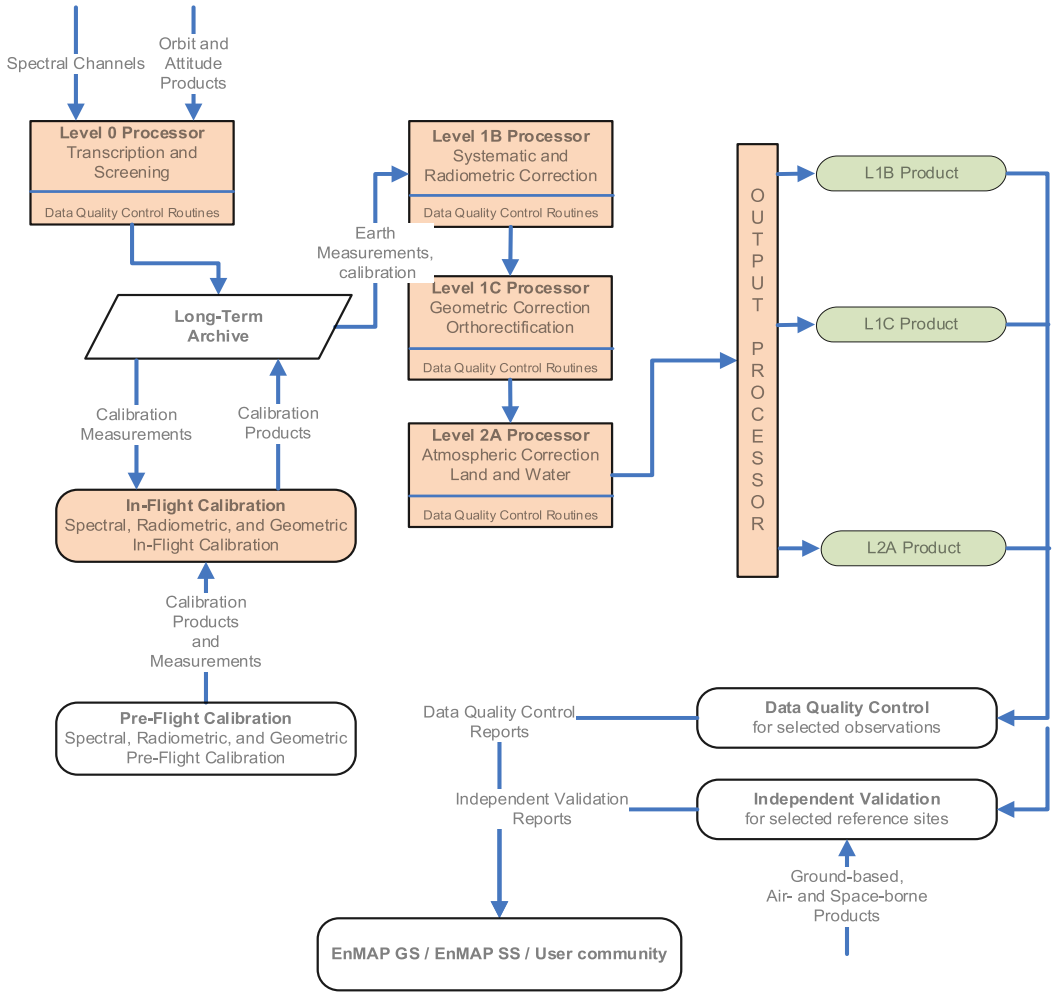
In-orbit calibration type	Mechanism	Frequency
Relative radiometric (lamp)	white spectralon	4x / month
Absolute radiometric (Sun)	Sun diffuser	1x / 2 months
Spectral	doped spectralon	2x / month
Linearity	focal plane LEDs	1x / month
Deep space	dark sky	1x / month
Dark frames	closed shutter	before/after imaging



Source: DLR, OHB

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
- L2A land CEOS CARD4L compliant (threshold)
- Official EnMAP products fullfil strict mission requirements that are validated extensively



Tasking orders and catalog browsing: https://planning.enmap.org/
Mission quarterly reports: https://www.enmap.org/mission/
Product specification, ATBDs, FAQ: https://www.enmap.org/data_access/

EnMAP processing and calibration: operations

Status of routine operations (since launch on 01.04.2022 and as of 28.03.2024):

- 177 calibration datatakes tasked, acquired, processed and analysed
- 71 calibration tables generated
- 63008 Earth tiles / 9006 datatakes processed (re-processing of datatakes before Aug 2023 ongoing)
- 3 Moon observations tasked, acquired and processed (internal use only, committment to perform yearly observations)
- 23 processor versions with updates and improvements
- 5-6 internal reports every quarter and contribution to mission quarterly reports

EnMAP processing and calibration: operations

Challenges and improvements (after end commissioning in Nov 2022):

▪ VNIR degradation*	**solved**	identified during commissioning
▪ L1B striping	**solved / in progress**	
▪ L1C geolocation accuracy and VNIR/SWIR co-registration	**solved**	
▪ VNIR/SWIR mismatch in overlapping spectral range*	**in progress**	identified during operations
▪ SWIR band configuration update	**solved**	
▪ L2A snow spectra	**solved**	
▪ L2A water spectra	**solved**	
▪ Sun calibration frequency	**solved**	

* see next talk by David Marshall Ingram

L1B striping

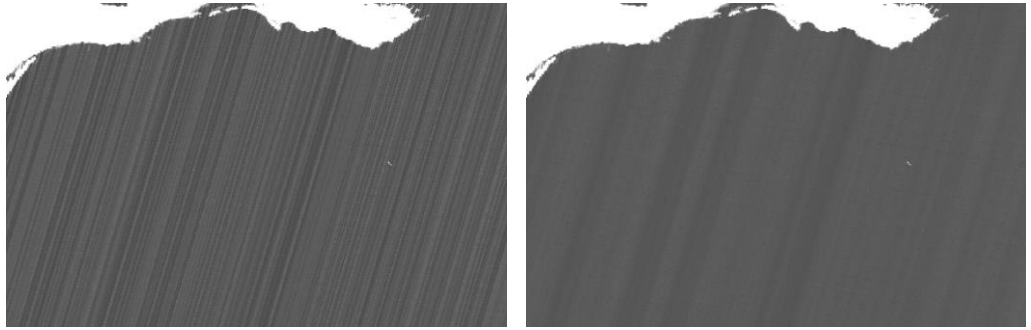
Challenge: Striping in L1B products below requirements but visible and important for users

Actions / results:

- In-depth analysis of striping and comparison of different destriping algorithms
- Calibration-based destriping not possible, so statistics-based algorithm (by GFZ) selected for implementation
- Across-track destriping implemented in processor version V01.02.00 (Mar 2023)
- SWIR along-track striping due to microvibrations under investigation

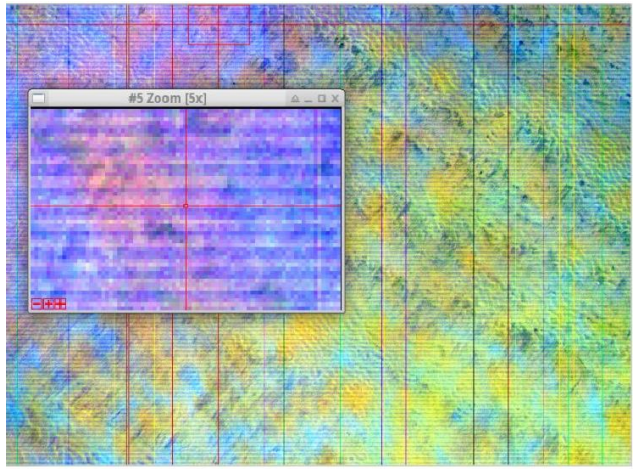
Conclusion: solved / in progress

Across-track striping
(VNIR and SWIR, all bands)



before after

Along-track striping
(SWIR, bands with high spectral slope)



L1C geolocation accuracy and VNIR/SWIR co-registration

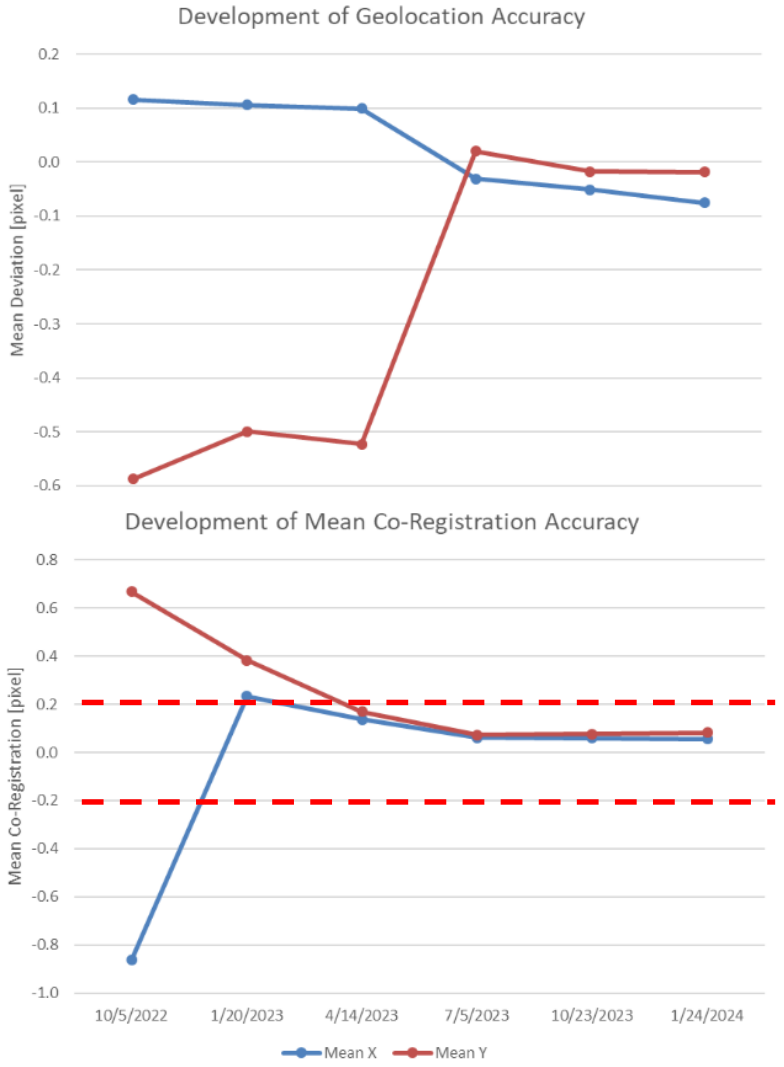
[Mission Quarterly Report #06]

Challenge: Geolocation errors below requirements but not optimal, co-registration errors above requirements

Actions / results:

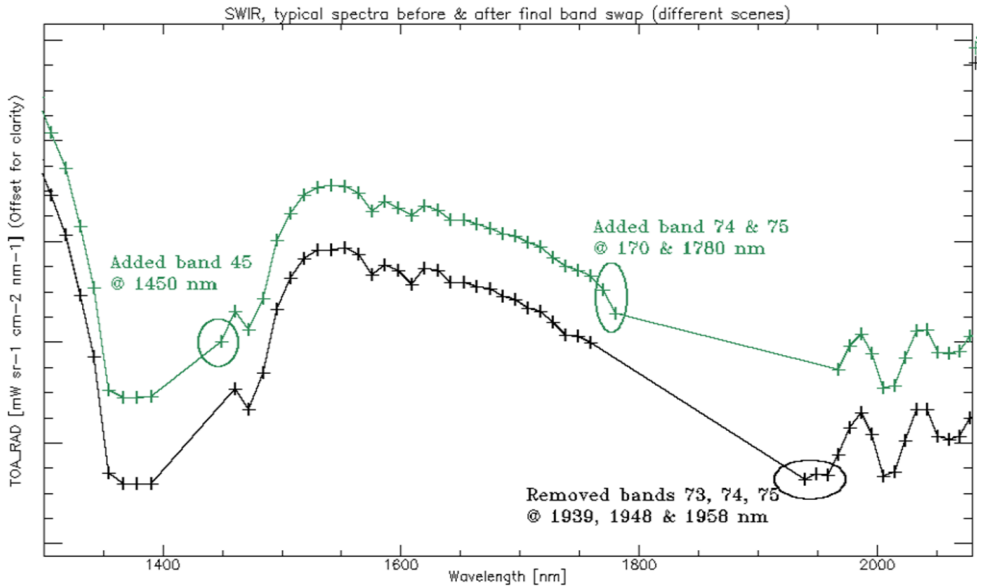
- Detailed analysis led to fix of attitude processing (Aug 2022)
- Boresight calibration (Sep 2022) and geometric calibrations (Nov 2022, Feb 2023) performed
- Bug fixes in processor versions V01.02.00 (Mar 2023) and V01.03.01 (May 2023)
- Current geolocation errors: -0.05 pix (req: 1 pix)
- Current co-registration errors: -0.07 pix (req: 0.2 pix)
- Reprocessing of past L0 products ongoing, users should make sure that „archivedVersion“ >= V01.03.01

Conclusion: solved



SWIR band configuration update

[Mission Quarterly Report #05]



Challenge: Science Segment requested change of SWIR transmitted bands in view of geological applications

Actions / results:

- GS and OHB commanded SWIR band change successfully:
  - Before 05.07.2023: 1939, 1949 and 1958 nm
  - After 05.07.2023: 1450, 1767 and 1782 nm
- Change checked by quality control with the help of pixel defects in introduced SWIR bands
- Users should always rely on product metadata to find band wavelengths

Conclusion: solved

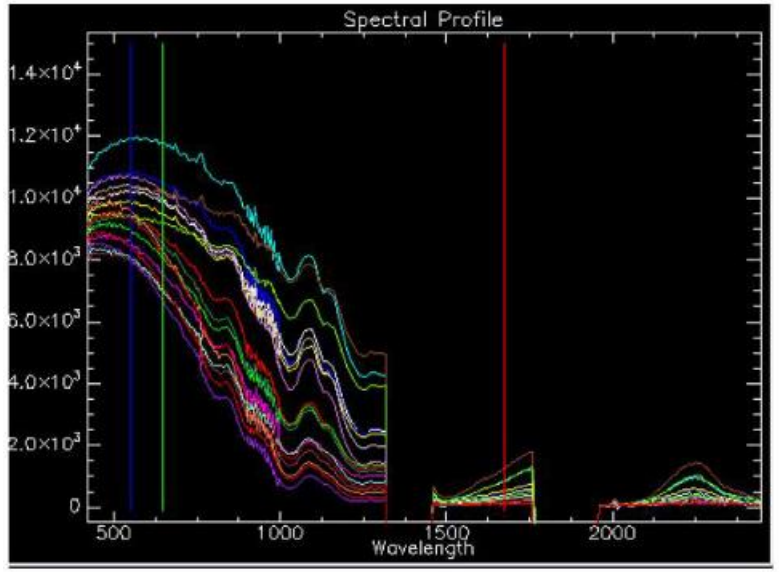
L2A snow spectra

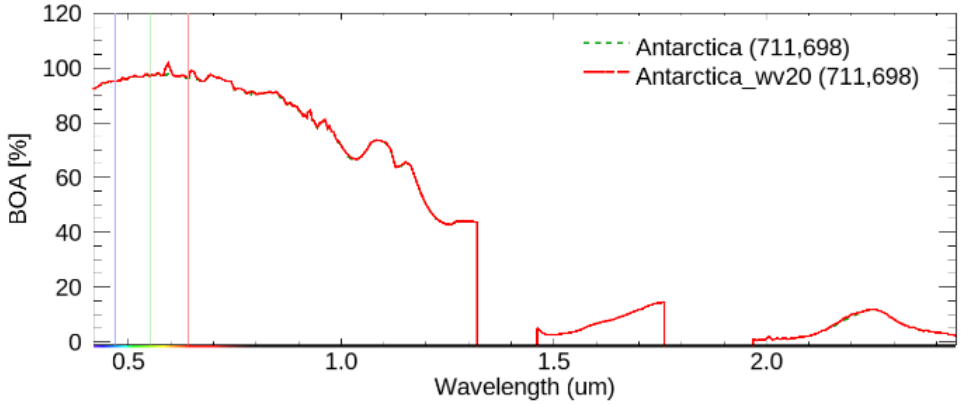
Challenge: Inconsistencies in L2A snow spectra reported by users

Actions / results:

- High reflectance at blue wavelengths due to misclassification of snow as cirrus, fixed in processor version V01.03.03 (Jul 2023)
- Features at 590 nm and 647 nm due to coarse water vapour correction, fixed in processor version V01.04.01 (Dec 2023)
- Both fixes validated by quality control
- Users may simply re-order their products to benefit from improvements

Conclusion: solved





L2A water spectra

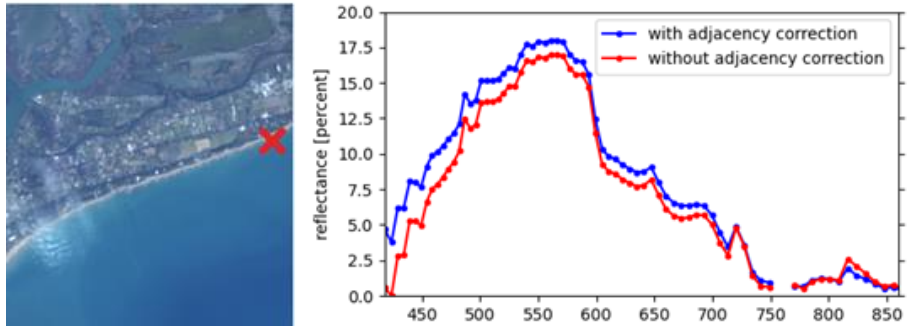
[Mission Quarterly Report #04]

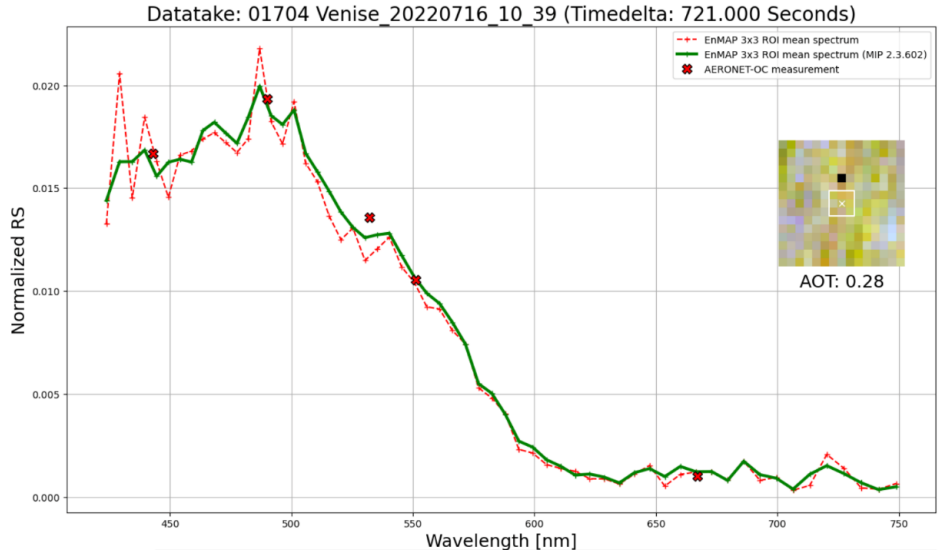
Challenge: Inconsistencies in L2A water spectra reported by users

Actions / results:

- Adjacency correction was unintentionally turned off in the MIP software since Nov 2022 and re-activated in processor version V01.04.00 (Sep 2023)
- Spectral noise below 500 nm due to sampling used in MIP for water look-up tables, fixed in processor version V01.04.02 (Mar 2024)
- Users may simply re-order their products to benefit from improvements

Conclusion: solved





Sun calibration frequency

Challenge: Current frequency of Sun calibrations may limit mission lifetime

Actions / results:

- Impact analysis of reduction of Sun calibration frequency on radiometric coefficients
- Mission decision: starting in April 2024, Sun calibrations are performed once every 2 months (instead of monthly)
- Radiometric stability requirement (2.5%) is not violated

Conclusion: solved

[Mission Quarterly Report #06]

Life-Limited Item	01.10.2023 to 31.12.2023	until 31.12.2023	Estimated total usage
Fuel	+0.6 kg	5.1 kg	>15 years
Battery and Solar Cells	nominal	nominal	nominal
Shutter Usage (*)	+1,12%	8,73%	20 years (@ daily use)
FAD movements (*)	+2,00%	18,00%	8,6 years (@ monthly use)
Diffuser exposure (*) time based on sole measurement time	+3,33%	30,00%	5,3 years (@ monthly use)
Diffuser exposure (*) time based on real cyclogram duration	+3,96%	35,63%	4,5 years (@ monthly use)
On-Board Calibration Equipment Usage (*)	On-board calibration equipment:		
- OBCA SPC lamp 1	+1,00%	8,03%	19,3 years (@ biweekly use)
- OBCA RAD lamp 1/LED 1	+2,61%	14,35%	8 years (@ weekly use)
- FPA LEDs 1	+0,37%	4,12%	44,4 years (@ monthly use)

Conclusion

- Two years of processing and calibration activities have been successfully performed.
- The main issues affecting the quality of end-user products have been solved.
- Performance and capability enhancements have been implemented.
- There is still room for improving EnMAP products and user feedback is always welcome.
- Both VNIR and SWIR instruments are stable and expected to continue delivering high-quality data for the rest of the mission (and beyond).

Acknowledgements

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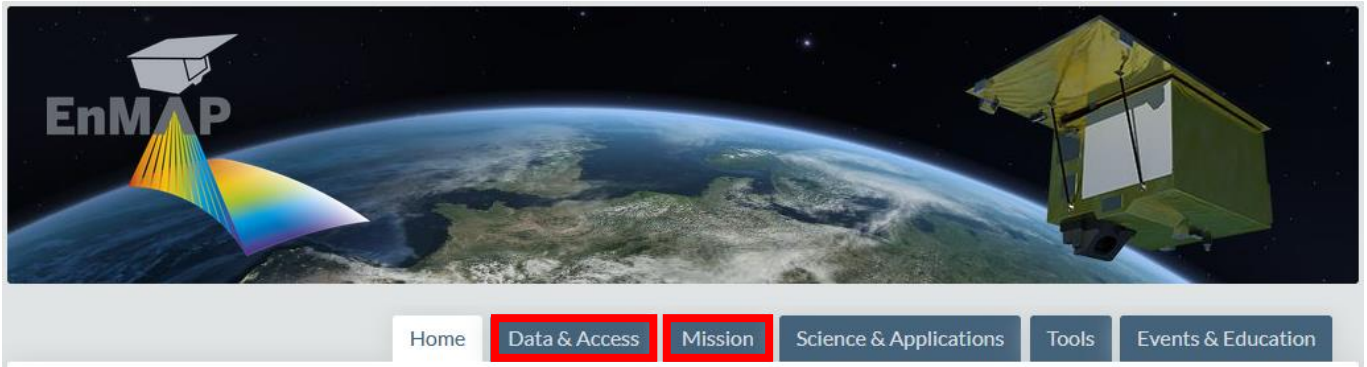

BACKUP SLIDES

EnMAP user feedback

- User feedback about EnMAP products is always welcome.
- Users may want to check the Frequently Asked Questions (FAQ):
  - Spectra noise pattern in VNIR/SWIR overlapping spectral range
  - EnMAP spectral response function
  - Radiance units of L1B products
  - Improvement of geometric accuracy and VNIR/SWIR co-registration
  - Different L2A processing modes
  - Definition of across-track and along-track off-nadir angles
  - Provision of view angles in LX metadata (ongoing)