Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

EnMAP Ground Segment

Mission Quarterly Report #07
01.01.2024 to 31.03.2024

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1 Introduction

1.1 Purpose

This mission quarterly report (MQR) states information on the EnMAP mission status with regard to the registered user community, announcements-of-opportunities and observations as well as the status of the user interfaces, satellite (platform and payload), ground stations (S-band and X-band), processor (Archive, Level 1B, Level 1C, Level 2A (land and water)), calibration (spectral, radiometric, geometric), data quality control and validation of EnMAP.

Please visit www.enmap.org for further information on EnMAP.

1.2 Scope

This seventh Mission Quarterly Report (MQR) applies to the operations of EnMAP in the reporting period of Routine Phase (RP) from **01.01.2024** to **31.03.2024 (Q1/2024)**.

2 References

Reference Identifier	Document Identifier and Title
[1]	L. Guanter et al. (2015) The EnMAP Spaceborne Imaging Spectroscopy Mission for Earth Observation. Remote Sensing, Issue 7, pp. 8830-8857.
[2]	EN-GS-UM-6020 Portals User Manual, Version 1.4
[3]	EN-PCV-ICD-2009 Product Specification, Version 1.8
[4]	EN-PCV-TN-4006 Level 1B ATBD, Version 1.7
[5]	EN-PCV-TN-5006 Level 1C ATBD, Version 1.6
[6]	EN-PCV-TN-6007 Level 2A (land) ATBD, Version 2.2
[7]	EN-PCV-TN-6008 Level 2A (water) ATBD, Version 3.1
[8]	Chabrillat, S. et al. (2022) EnMAP Science Plan. EnMAP Technical Report, DOI: 10.48440/enmap.2022.001
[9]	Storch, T.; Honold, H.-P.; Chabrillat, et al. The EnMAP imaging spectroscopy mission towards operations. Remote Sens. Environ. 2023, 294, 113632. DOI: 10.1016/j.rse.2023.113632

Table 2-1 References

3 Terms, Definitions and Abbreviations

Terms, definitions and abbreviations for EnMAP are collected in a database which is publicly accessible via Internet on www.enmap.org.

An Earth observation of swath length $n \times 30$ km (and swath width 30 km) is separated into n tiles of size 30 km × 30 km.

4 Mission

4.1 Mission Objectives

The primary goal of EnMAP (Environmental Mapping and Analysis Program) is to measure, derive and analyze quantitative diagnostic parameters describing key processes on the Earth's surface [1].

During the mission operations, with the successful launch on 1st of April 2022 and an expected operational mission lifetime of at least 5 years, EnMAP will provide valuable information for various application fields comprising soil and geology, agriculture, forestry, urban areas, aquatic systems, ecosystem transitions.

4.2 Mission Description

The major elements of the EnMAP mission are the EnMAP Space Segment, built by OHB System AG and owned by the German Space Agency at DLR, the EnMAP Ground Segment built and operated by DLR institutes DFD, MF, RB, and the EnMAP User and Science Segment represented by GFZ. The project management of the EnMAP mission is responsibility of the German Space Agency at DLR.

The EnMAP Space Segment is composed of

- the platform providing power and thermal stability, orbit and attitude control, memory, S-band uplink/downlink for TM/TC data transmission/reception, X-band downlink for payload data transmission, and
- the payload realized as a pushbroom imaging dual-spectrometer covering the wavelength range between 420 nm and 2450 nm with a nominal spectral resolution ≤ 10 nm and allows in combination with a high radiometric resolution and stability to measure subtle reflectance changes.

The EnMAP satellite is operated on a sun-synchronous repeat orbit to observe any location on the globe with comparable illumination conditions. This allows a maximum reflected solar input radiance at the sensor with an acceptable risk for cloud coverage.

The EnMAP Ground Segment is the interface between Space Segment and User and Science Segment. It comprises functionalities to

- perform planning of imaging, communication and orbit maneuver operations, provision of orbit and attitude data, command and control of the satellite, ground station networks (in particular: Weilheim, Germany, for S-band and Neustrelitz, Germany, for X-Band), receive satellite data, perform long-term archiving and delivery of products, and
- perform processing chain (for systematic and radiometric correction, orthorectification, atmospheric compensation), instrument calibration operations, and the data quality control of the products.

The EnMAP mission interfaces to the international science and user community through the EnMAP Portal www.enmap.org with official information related to EnMAP by DLR and GFZ-Potsdam (as the document in hand) and links for ordering observations and products.

The EnMAP Science Segment is represented by the EnMAP Science Advisory Group chaired by the mission principal investigator at the GFZ-Potsdam. The Science Segment addresses aspects such as

- supporting and performing validation activities to improve sensor performance and product quality
- developing scientific and application research to fully exploit the scientific potential of EnMAP [8] including provision of software tools for EnMAP data processing and analyses (EnMAP-Box) and provision of teaching and education materials (HYPERedu)
- Organizing workshops, summer schools and in general information, training and networking activities for the user community

The EnMAP User Segment is the community of German and international users ordering acquisitions and accessing products of EnMAP.

4.3 Mission Status Summary

The mission successfully finished the commissioning phase (CP) on 01.11.2022 [9] and entered its routine phase (RP) on 02.11.2022. In the reporting period between 01.01.2024 and 31.03.2024 there have been no major issues affecting the instrument or the satellite. The mission has been operating normally with only one minor outage of few hours on 24.01.2024 due to a DSHA reset. There have been no further issues with the thermal control system of the instrument after a software update was performed January 24. This problem caused in Q3 2023 the loss of 23 days of data acquisition during two outages. Like in previous quarter, the mission is regularly reaching, even surpassing, the maximum acquisition capacity of 5000 km / day.

In this period, 1620 Earth observations of 30 km swath width and up to 990 km swath length were successfully performed which resulted in 16707 archived Earth observation tiles of 30 km × 30 km and 26 calibration acquisitions. In addition, 17843 products were delivered from catalog orders. In total, 9274 Earth observations were performed until 31.03.2024 by the EnMAP team and the 2126 registered Science users. This results in 63747 archived Earth observation tiles (84734 including re-processed products with different versions) and 112261 Earth products delivered to users from observations requests (61284) and catalogue orders (50977) since the start of the mission. More details are presented in Section 5 and 6.

The following limitations are applicable at 31.03.2024:

- Some striping effects in SWIR data in the along-track direction more visible in uniform areas with a strong spectral gradient.
- Between 21 and 25 February the maximum limit of requests was reached again in the planning system, causing a delay for new requests to enter the system. Acquisition requests were buffered during this period and resubmitted at a later time, but some of them could have exceeded their validity time window at the time of being considered, what leads to their cancellation.

Other effects observed in the data by our Quality Control team are reported in section 7.6 while they are investigated in more detail.

The following changes were implemented in the reporting period:

- Processing software update (**V01.04.02**), with new version of the MIP program for L2A-water processing that will improve/solve the following aspects:
  - Reduce spectral peaks in the reflectance spectra around Fraunhofer lines in L2A water products
  - Water turbidity option correctly interpreted
  - Issue with glint-band values in L2A water products
- Default off-nadir angle range to command new acquisitions is changed from ±30° to ±15°. Users are free to change the value to the old range if necessary, but this reduction will help to reduce the number of conflicting orders in case the user does not modify the default value.
- Re-processing of archived products is in progress. Priority processing is now assigned to the oldest data (commissioning phase). On these data the co-registration errors are larger, what makes the re-processing of the data more necessary for them. Reprocessed products can be identified with **archived version ≥ 01.03.01** in the EnMAP archive. Re-processed products benefit from improved co-registration accuracy, improved absolute geometric performance and addition of VC-AUX products for improved data screening. The re-processing will continue over the coming months. For more details on geometric performance check Section 7.6.3.
- Announcement of priority observations, Foreground Mission, in the EnMAP web site (https://www.enmap.org/data_tools/foreground_mission/).

The following changes are expected to be performed in the next quarters:

- Correction of radiometric striping in the along-track direction.
- Continue re-processing of archived data (see note above concerning re-processed data improvements).

- Implementation of back-to-back imaging what shall reduce in certain circumstances the minimum distance between consecutive acquisitions.
- Implementation of new measures to improve planning and acquisition activities.
- Implementation of new linearity calibration (and updated calibration) to improve the VNIR-SWIR matching between spectrometers, specially at low radiances

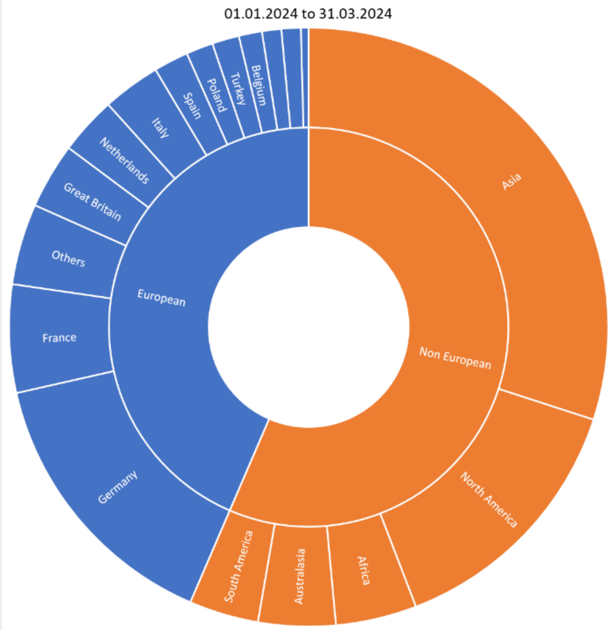
5 Users and Announcements-of-Opportunities

5.1 Users

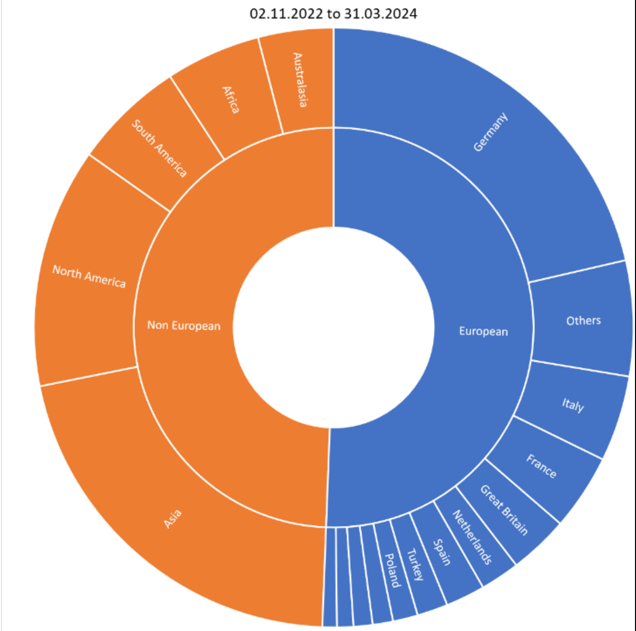
	Country/*Continent (No of Countries)*	Reporting Period 01.01.2024 to 31.03.2024	Since beginning of routine Phase until 31.03.2024 (end of reporting period)
Total European Users	*Europe (21)*	209	1431
European	• Germany	72	605
	• Italy	15	131
	• France	28	116
	• Great Britain	17	91
	• Spain	9	60
	• Netherlands	15	60
	• Portugal	2	25
	• Turkey	7	47
	• Greece	5	31
	• Belgium	6	29
	• Poland	7	38
	• Austria	5	22
	• Others (9)	21	176
Non European	*North America (2)*	68	366
	South America (5)	18	170
	Asia (16)	144	601
	Africa (8)	21	145
	Australia + New Zealand (2)	20	115
	Total (54)	480	2828
	*Rejected**	2	9

Table 5-1 Number of registered users per continent **(number of user countries during reporting period)**

*Users are rejected because of, e.g. EU sanction list checks, data policy or license violations.



Reporting Period 01.01.2024 to 31.03.2024 with a total of 480 Users of 54 different countries.



Since beginning of operational phase until 31.03.2024 (end of reporting period) with total of 2828 Users of 88 different countries.

Figure 5-1 Number of registered users per country

Registered users belong to different categories, therefore e.g. All/World ≠ Science/World + Others/World.

User per Category		New within reporting period 01.01.2024 to 31.03.2024	Since beginning of routine phase start until 31.03.2024 (end of reporting period)
Registered users	Total	480	2828
	with role assignment*	361	2126
Cat-1 Science	Total	284	1694
	AO Process 00001	284	1589
	AO Process 00002	6	621
	AO Process 00003	2	196
Cat-1 Distributor**	Total	283	1628

Table 5-2 Number of registered users per category (Cat-1 Science and Cat-1 Distributor)

*Registered users with at least one user role assignment

**Catalogue User, ordering EnMAP data from archive

5.2 Announcements-of-Opportunities

Announcement-of-Opportunity	New within reporting period 01.01.2024 to 31.03.2024			Since beginning of routine Phase until 31.03.2024 (end of reporting period)		
	Proposals	Total tiles requested	Total tiles granted	Proposals	Total tiles requested	Total tiles granted
A00001	47	3083	835	353	24349	13352
A00002	0	0	0	123	20430	9339
A00003	0	0	0	4	151	97
Total	57	3083	835	480	44930	22788

Table 5-3 Number of released science proposals per Announcement-of-Opportunity (AOs#) and total number of requested and granted tiles per AO#.

Icon	Topic	New within reporting period 01.01.2024 to 31.03.2024			Since beginning of routine Phase until 31.03.2024 (end of reporting period)		
		Proposal	Total tiles requested	Total tiles granted	Proposal	Total tiles requested	Total tiles granted
	VEGETATION	22	1849	457	192	24537	10743
	GEO/SOIL	8	186	86	144	5885	3803
	WATER	8	793	166	60	3817	2712
	SNOW/ICE	4	57	60	11	1913	758
	URBAN	0	0	0	8	774	307
	ATMOSPHERE	3	172	36	17	3076	1206
	HAZARD/RISK	0	0	0	9	283	241
	METHODS	0	0	0	13	937	537
	CAL/VAL	4	186	190	26	3708	2481
	Total	**49**	**3243**	**995**	**480**	**44930**	**22788**

Table 5-4 Number of accepted science proposals and total number of requested and granted tiles per topic

6 Archived and Delivered Observations

The following table shows the number of archived Earth Observation and Calibration products and their sizes within the specified time frames. Reason for "Archived = No" is that datatakes were commanded but no data arrived at the Processing System HSI.

Type	Archived		During reporting period 01.01.2024 to 31.03.2024		Since beginning of Commissioning Phase until 31.03.2024 (end of reporting period)	
			Number Tiles / Observations	Size (in GB)	Number Tiles / Observations	Size (in GB)
Earth Observation (EO)	Yes	Total	16707 / 1620	8140.78	84734 / 9274	41288.16
		Average / Day	183.59 / 17.80	89.45	115.91 / 12.68	56.48
	No	Total	16		874	
		Average / Day	0.17		1.19	
Calibration (CAL)	Yes	Total	26	108.56	260	1085.69
		Average / Day	0.28	1.19	0.35	1.48
	No	Total	0		2	
		Average / Day	0		0.002	

Table 6-1 Number and size of archived and not archived products

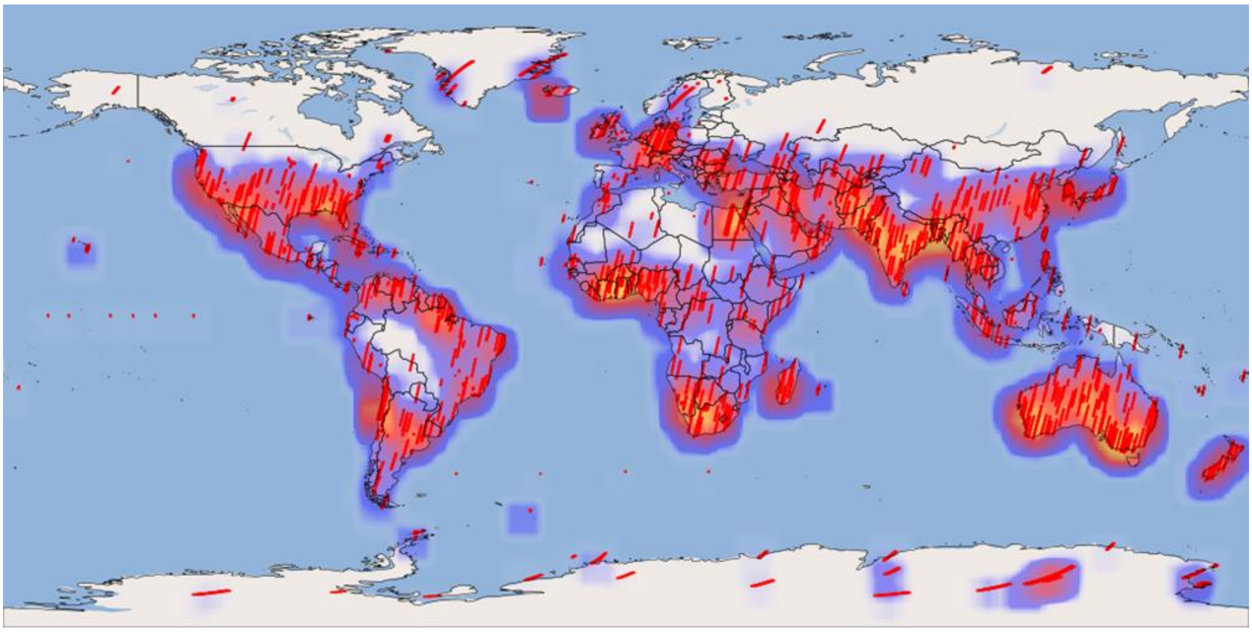
The following table shows the number of delivered products and their sizes within the specified time frames. Product deliveries result either directly from acquisition orders ("Observation") or catalog orders ("Archive").

Type	Delivered		During reporting period 01.01.2024 to 31.03.2024		Since beginning of Commissioning Phase until 31.03.2024 (end of reporting period)	
			Number Tiles / Observations	Size (in GB)	Number Tiles / Observations	Size (in GB)
Earth Observation (EO)	Observation	Total	16400 / 1247	7419.38	61284 / 6812	26723.93
		Average / Day	180.21 / 13.70	81.53	83.83 / 9.31	36.55
	Archive	Total	17843	104157.79	50977	282520.10
		Average / Day	196.07	1144.59	69.73	386.48
Calibration (CAL)	Observation	Total	26	115.60	149	657.00
		Average / Day	0.28	1.27	0.20	0.89
	Archive	Total	0	0	67	3486.14
		Average / Day	0.00	0	0.09	4.76

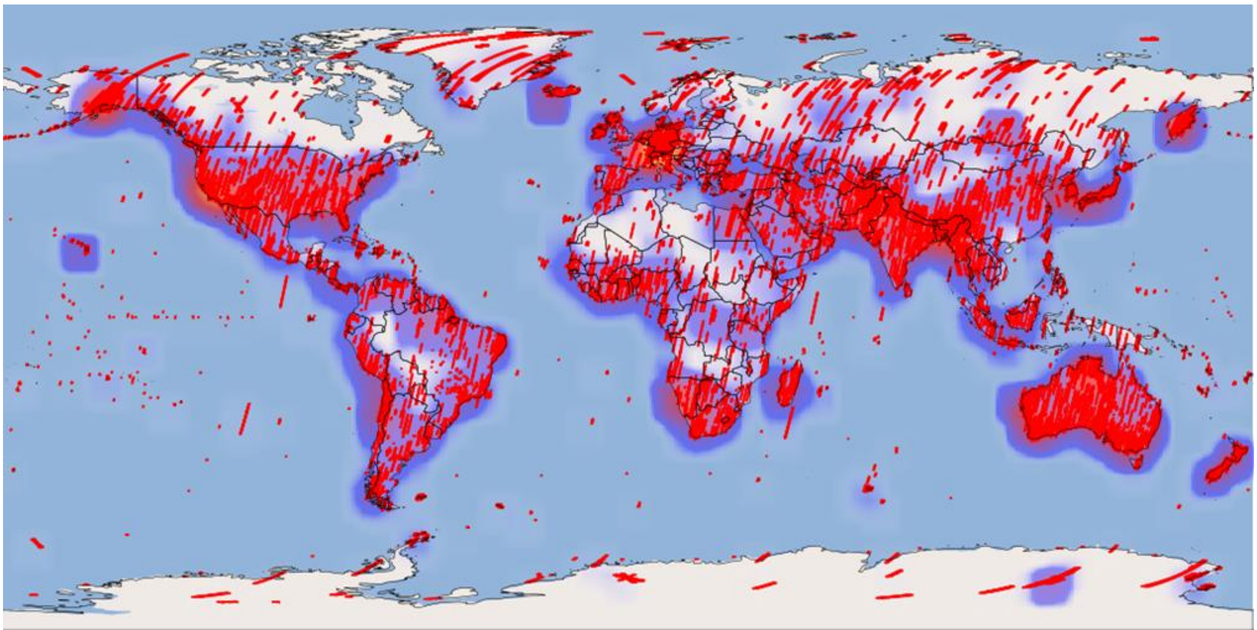
Table 6-2 Number and size of delivered products

6.1 Archived Observations

The following figures show the heatmaps for the whole world and for Europe within the specified time frames. The heatmaps represent the frequencies of products at a geographic location, where the number of products increases from blue over red to yellow.

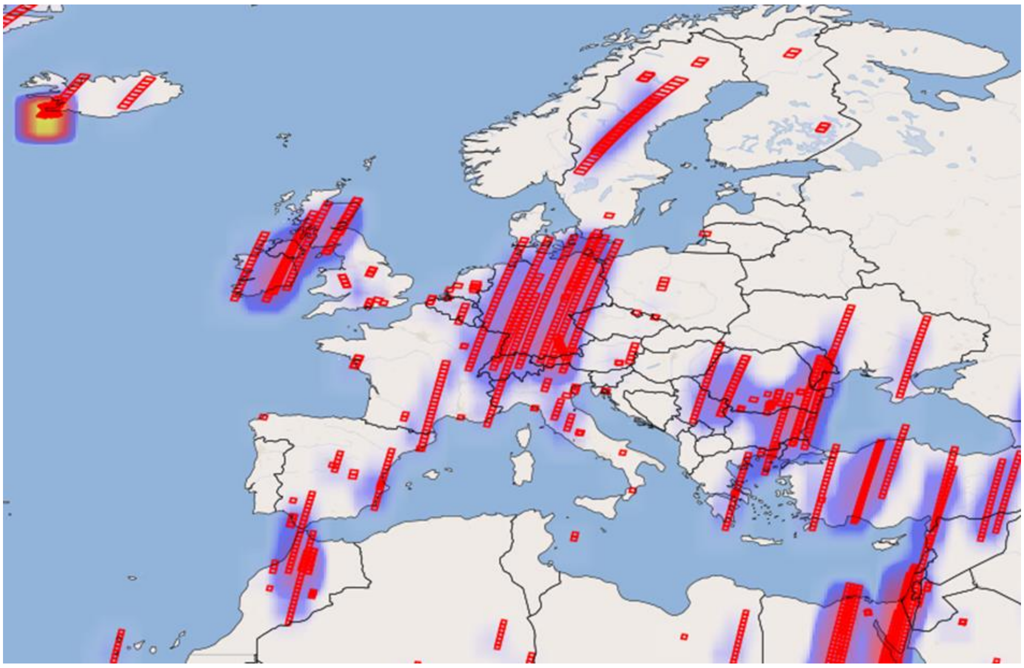


01.01.2024 to 31.03.2024 with 16707 tiles

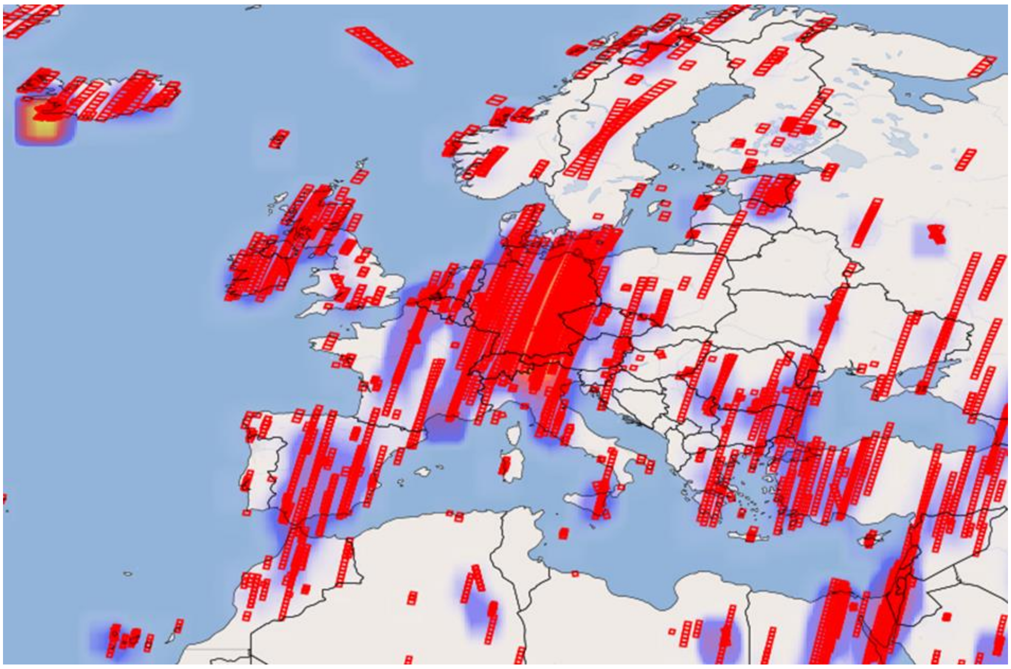


until 31.03.2024 with 84734 tiles (includes commissioning phase acquisitions)

Figure 6-1 Geographic location of all Earth observation tiles archived, World



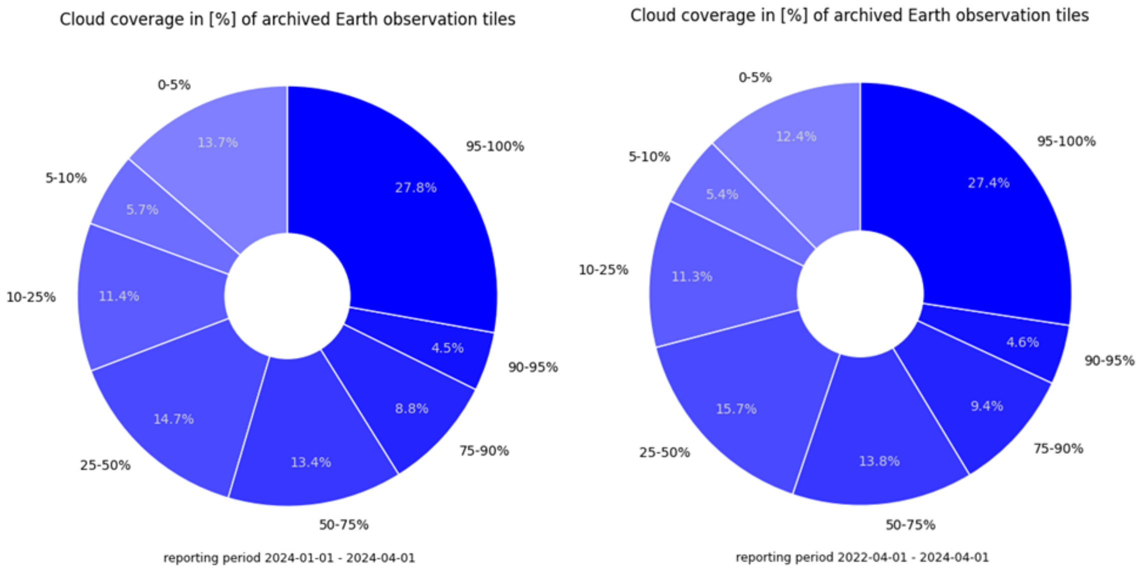
01.01.2024 to 31.03.2024



until 31.03.2024 (includes commissioning phase acquisitions)

Figure 6-2 Geographic location of all Earth observation tiles archived, Europe

The following figures show the distribution of cloud coverage for the archived products.

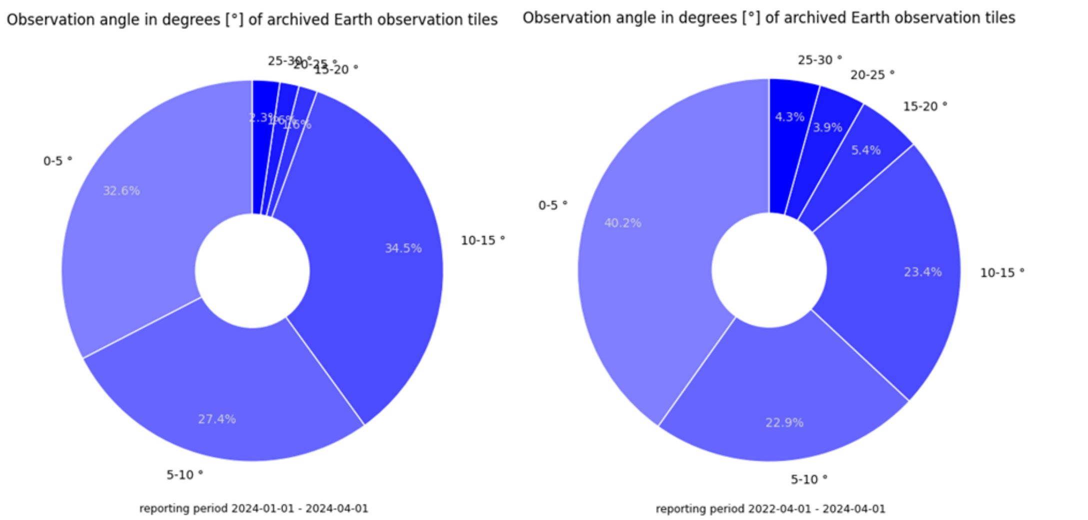


01.01.2024 to 31.03.2024 with 16707 tiles

until 31.03.2024 with 84734 tiles (includes commissioning)

Figure 6-3 Cloud coverage in [%] of archived Earth observation tiles

The following figures show the distribution of observation angles for the archived products.



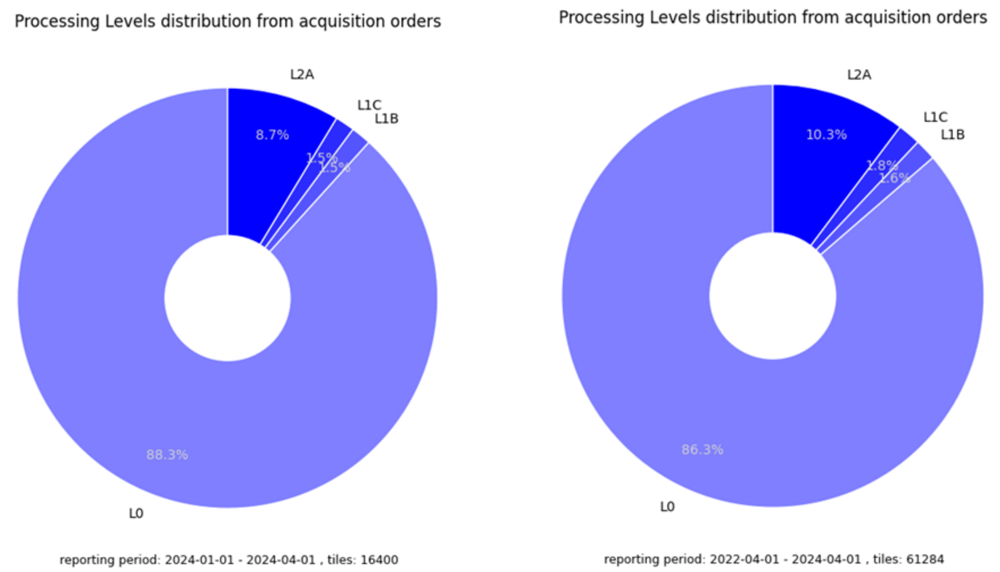
01.01.2024 to 31.03.2024 with 16707 tiles

until 31.12.2023 with 58548 tiles (includes commissioning)

Figure 6-4 Observation angle of archived Earth observation tiles

6.2 Delivered Observations

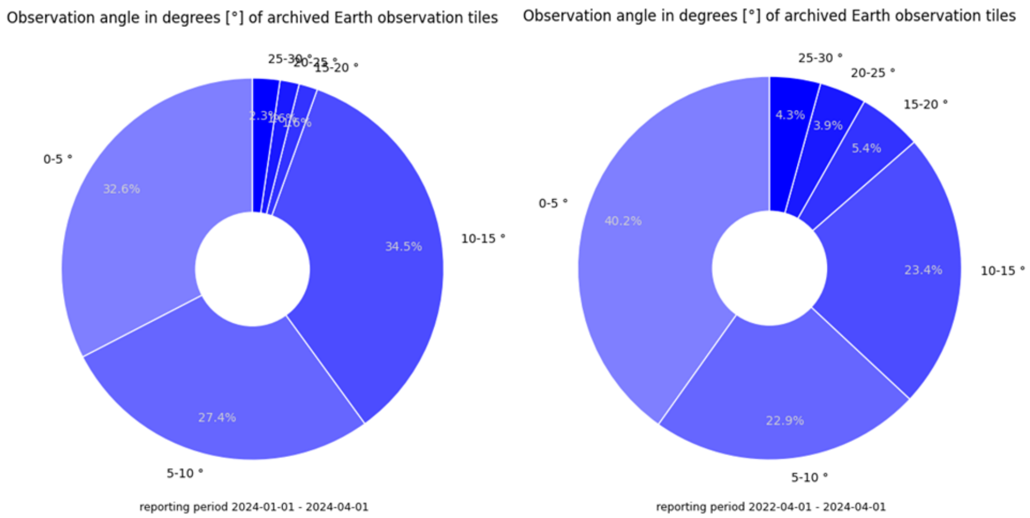
The following figures show the distribution of processing level of the delivered products from acquisition orders.



01.01.2024 to 31.03.2024 with 16400 tiles   until 31.03.2024 with 61284 tiles (includes commissioning)

Figure 6-5 Levels of delivered Earth observation tiles from acquisition orders

The following figures show the distribution of processing level and correction type (for L2A) of the delivered products from catalog orders.



01.01.2024 to 31.03.2024 with 17843 tiles   until 31.03.2024 with 50977 tiles (includes commissioning)

Figure 6-6 Levels of delivered Earth observation tiles from catalog orders

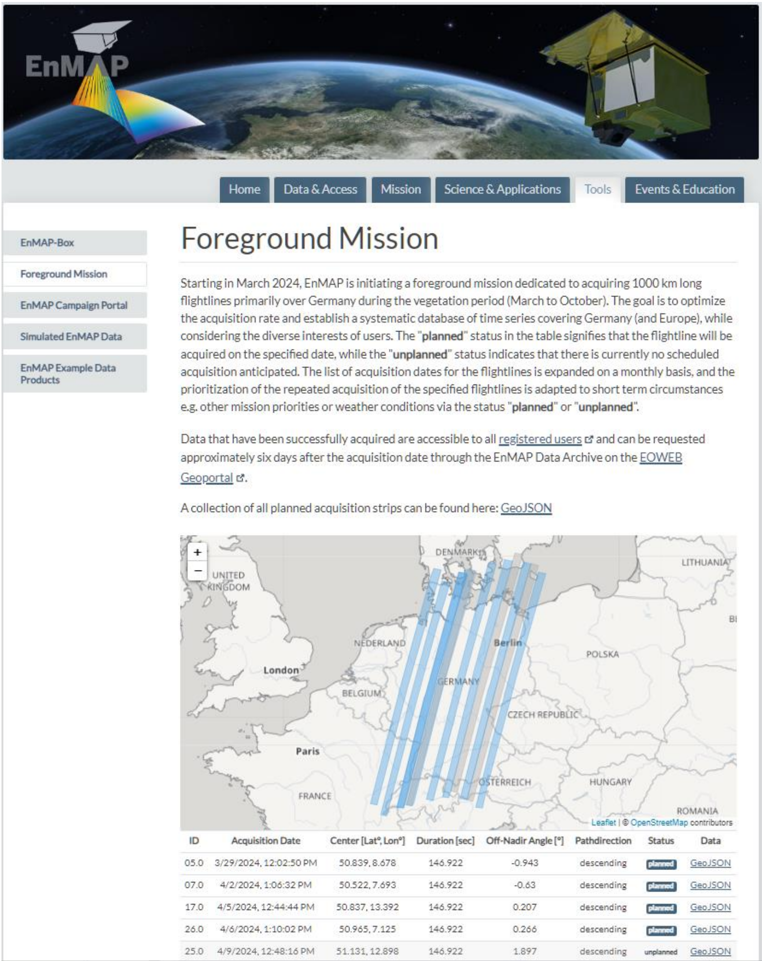
7 Detailed Status

7.1 User Interfaces

Further improvements to the user interfaces are continuously on-going and will be reported in this section.

During the reporting period the default value of the off-nadir angles for new observations was changed from ±30° to ±15°. Observations up to ±30° continue to be possible, but they are not the default value of the user interface

During the reporting period the Ground Segment of EnMAP has introduced a new tool that shows the schedule of future high priority observations of the EnMAP mission (*Foreground Mission*). The tool is available at the EnMAP web site under: https://www.enmap.org/data_tools/foreground_mission/



ID	Acquisition Date	Center [Lat°, Lon°]	Duration [sec]	Off-Nadir Angle [°]	Pathdirection	Status	Data
05.0	3/29/2024, 12:02:50 PM	50.839, 8.678	146.922	-0.943	descending	planned	GeoJSON
07.0	4/2/2024, 1:06:32 PM	50.522, 7.693	146.922	-0.63	descending	planned	GeoJSON
17.0	4/5/2024, 12:44:44 PM	50.837, 13.392	146.922	0.207	descending	planned	GeoJSON
26.0	4/6/2024, 1:10:02 PM	50.965, 7.125	146.922	0.266	descending	planned	GeoJSON
25.0	4/9/2024, 12:48:16 PM	51.131, 12.898	146.922	1.897	descending	unplanned	GeoJSON

Figure 7-1 Image of the Foreground mission tool available at the EnMAP web site. The map is interactive and the user can download a GeoJSON file with the planned acquisitions.

With this tool the users can get informed weeks in advance about future priority observations with EnMAP. Initially, a set of 10 flight-lines over Germany have been identified together with the user community and will be regularly scheduled (~8 of them per month) until Autumn 2024. Other priority observations at other locations will also be announced in the Foreground Mission page.

7.2 Satellite

No major satellite issues have been observed in the reporting period. There has been only a partial outage caused by the DSHA of the satellite that could be resolved with a reset and resulted just in a few hours outage on 24.01.2024. Since 01.02.2024 the software update introduced in January to prevent issues with the thermal control system of hyperspectral Instrument, is permanently installed. No further events like the two ones observed during Q3 2023 have been observed.

On the ground systems, the number of acquisition requests in the planning system continues to be relatively high what triggers the buffering of the excess of requests in the system. This mechanism prevents the saturation of the system, but can cause that tasking requests are buffered until they are considered for observation. During the reporting period this situation happened between 21 and 25 February 2024.

7.2.1 Orbit

The reference orbit is a Sun-synchronous polar orbit with a mean local time of descending node of 11:00 hrs and a repeat cycle of 398 revolutions in 27 days at an altitude of 643 km (lateral deviation of at most 22 km at equator and altitude deviation of at most 6 km).

During 2024 Q1, a total of 1988 ACS Precise Modes were executed onBoard, compared to 1179 during the previous quarter. The distribution of ACS Precise Modes during 2024 Q1 is shown in Figure 7-2. On average, the ACS performed 20.9 ACS Precise Modes per day with 17.0 related to Image Acquisitions (not included calibrations without ACS involvement) and 3.9 related to X-Band Downlinks per day. Over the whole mission, a total of 11436 ACS Precise Modes have been successfully executed. No collision avoidance maneuvers were required.

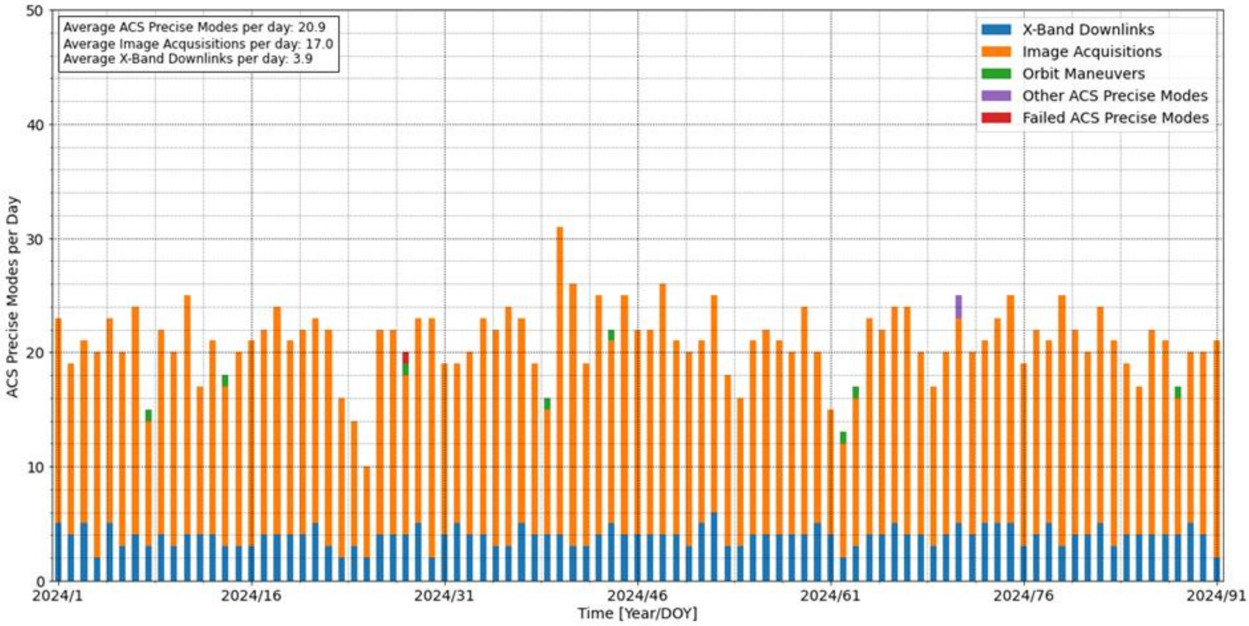


Figure 7-2 Number of ACS Precise Modes per day during 2024 Q1

7.2.2 Life Limited Items

Life-Limited Item	01.01.2024 to 31.03.2024	until 31.03.2024	Estimated total usage
Fuel	+0.9 kg	6.0 kg	>15 years
Battery and Solar Cells	nominal	nominal	nominal
Shutter Usage	+1,85%	10,59%	18,9 years (@ daily use)
FAD movements	+3,00%	21%	8,6 years (@ monthly use)
Diffuser exposure time based on sole measurement time	+5,00%	35,00%	5,3 years (@ monthly use)

Diffuser exposure time based on real cyclogram duration	+5,94%	41,60%	4,5 years (@ monthly use)
On-Board Calibration Equipment Usage	On-board calibration equipment:		
- OBCA SPC lamp 1	+1,41%	9,44%	19,3 years (@ biweekly use)
- OBCA RAD lamp 1/LED 1	+2,35%	16,70%	8,1 years (@ weekly use)
- FPA LEDs 1	+0,75%	4,87%	44,3 years (@ monthly use)

Table 7-1 Status of life-limited items

7.2.3 Redundancies

To date, the SWIR wavelength range is covered by SWIR-A (SWIR-B can be activated using a one-time switch mechanism).

All satellite subsystems are using nominal configurations.

7.3 Ground Stations

7.3.1 S-Band

S-Band Ground Stations	01.01.2024 to 31.03.2024		
	Total Passes	Non-Routine Passes (e.g. Anomaly Handling/SW Updates)	Failed Passes
All stations (Weilheim-Germany, Neustrelitz,-Germany, Inuvik,-Canada, O'Higgins-Antarctica, Svalbard-Norway)	549 (390 WHM, 152 INU)	7	6

Table 7-2 S-Band Ground Station Passes

7.3.2 X-Band

X-Band Ground Stations	01.01.2024 to 31.03.2024	
	Executed Passes	Successful Passes
All stations (Neustrelitz-Germany, Inuvik-Canada)	354 (239 NZ, 115 INU)	354 (239 NZ, 115 INU)

Table 7-3 X-Band Ground Station Passes

Inuvik (Canada) station is now part of the regular operations of the EnMAP Ground Segment for X-Band and S-Band downlinks. After integration, more data and more flexibility in S-band and X-band data reception is achieved, especially concerning image acquisitions over Europe..

7.4 Processors

Reference [3] provides the product specification and [4], [5], [6], [7] the algorithm theoretical basis for Level 1B, Level 1C and Level 2A (land / water).

In the reporting period (01.01.2024-31.03.2024) there was one processor update:

1. **Version 01.04.02 (01.03.2024, available to users on 16.03.2024)**

This version includes the following changes:

- Fixed problems in atmospheric correction over water, concerning spectral spikes, turbidity and sunglint.
- Fixed wrong background value in dead pixel mask.
- Changed format of citation entry as requested by Geoservice team.
- For Envi outputs (BSQ, BIP, BIL), the gain and offset values are now written to the HDR files.

The following limitations are applicable as of 31.03.2023:

- The SWIR-A compressor cooler produces a micro-vibration pattern of horizontal stripes on SWIR bands with strong spectral gradients. Still, all spectral and radiometric requirements are within the specification of the mission. The correction is implemented and being tested since V01.04.01, but not active by default.

The following changes are expected to be performed by 30.06.2024:

- Update of the linearity calibration to improve the matching between VNIR and SWIR spectrometers, specially at low radiance level.

7.5 Calibrations

Table 7-4 summarizes the radiometric calibration observations acquired in this quarter and which will be described in the rest of this section. The calibration acquisitions were generally acquired according to the routine operations plan.

Category	01.01.2024 to 31.03.2024	
	Number of Archived Observations	Size (in GB)
Total	26	117.2
Deep Space	3	3.9
Rel. Radiometric	9	35.1
Abs. Radiometric	3	3.9
Linearity	4	68
Spectral Calibration	7	6.3

Table 7-4 Number and size of archived radiometric and spectral calibration observations

The continuous degradation of the VNIR sensor was monitored and quantified. The rate of degradation is constantly decreasing as illustrated in Figure 7-3 and by the end of March 2023 it has reached the point where it is practically negligible and has been kept that way during the reporting period. The effect on the radiometric calibration coefficients of a few selected bands is shown in Figure 7-4.

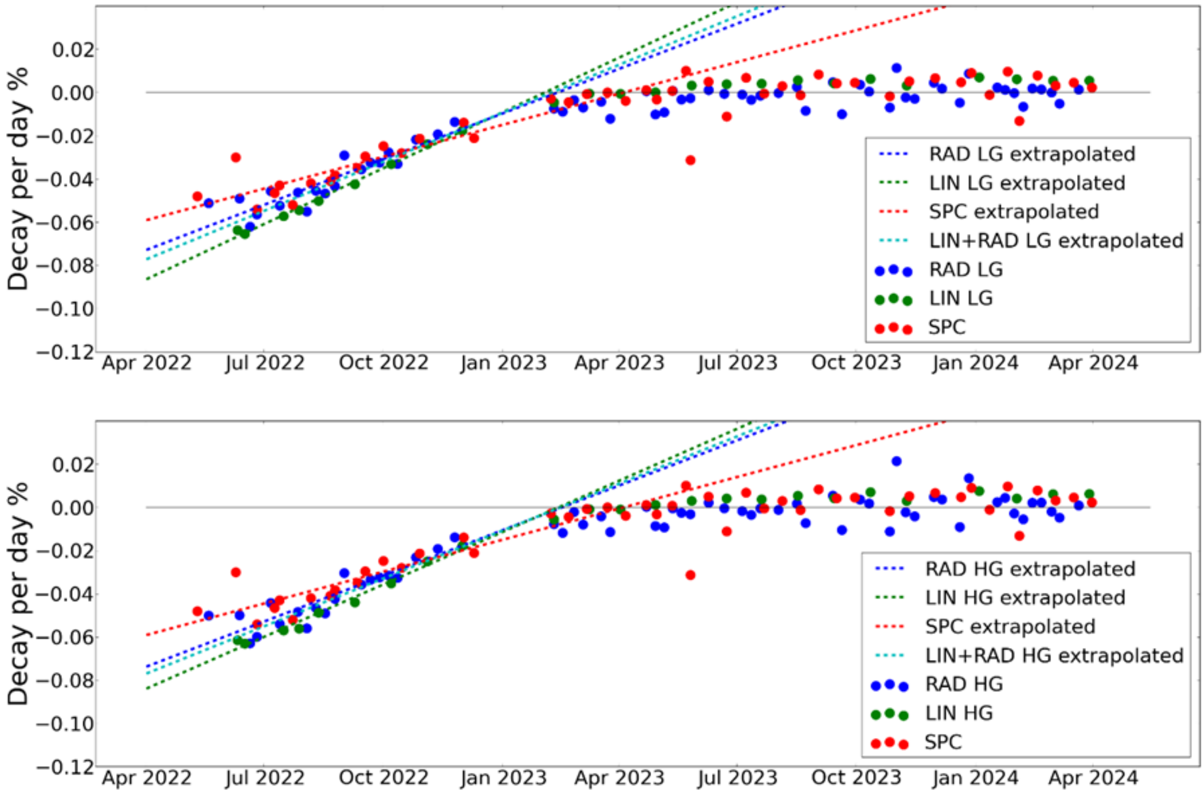


Figure 7-3 Decay per day from Lamp (RAD), Linearity (LIN) and Spectral (SPC) measurements for low gain (top) and high gain (bottom)

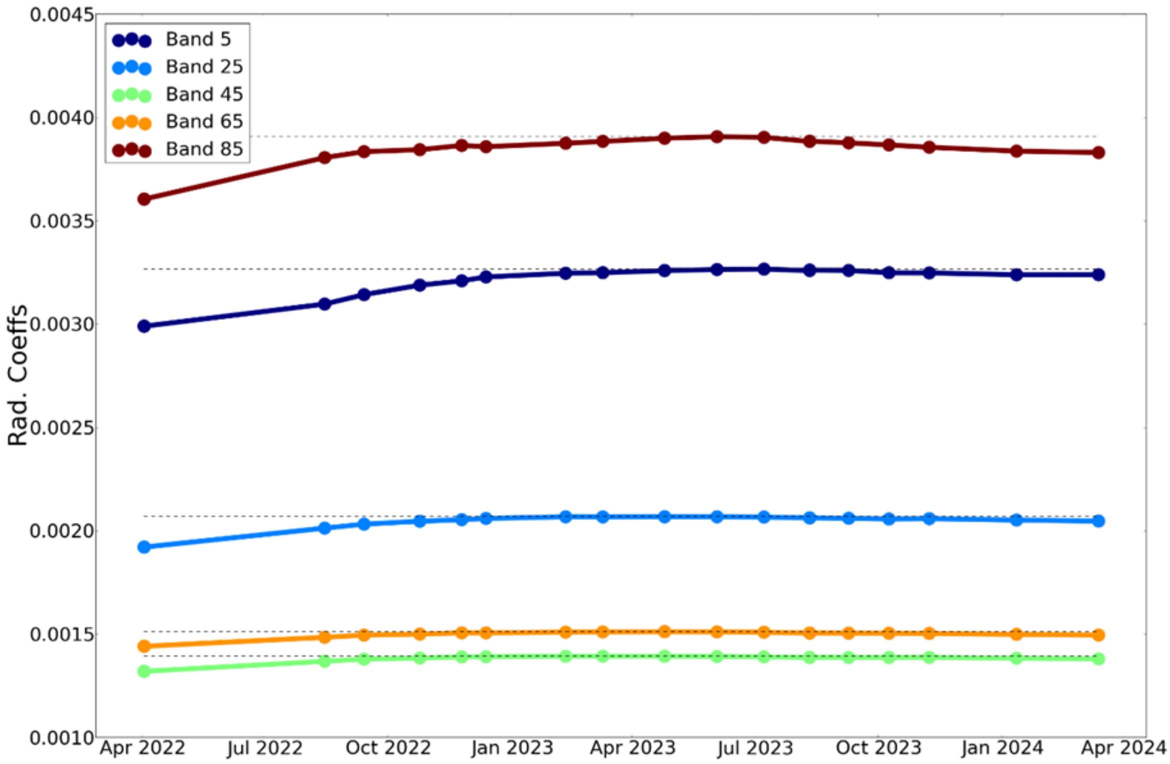


Figure 7-4 Average percentage change in the VNIR radiometric coefficients for five selected bands since launch

7.5.1 Dead Pixels

The following table shows the number and percentage of dead pixels. Figure 7-5 and Figure 7-6 show the position of the dead pixels in the focal plane of VNIR and SWIR sensors respectively. There have been no updates since 31.08.2022.

Defect Pixels	01.01.2024 to 31.03.2024	
	Number of Pixels	Percent
Total	1921	0.8
VNIR	137	0.2
SWIR	1784	1.2

Table 7-5 Number and percent of dead pixels

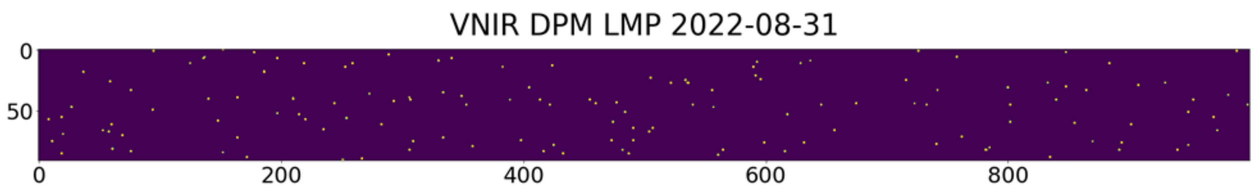


Figure 7-5 VNIR Dead Pixel Mask

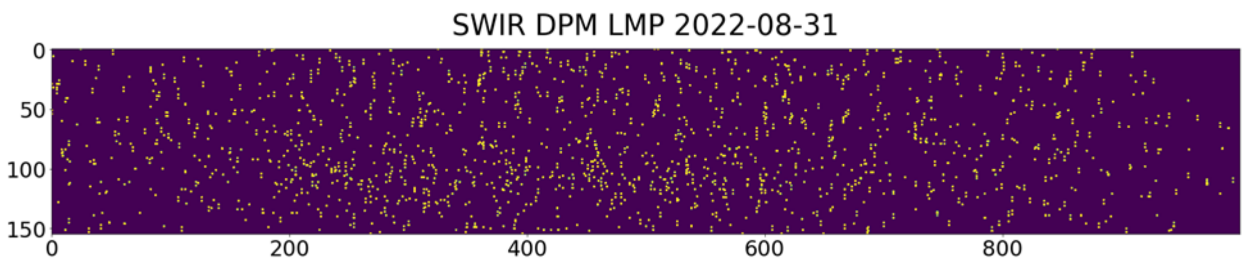


Figure 7-6 SWIR Dead Pixel Mask

There are no clusters of more than three spectrally or spatially adjacent dead pixels.

7.5.2 Spectral Calibration

Remark: In the following figures, OBCA is abbreviation for On-Board Calibration Assembly for spectral and radiometric calibrations.

Category	01.01.2024 to 31.03.2024	
	Number of Archived Observations	Size (in GB)
Total	7	6.3
Spectral Calibration	7	6.3

Table 7-6 Number and size of archived spectral calibration observations

The spectral properties – in particular center wavelength (CW) (see Figure 7-7 and Figure 7-8) and full width at half maximum (FWHM) (see Figure 7-9) for each band (spectral coordinate) and pixel (spatial coordinate) – have been characterized, considering all bands and pixels provided in Level 1B, Level 1C and Level 2A products.

The major conclusions of the monitoring of the spectral performance is summarized as follows:

- During the reporting period, 7 spectral calibration measurements were made which took place on: 11.01.2024, 25.01.2024, 03.02.2024, 17.02.2024, 02.03.2024, 16.03.2024 and 30.03.2024.

- The VNIR spectral range in this reporting period was found to be 418.4 – 993.3 nm over 91 bands (Figure 7-7). The average spectral sampling distance was 6.4 nm with a total range of 4.7 – 8.2 nm. This meets the requirement for overall wavelength coverage [HSI-POSS-0210], average spectral sampling distance [HSI-POSS-0310] and spectral sampling distance range [HSI-POSS-0320].
- The SWIR spectral range in this reporting period was found to be 902.1 – 2445.4 nm over 155 bands (Figure 7-7). The average spectral sampling distance was 10.0 nm with a total range of 7.5 – 12.0 nm. This meets the requirement for overall wavelength coverage [HSI-POSS-0210], average spectral sampling distance [HSI-POSS-0310] and spectral sampling distance range [HSI-POSS-0320].
- The spectral calibration measurements from this quarter show good temporal stability – measurements showed an absolute <0.3 nm change from the VNIR sensor and <0.2 nm change in SWIR (Figure 7-8). All changes were below 0.5 nm between measurements for VNIR and SWIR. This meets the requirement for consecutive spectral stability [HSI-POSS-0510] and overall spectral stability [HSI-POSS-0520].
- FWHM for VNIR and SWIR (Figure 7-9) are shown below but are not recalculated inflight.
- A degradation pattern is not clearly visible between consecutive spectral reference measurements acquired in this period, but there are positive and negative changes across the detector and on average the signal appears to have increased by 0.22% across all pixels from 28.12.2023 to 30.03.2024. A slightly larger change was reported in the previous quarter (0.34%). Although small, this behavior should be monitored in the next reporting period.

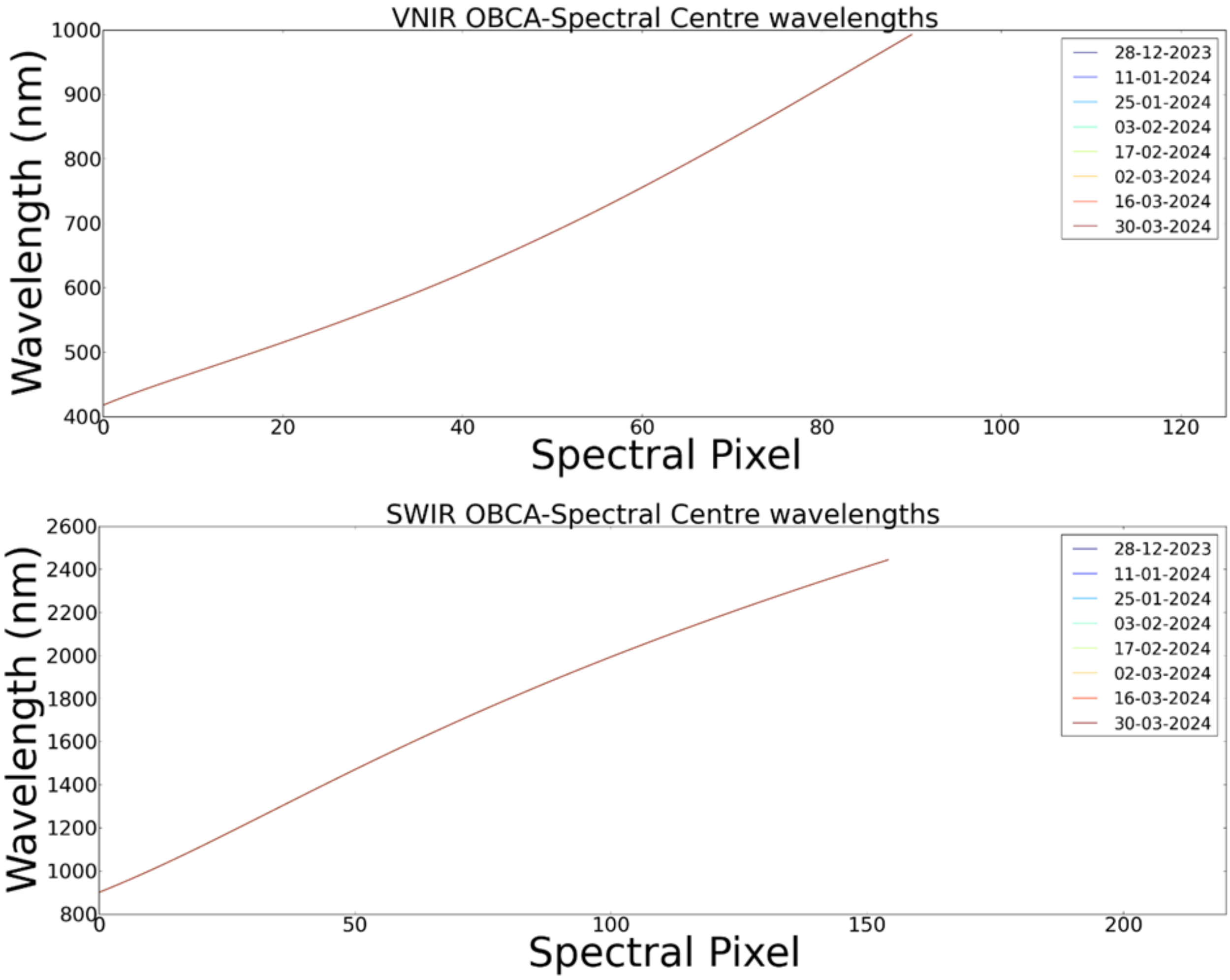


Figure 7-7 VNIR (top) and SWIR (bottom) center wavelength in nm

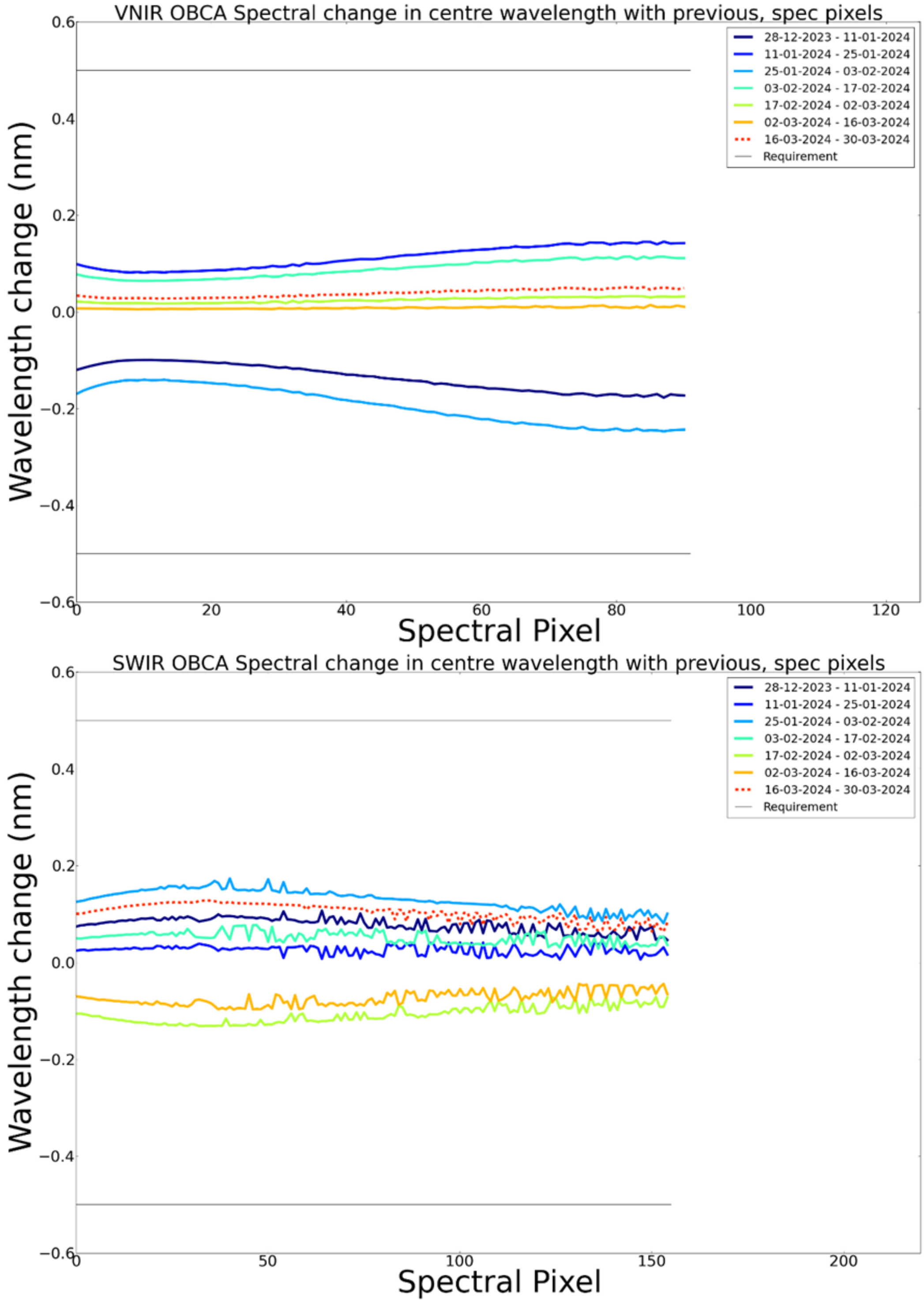
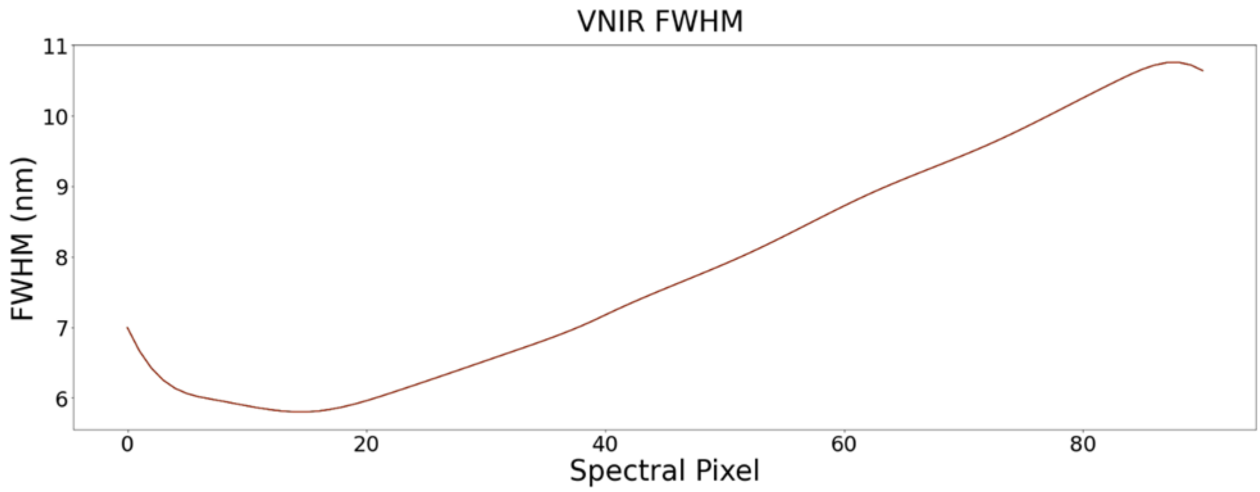


Figure 7-8 Change in center wavelength per spectral pixel for VNIR (top) and SWIR (bottom)



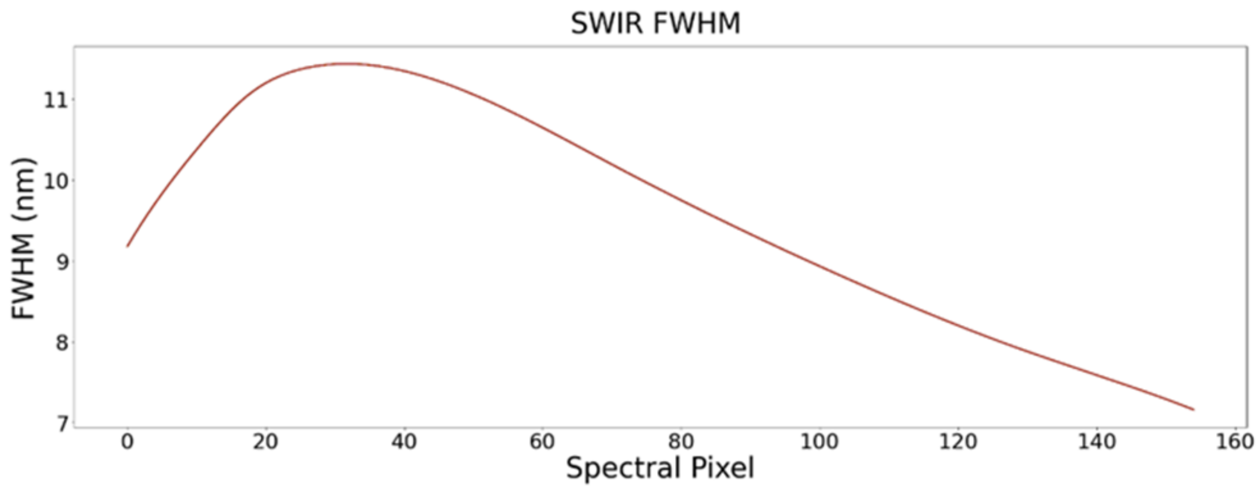


Figure 7-9 VNIR (top) and SWIR (bottom) FWHM in nm

CW and FWHM are available in the spectral calibration tables (see Table 7-7) and System Response Functions (SRF) per band are modelled by a Gaussian shape using those parameters.

No new calibration products were generated and delivered during the reporting period. All of the old spectral calibration tables were updated due to a change in MIP which led to the calculation of new water LUTs to fix the spectral noise below 500 nm in water spectra (new processor version V04.01.00.). However, the contents of the spectral calibration tables did not change with the updated versions.

Product	Type	Date of Generation	Date of Validity Start	Date of Validity End	Delivered to
ENMAP01-CTB_SPC-20220402T000000Z_V040100_20240129T161329Z	CTB_SPC	29.01.2024	02.04.2022	09.05.2022	DIMS
ENMAP01-CTB_SPC-20220510T000000Z_V040100_20240125T143805Z	CTB_SPC	25.01.2024	10.05.2022	31.05.2022	DIMS
ENMAP01-CTB_SPC-20220601T101000Z_V040100_20240124T151201Z	CTB_SPC	24.01.2024	01.06.2022	24.06.2022	DIMS
ENMAP01-CTB_SPC-20220625T000000Z_V040100_20240123T150741Z	CTB_SPC	23.02.2024	25.06.2022	07.02.2023	DIMS
ENMAP01-CTB_SPC-20230208T000000Z_V040100_20240119T072914Z	CTB_SPC	19.01.2024	08.02.2023	05.07.2023	DIMS

ENMAP01-CTB_SPC-20230705T101000Z_V040100_20240122T163903Z	CTB_SPC	22.01.2024	05.07.2023	-	DIMS

Table 7-7 Generated spectral calibration tables

7.5.3 Radiometric Calibration

Category	01.10.2023 to 31.12.2023	
	Number of Archived Observations	Size (in GB)
Total	16	78.2
Deep Space	2	2.6
Rel. Radiometric	10	39
Abs. Radiometric	2	2.6
Linearity	2	34

Table 7-8 Number and size of archived radiometric calibration observations

The radiometric properties – characterized in particular by the calibration coefficient for each band (spectral coordinate) and pixel (spatial coordinate) and radiance – during this reporting period are investigated, considering all bands and pixels and radiances provided in Level 1B, Level 1C and Level 2A products.

Both sensors feature two gain settings each. VNIR applies a quantization of 13 bits using a pixel-individual automatic gain switching, where the low gain value is automatically selected, if the signal exceeds a defined threshold. SWIR applies a fixed gain setting, where bands below 1980 nm take the low gain value and bands above 1980 nm take the high gain value.

Radiometric calibration coefficients (see Figure 7-10, Figure 7-11 and Table 7-9) and VNIR RNU (response non-uniformity, see Figure 7-13) were affected by the degradation of the VNIR sensor during commissioning but have stabilized from Q1 2023. In-flight, the gain matching coefficients (see Figure 7-12), the SWIR calibration coefficients, and the SWIR RNU (response non-uniformity, see Figure 7-13) have been stable.

During the reporting period, 3 Absolute Radiometric calibration measurements were obtained. These took place on: 12.01.2024, 11.02.2024 and 13.03.2024. Owing to the initial degradation in the VNIR sensor during commissioning, new calibration and reference tables were created for each new absolute radiometric measurement. Although the VNIR degradation has almost stopped, the overall effects are visible in the reference measurements of the sun. However geometric conditions (sun-earth distance, pointing angle) also play a role in the absolute magnitude so the degradation cannot be quantified with these reference measurements.

The major conclusions of the monitoring of the absolute performance is summarized as follows:

- Changes in the VNIR sensor have affected the absolute Radiometric calibration coefficients: the increasing signal in the VNIR sensor, although not homogeneous, has resulted in decreasing radiometric coefficients. In this reporting period, the calibration coefficients decreased by about -0.527% to offset the increase in absolute signal, relative to the sun calibration on 08.11.2023 (Figure 7-10 and Figure 7-11). Regarding RNU, the degradation features are still visible in the focal plane. Looking at the average along across track pixels, the RNU correction appears to have changed slightly in this reporting period (Figure 7-13). Lastly, the Gain Matching correction has been relatively stable during this reporting period (Figure 7-12).
- The SWIR sensor has shown good stability during this reporting period, with no significant changes in the gain matching, RNU or radiometric calibration coefficients (Figure 7-10 and Figure 7-11).
- Regarding the total change in calibration corrections as a result of the VNIR degradation, almost all pixels experienced a change of less than 2.5% between consecutive measurements as set in requirement [HSI-POSR-0410]. The only pixels which exceeded this value were already marked as dead during inflight assessment. No SWIR pixels experienced a change of more than 2.5% between consecutive absolute calibration measurements.

- New VNIR and SWIR calibration and reference tables were created for both absolute radiometric measurements, mainly due to the changes in the VNIR sensor. The VNIR radiometric calibration coefficients have decreased in this reporting period to offset the increasing VNIR signal. The changes are small, and within requirements, so the dynamic coefficients are not calculated and calibration coefficients are taken directly from the most recent calibration table as envisioned at the beginning of the mission.
- Starting from April 2024, Absolute Radiometric calibration measurements will be made at intervals of two months following the stable performance of both sensors and to allow for the extension of the lifetime of the solar diffuser.

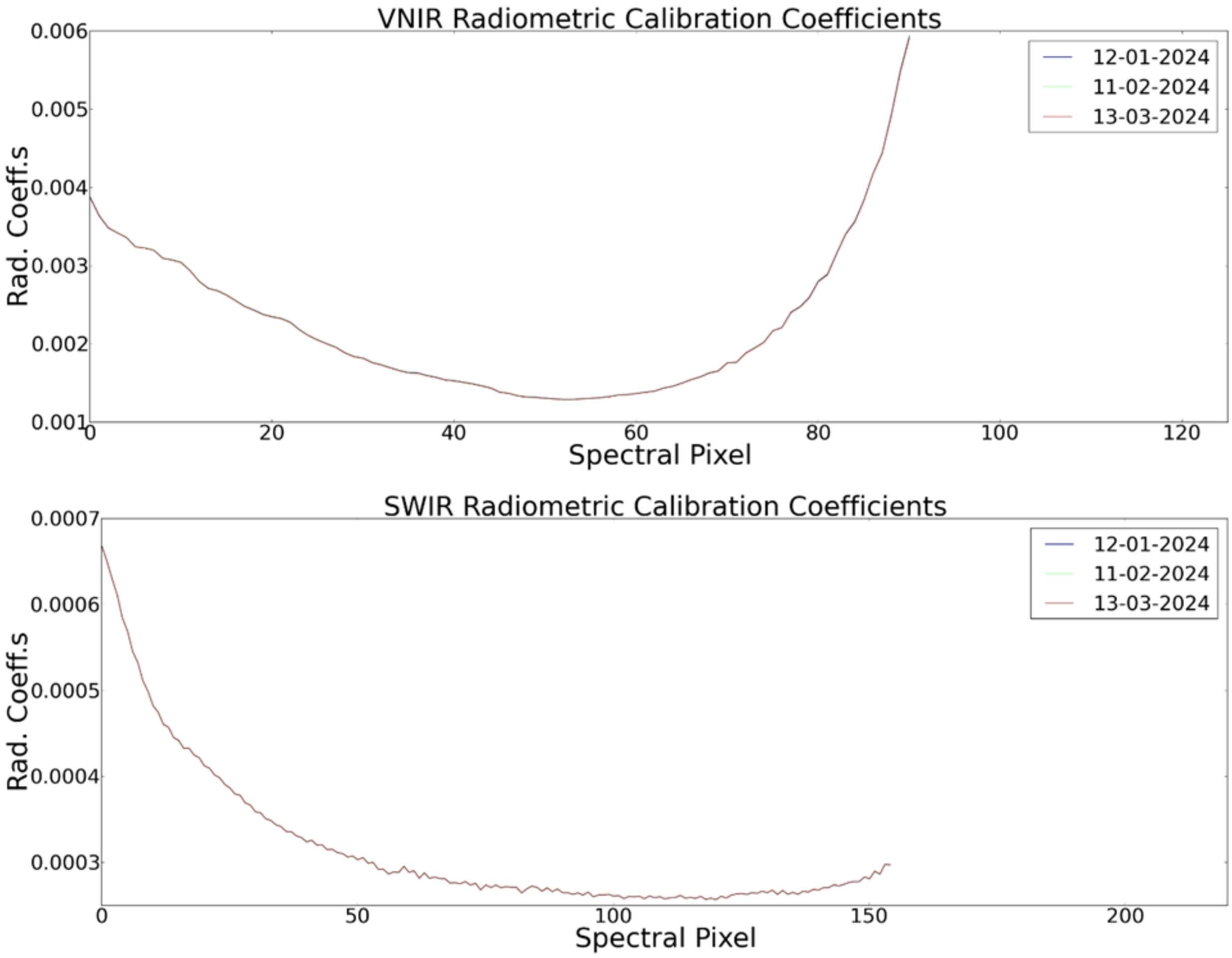


Figure 7-10 VNIR (top) and SWIR (bottom) calibration coefficient in mW/cm²/sr/µm

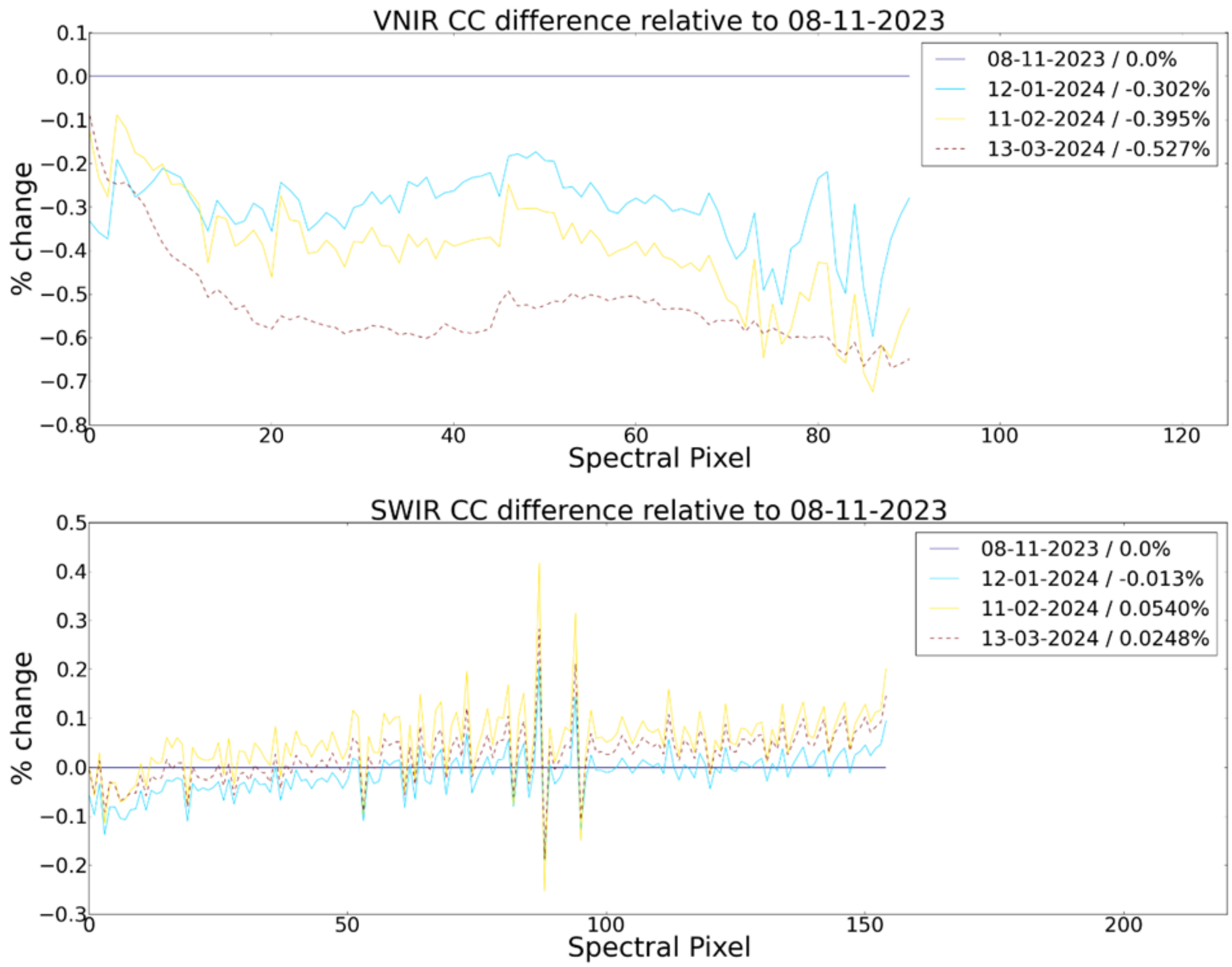
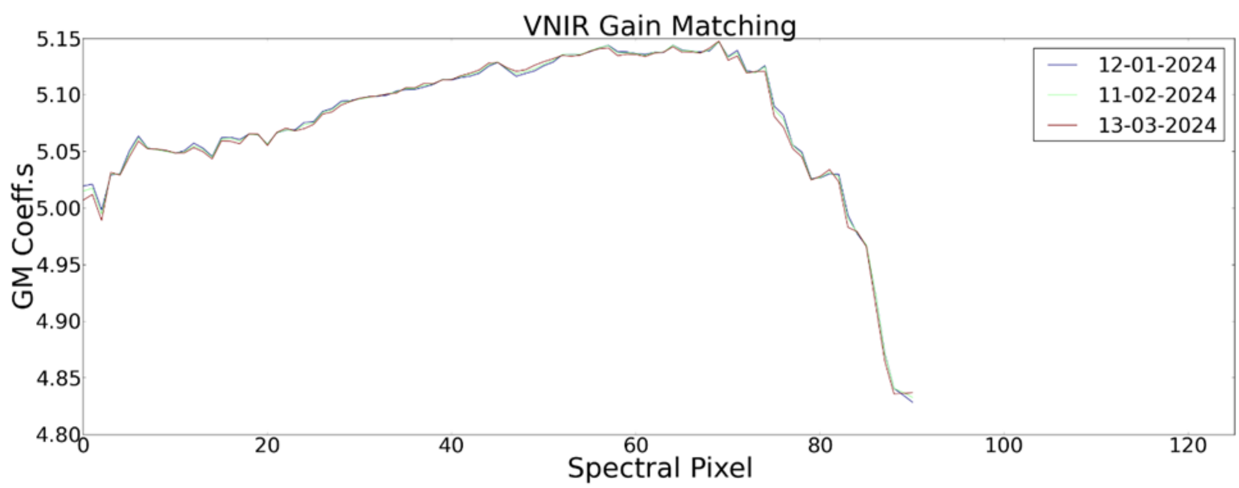


Figure 7-11 Percentage change in VNIR Calibration Coefficients (top) and SWIR Calibration Coefficients (bottom)



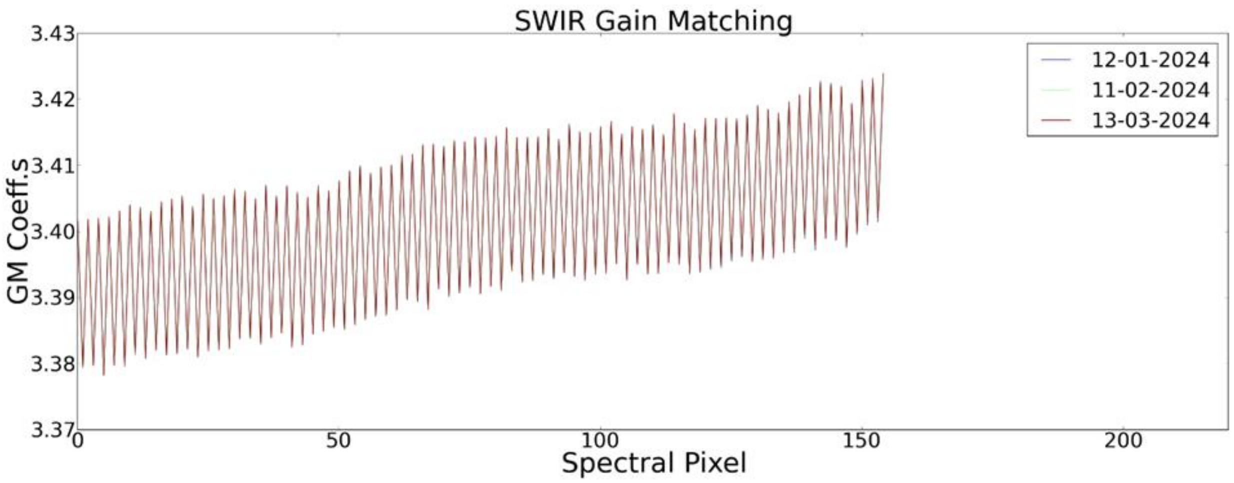


Figure 7-12 VNIR (top) and SWIR (bottom) gain matching calibration coefficients

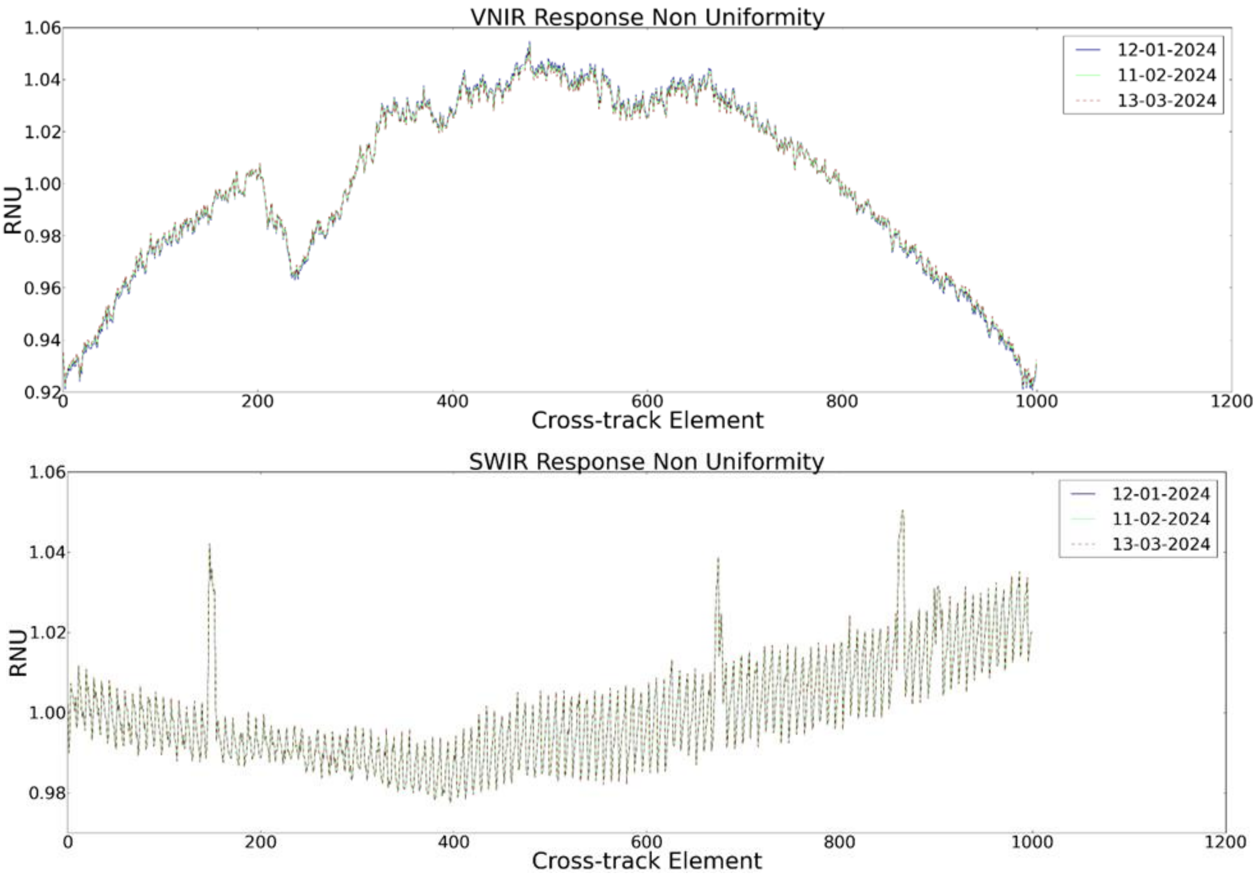


Figure 7-13 VNIR (top) and SWIR (bottom) response non-uniformity coefficients

The Signal-to-Noise Ratio (SNR) is derived from the Linearity reference measurements. This is not a perfect set-up for the assessment of the SNR as the linearity measurements only cover a single wavelength and light level at increasing integration times. However, it is well constrained, covering a wide range of radiances including the levels of the solar reference spectrum (30% reflectance, 30° sun incidence angle, 21 km visibility, target 500 m above sea level). The lamp reference measurements are not used, as the reference spectrum is not well covered at the radiances of the lamp and extrapolation would be required to test the performance at the SNR requirements: SNR greater than 500 at 495 nm in VNIR for the solar reference spectrum value; and SNR greater than 150 at 2200 nm in SWIR for the reference spectrum.

For the VNIR sensor, SNR is computed from the linearity calibration measurement. SNR values are shown as a contour map with the solar reference spectrum (30% reflectance, 30° sun incidence angle, 21 km visibility, target 500 m above sea level) as a blue line. Contour lines with SNR values of 150 and 500 are also shown in black. A similar plot for the low gain mode including the position of the requirement [HIS-POSR-0010] which is marked with a black cross.

For the SWIR sensor, SNR is also computed from the linearity calibration measurement. SNR values for the high gain mode are shown as a contour map with the solar reference spectrum (30% reflectance, 30° sun incidence angle, 21 km visibility, target 500 m above sea level) as a blue line and the position of the requirement [HIS-POSR-0010] is marked with a black cross. Contour lines with SNR values of 150 and 500 are also shown in black.

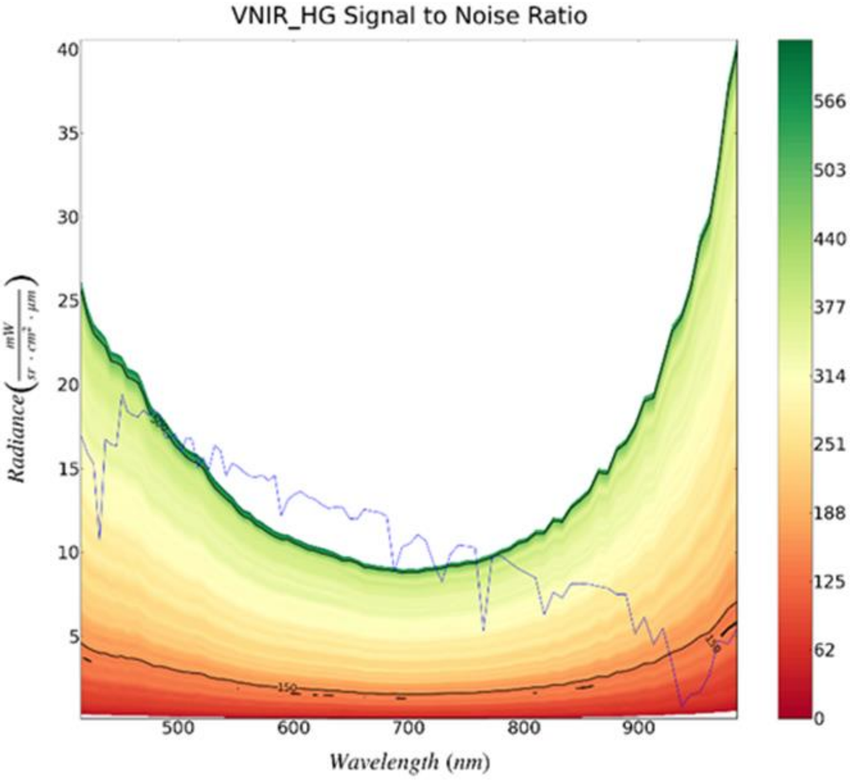


Figure 7-14 SNR contour map for VNIR high gain from the LED linearity observations observed on 28.03.2024. The solar reference spectrum is shown with a blue line. Contour lines with SNR values of 150 and 500 are also shown in black.

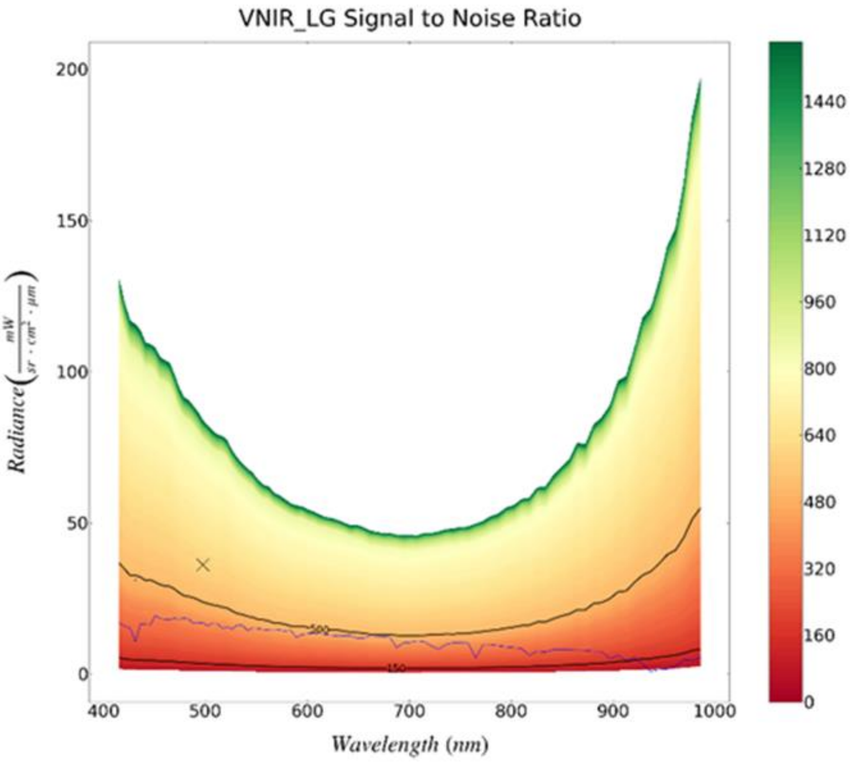


Figure 7-15 SNR contour map for VNIR low gain from the LED linearity observations observed on 28.03.2024. The solar reference spectrum is shown with a blue line and the position of the requirement is marked on the reference spectrum with a black cross. Contour lines with SNR values of 150 and 500 are also shown in black.

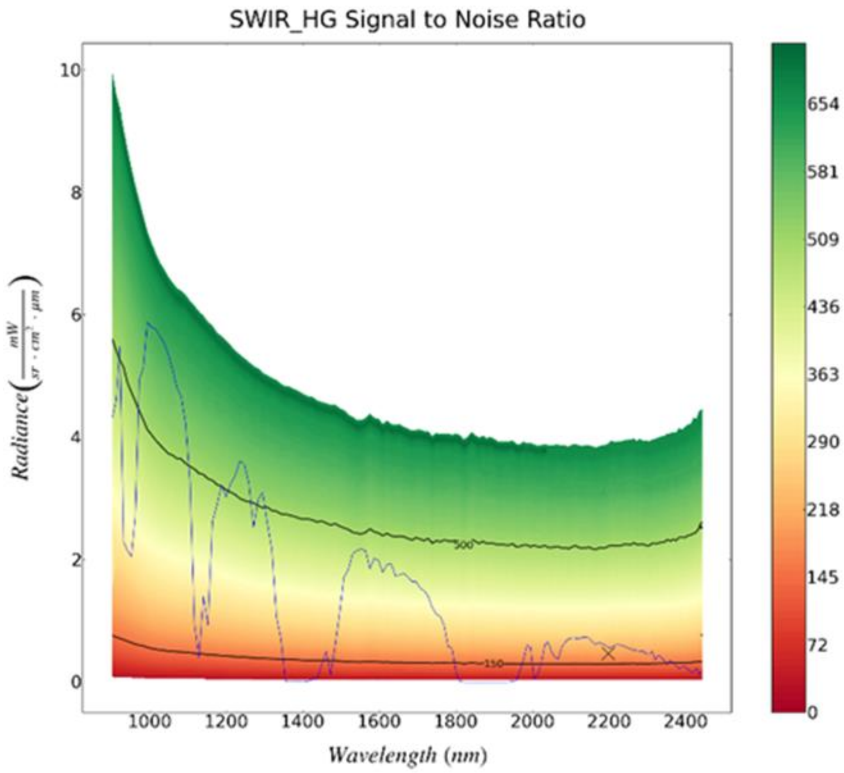


Figure 7-16 SNR contour map for SWIR high gain from the LED linearity observations observed on 28.03.2024. The solar reference spectrum is shown with a blue line and the position of the requirement is marked on the reference spectrum with a black cross. Contour lines with SNR values of 150 and 500 are also shown in black.

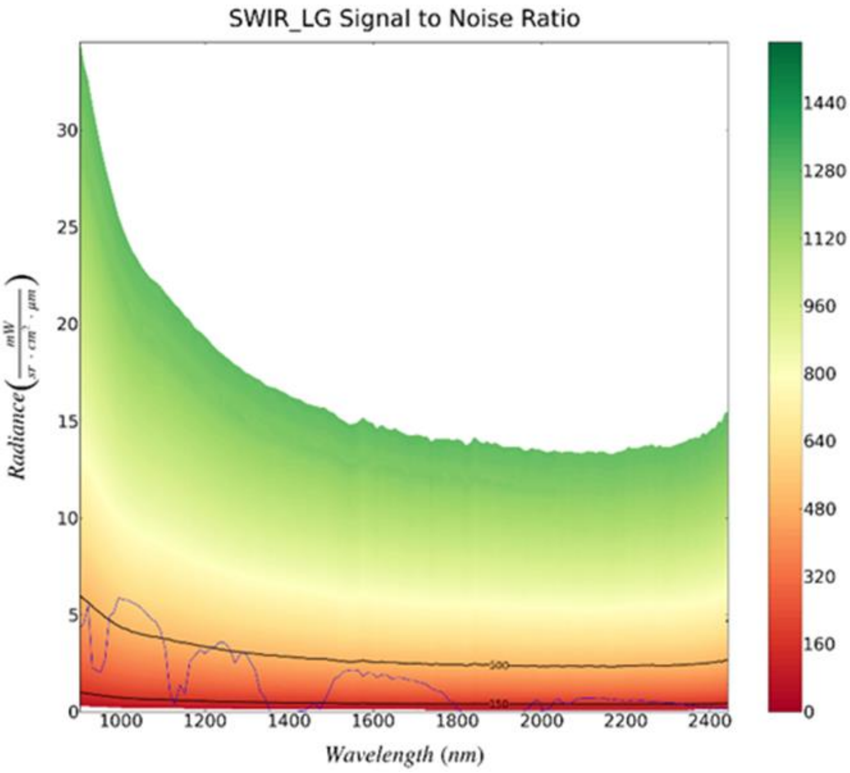


Figure 7-17 SNR contour map for SWIR low gain from the LED linearity observations observed on 28.03.2024. The solar reference spectrum is shown with a blue line. Contour lines with SNR values of 150 and 500 are also shown in black.

The following calibration products were generated and delivered:

Product	Type	Date of Generation	Date of Validity Start	Date of Validity End	Delivered to
ENMAP01-CTB_RAD-20240119T000000Z_V040005_20240115T080452Z	CTB_RAD	15.01.2024	19.01.2024	22.02.2024	DIMS
ENMAP01-CTB_RAD-20240223T000000Z_V040100_20240215T072104Z	CTB_RAD	15.02.2024	23.02.2024	24.03.2024	DIMS
ENMAP01-CTB_RAD-20240325T000000Z_V040100_20240318T124212Z	CTB_RAD	18.03.2024	25.03.2024	-	DIMS
ENMAP01-REF_SUN-20240119T000000Z_V040005_20240115T080452Z	REF_SUN	15.01.2024	19.01.2024	22.02.2024	DIMS
ENMAP01-REF_SUN-20240223T000000Z_V040100_20240215T072104Z	REF_SUN	15.02.2024	23.02.2024	24.03.2024	DIMS
ENMAP01-REF_SUN-20240325T000000Z_V040100_20240318T124212Z	REF_SUN	18.03.2024	25.03.2024	-	DIMS

Table 7-9 Generated radiometric calibration tables

7.5.4 Geometric Calibration

There have been no new geometric calibration tables generated in the reporting period.

Type of Calibration Table	ID of Calibration Table	Date of Generation	Date of Validity Start	Date of Validity End
None				

Table 7-10 Generated new geometric calibration tables

The performance of the geometric calibration table is assessed in chapter 7.6.3.

7.6 Internal Quality Control

7.6.1 Archive

Within the given time period (2024-01-01 and 2024-03-31), 1597 datatakes with a total of 16707 tiles were acquired and archived (remark: additional datatakes acquired during this period but for which the archiving is pending might be missing in the statistics).

The overall quality rating statistics are listed in Table 7-11, and in relation to the Solar Zenith Angle (SZA) in Table 7-12. Also these ratings are further detailed for the VNIR and SWIR detector in Table 7-13, showing a nominal performance rating for the given quality thresholds.

In addition, the rating for the atmospheric conditions for the scenes are depicted in Table 7-14. When setting the atmospheric quality rating in relation to the illumination conditions (i.e., large SZA) during data acquisition (Table 7-15), 13% of the “reduced quality” ratings and over 25% of the “low quality” ratings can be related to low Sun angles / night time acquisitions. This increase can be explained as more acquisitions were taken in the northern hemisphere where during winter unfavourable illumination conditions apply.

In addition, the “low qualityAtmosphere” rating can be further related to high cloud cover (58% of the low qualityAtmosphere tiles) and the unavailability of enough DDV pixels (76%) (see Table 7-16). Consequently, the rating is absolutely reasonable and can be explained.

Parameter	Value	Percentage	Number of tiles
overallQuality	Nominal	98,8%	16507
	Reduced	<1%	27
	Low	1,0%	173

Table 7-11 Overall quality rating statistics

Parameter	Number of tiles	Sub-Parameter	Number of tiles
overallQuality = Low	173		
		Thereof with SZA > 70°	173

Table 7-12 Overall quality rating in relation to Sun Zenith Angle (SZA)

Parameter	Number of tiles	Sub-Parameter	Number of tiles
overallQuality = Reduced	1		
		Thereof with qualityVNIR nominal	0
		Thereof with qualitySWIR nominal	27

overallQuality = Low	134		
		Thereof with qualityVNIR nominal or reduced	0
		Thereof with qualitySWIR nominal or reduced	173

Table 7-13 Reduced and low quality rating statistics

Parameter	Value	Percentage
QualityAtmosphere	Nominal	34%
	Reduced	13%
	Low	53%

Table 7-14 QualityAtmosphere rating statistics

Parameter	Number of tiles	Sub-Parameter	Number of tiles
overallAtmosphere = Reduced	2186		
		Thereof with SZA > 60°	203
		Thereof with SZA > 70°	68
		Thereof with SZA > 80°	9
overallAtmosphere = Low	8897		
		Thereof with SZA > 60°	1372
		Thereof with SZA > 70°	585
		Thereof with SZA > 80°	243

Table 7-15 QualityAtmosphere rating in realtion to Sun Zenith Angle (SZA)

Parameter	Number of tiles	Sub-Parameter	Number of tiles
overallAtmosphere = Low	8897		
		Thereof with Cloud Cover > 66%	5197
		Thereof with DDV warnings	6757

Table 7-16 QualityAtmosphere rating in relation to Cloud Cover and DDV availability

Remark about definition of EnMAP low quality collection

The quality rating of EnMAP products is based on image parameters, such as illumination conditions (i.e., sun elevation angle) and image defects, and on possible anomalies in the image data or instrument telemetry. These parameters are retrieved during the pre-processing and are added to the metadata and quality layers for every archived L0 product. In EOWEB GeoPortal two collections of EnMAP L0 products are available: “EnMAP-HSI (L0)” and “EnMAP-HSI (L0), Low Quality”. An L0 product is assigned to the low-quality collection if the corresponding metadata item qualityFlags.overallQuality is equal to 2 (low quality). This happens for products with a significant number of striping, saturation, artefact or dead pixels, when the screening of data and instrument indicates non-nominal behavior or, in the majority of cases, when the sun elevation angle is less than or equal to 0 (e.g., night scenes). A detailed definition of qualityFlags.overallQuality is given in Sec. 4.4.9 in the L1B ATBD (EN-PCV-TN-4006).

7.6.2 Level 1B

7.6.2.1 Radiometric Performance

Defective / de-calibrated detector elements

Using the Detector Map components, an offline check of possibly defective or de-calibrated detector elements is conducted. In particular, a detector element is identified as "possibly defective" if it is suspicious in at least 75% of the useful tiles. Note that this analysis is based on L1B_RAD data, so no dead / defective pixel interpolation was carried out. Within the given reporting period, the following indications for defective pixels are found for the VNIR and the SWIR camera:

VNIR (total of 16380 tiles, with 16207 suitable for analysis):

Newly found suspicious pixels in green, previously detected in **black**, no longer present ones in ~~red~~.

Band	Cross-track element
19	187
85	14
89	395

Note that the band index starts at 1.

SWIR (total of 16380 tiles, with 16101 suitable for analysis):

Newly found suspicious pixels in green, previously detected in **black**, no longer present ones in ~~red~~.

NOTE: due to the change in SWIR band configuration within the previous period Q3 (see EN-GS-RPT-1803 Issue 5), the band index from band 45 till 75 did change by +1 (with bands 45, 74 & 75 newly added). Thus, in the following, the new band numbers are given, while the colour index is adjusted in order to account for real changes.

Band	Cross-track element
1	817
2	235, 286, 593, 673
~~3~~	~~381~~
4	362, 363, 418
5	687
7	910
8	801
8	124
11	715
14	29, 684
16	535
19	84
~~20~~	~~766~~
28	104
29	855, 928
30	360, 855
31	360
48	511
~~49~~	~~218~~
50	311, 344, 395
51	~~154,~~ 155
53	97, 98
54	602, 941
56	221, 965
58	632, 922
59	89, 90
61	312
63	123
~~66~~	~~93~~
69	864
72	801, 844, 845
75	737
85	525
91	973
96	341, 819
101	318
106	107
107	265, 764
108	886
111	315
118	837

33	560	92	677, 973
38	241		
39	486		

Dead detector elements

Within the given reporting period, the statistics for dead pixels are provided in Table 7-17 and Table 7-18. When comparing these numbers to the estimates in the EN-GS-RPT-1702 Radiometric Calibration Report, one must bear in mind that the latter is based on the full detector readout configuration, while the numbers provided in the following are related to the standard readout configuration as provided in the user product. Because of the smaller readout area, these following dead pixel numbers are lower in comparison.

Parameter	Number of dead pixels	Percentage of tiles in reporting period
DeadPixelsVNIR	137	100%

Table 7-17 Dead pixel statistics, VNIR

Parameter	Number of dead pixels	Percentage of tiles in reporting period
DeadPixelsVNIR	1509	100%

Table 7-18 Dead pixel statistics, SWIR

Saturation and radiance levels

Within the given reporting period, no indications for increased saturation defects are found for the VNIR and the SWIR camera (see Table 7-19 and Table 7-20).

Parameter	Value (per mille of scene)	Percentage of tiles
SaturationCrosstalkVNIR	0	91%
	> 0 per mille	9.3%
	> 10 per mille	1.7%

Table 7-19 Saturation statistics, VNIR

Parameter	Value (per mille of scene)	Percentage of tiles
SaturationCrosstalkSWIR	0	92%
	> 0 per mille	7.7%
	> 10 per mille	0.5%

Table 7-20 Saturation statistics, SWIR

Other radiometric artifacts

Within the given reporting period, the striping performance is similar to the one encountered during the Commissioning Phase. Within PCV, different de-striping approaches were tested, and the selected one by M. Brell (GFZ) is implemented in processor version V010200 (07.03.2023).

Apart from this, no indications for an increase in general radiometric artifacts are found for the VNIR and the SWIR camera (see following tables).

Parameter	Value (number of pix)	Percentage of tiles
generalArtifactsVNIR	0	0%
	> 0	100%
	> 10	5%
	> 100	1.4%
	> 1000	0%

Table 7-21 Artifacts statistics (without striping), VNIR

Parameter	Value (number of pix)	Percentage of tiles
generalArtifactsSWIR	0	0%
	> 0	100%
	> 10	100%
	> 25	5.8%
	> 100	1.4%
	> 1000	0%

Table 7-22 Artifact statistics (without striping), SWIR

7.6.2.2 Spectral Performance

For the analysis of the spectral stability, the Detector Maps of all Earth datatakes acquired in the reporting period were used. Note that no smile correction was applied, so the analysis shows only on the instrument characteristics. At the wavelengths of stable atmospheric features (760 nm Oxygen absorption and CO2 absorption at ~2050 nm), simulations of spectral shifts were carried out by resampling the absorption in the interval of +/- 3.0 nm with steps of 0.05 nm. Then the signal of the Detector Maps and the simulated shifted absorptions were normalized, and a least-square fit was used where the sensed absorption matches the simulations. Also an additional polynomial fitting was applied, as especially the CO2 absorption band region has low signal an is thus significantly influenced by noise.

For the VNIR, when aggregating the shifts (Figure 7-18) relative to the CTB_SPC (Figure 7-19) the mean derivation is almost constant in across-track direction and around 0.5 nm towards shorter wavelengths, underpinning the consistency with the in-orbit spectral calibration and especially regarding the shape of the spectral smile while. Note that of course these results are consistent within the limitations of this vicarious approach. Additionally, the variability of the vicariously estimated spectral calibration can be expressed as the standard deviation at 1 sigma is below 0.4 nm, which includes the spectral stability of EnMAP and as well the variations of the used Earth datatakes and the limitations of the method.

In summary, these findings agree well with the instrument performance estimated during the Commissioning Phase and previous QC reports.

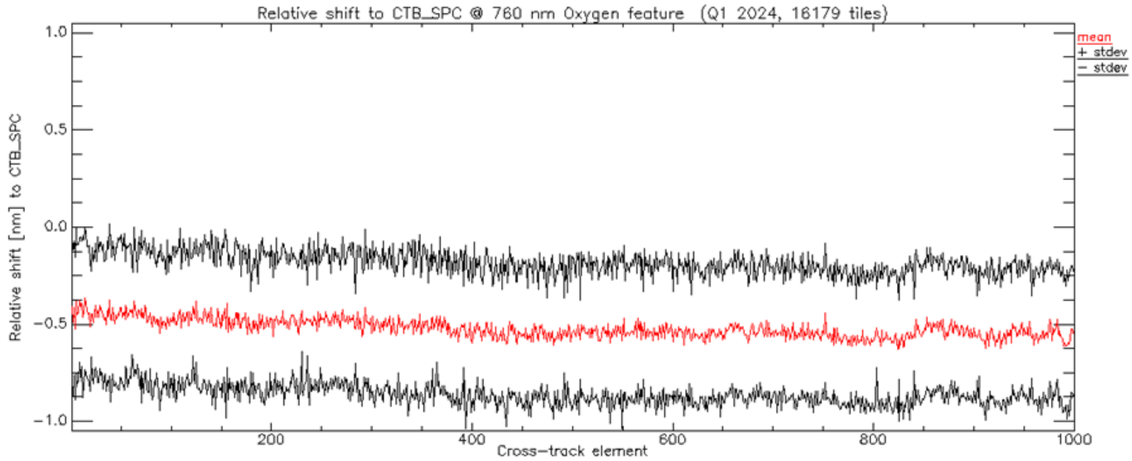


Figure 7-18 VNIR estimated spectral shift at 760 nm w.r.t the valid spectral calibration table (CTB_SPC, shown in Figure 2), and relative spectral stability expressed at 1 sigma (Q1 2024, 16179 tiles)

For this analysis, the reference is thus not the nominal center wavelengths (i.e., a single number per band), but the CW per cross-track pixel, thus explicitly including the spectral smile (see Figure 7-19).

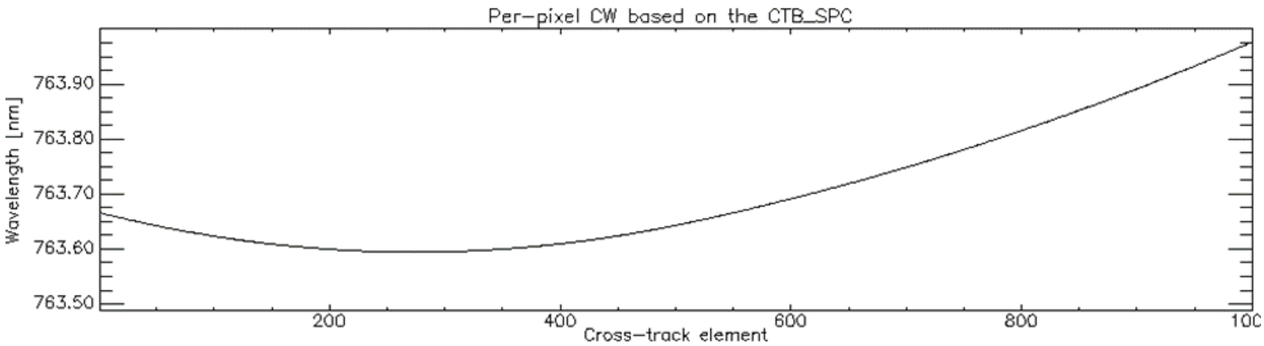


Figure 7-19 Center wavelengths per cross-track pixel based on the spectral calibration table (VNIR band 62) in the calibration table (CTB_SPC).

For the SWIR having less pronounced atmospheric absorption features, more influence of the background and a much lower signal level, the fitting also results in more clutter, as shown in Figure 7-20. Also there is now an increased number of DMs where no fit was achieved, as stated in the number of finally used tiles.

In order to demonstrate that the mean derivation to the CTB_SPC is within the spread of the data, the mean and standard deviation are calculated using the relative values, as shown in Figure 7-20. Here the differences to the CTB_SPC (Figure 7-21) are well within 1 standard deviation, confirming the validity of the spectral calibration.

Considering the EnMAP bandwidths of ~8.5 nm (FWHM), the spread of the vast majority of successful fits is within 3 nm, which agrees with the estimated overall stdev of ~0.6 nm (1 sigma) shown in Figure 7-20. To conclude, also for the SWIR the spectral calibration and the instrument stability can be confirmed, and no significant changes to previous reporting periods were found.

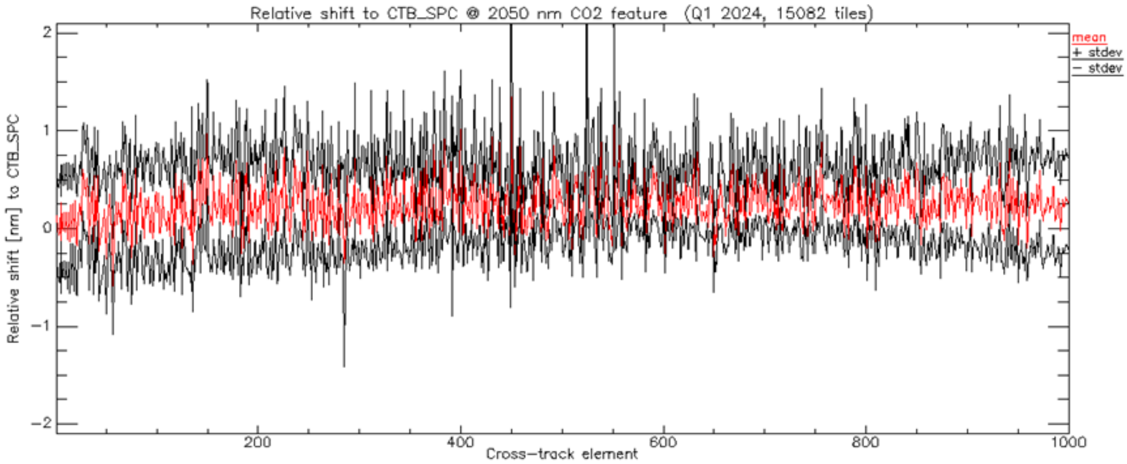


Figure 7-20 SWIR estimated spectral shift at 2050 nm w.r.t the valid spectral calibration table (CTB_SPC, shown below), and relative spectral stability expressed at 1 sigma (Q1 2024, 16179 tiles)

For this analysis, the reference is thus not the nominal center wavelengths (i.e., a single number per band), but the CW per cross-track pixel, thus explicitly including the spectral smile (see Figure 7-21).

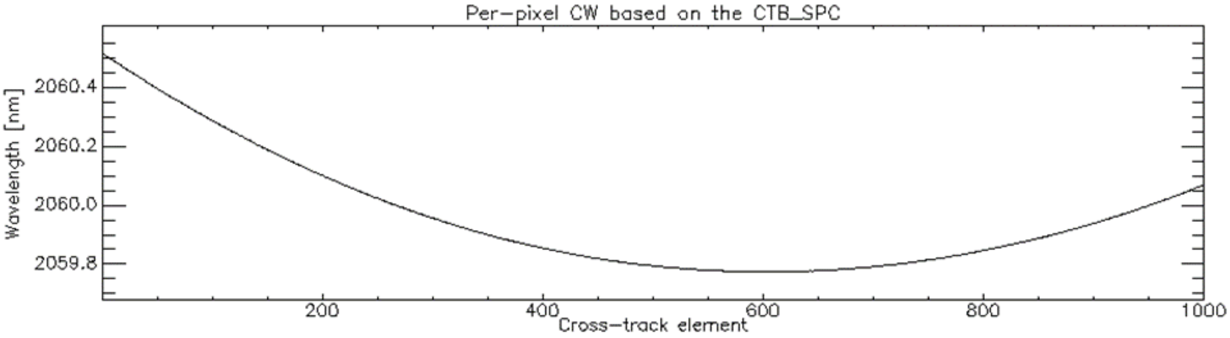


Figure 7-21 Center wavelengths per cross-track pixel based on the spectral calibration table (SWIR band 86).

7.6.2.3 Routine check of scenes in context of updates in CTB_RAD, CTB_SPC calibration tables

7.6.2.3.1 CTB_RAD

In the context of routine checks after radiometric calibration update, Table 7-23 shows the summary.

Table 7-23 Validated CTB_RAD

Validated CTB	ENMAP01-CTB_RAD-20240119T000000Z_V040005_20240115T080452Z
Datatake used	ENMAP01-_____L0-DT0000057887_20240121T083110Z_001  Figure 7-22 Datatake used (Saudi Arabia)
Summary of result	New CTB_RAD confirmed

	• VNIR: for the given scene,
	  • relative changes to P26 higher w.r.t. last periods, but still below 0.4% in most part of the VIS and NIR. For the given scene, the standard deviation of change is increased above 700nm
	  • absolute change is fluctuating about 0.02, therefore being clearly positive (i.e., higher sensitivity w.r.t. last period)
	  • for the given scene, fringing has only a very minor influence
	  • for given scene, differences are slightly higher at center than towards edges of detector, with the stable “fingerprint” showing up
	  • differences between calibrations are now bigger compared to those early in the mission – this is in line with the results of the calibration analysis
	
	• SWIR: for the given scene:
	  • relative and absolute change to P26 are small, similar to the previous period
	  • for given scene, SWIR fringing is not visible

Validated CTB	ENMAP01-CTB_RAD-20240119T000000Z_V040005_20240115T080452Z
Datatake used	ENMAP01-_____L0-DT0000060925_20240212T111940Z_004  Figure 7-23 Datatake used (Mali)

Summary of result	New CTB_RAD confirmed
	
	• VNIR: for the given scene,
	  • relative changes to P27 smaller w.r.t. last period‘s results (mainly below 0.2%)
	  • For the given scene, the standard deviation of change is increasing above 525nm
	  • for given scene, the absolute change is between -0.02 and +0.02
	  • for given scene, for bands above ~450 nm differences are slightly higher at center than towards edges of detector, with the stable “fingerprint” showing up. First bands show a bit of increase towards the edge of the FOV
	
	• SWIR: for the given scene:
	  • relative and absolute change to P27 are small, similar to the previous period
	  • for given scene, SWIR fringing is not visible

<table>
<tr><td>Validated CTB</td><td>ENMAP01-CTB_RAD-20240325T000000Z_V040100_20240318T124212Z</td></tr>
<tr><td>Datatake used</td><td>L0-DT0000064582_20240310T080809Z_016

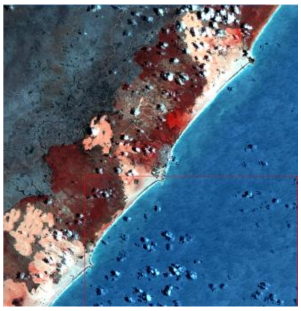



Figure 7-24 Datatake used (Coast of Somalia)</td></tr>
<tr><td>Summary of result</td><td>New CTB_RAD confirmed

VNIR: for the given scene,

relative changes to P28 are similar as between periods before (mainly below 0.2%)
for given scene, absolute change is between -0.05 and +0.025 with a slight recovery in almost all bands
for the given scene, fringing has a small influence in some bands
as before, for bands above ~450 nm differences are slightly higher at center than towards edges of detector, with the stable “fingerprint” showing up

SWIR: for the given scene:

relative and absolute change to P28 are very small (below 0.8%), similar to the previous period
absolute change is very small and fluctuates around 0
for given scene, SWIR fringing is slightly visible

</td></tr>
</table>

7.6.2.3.2 CTB_SPC

In the context of routine checks after spectral calibration update, Table 7-24 shows the summary.

Table 7-24 Validated CTB_SPC

Validated CTB	None
Datatake used	
Summary of result	

7.6.3 Level 1C

This report covers the timeframe between 01.10.2023 and 31.12.2023. No geometric calibration was performed during this period.

In the timeframe of this report, 1594 datatakes have been acquired. In 1049 of those datatakes (~66 %), enough GCPs and ICPs were found to perform a geometric accuracy assessment. The datatakes without enough GCPs were not assessed quantitatively, but a random subset of them was inspected visually. The vast majority of those datatakes was either almost fully covered with clouds or showing only water, desert or rain forest. The behavior is thus as expected.

The assessment of the RMSE values in the metadata is shown below in Figure 7-25.

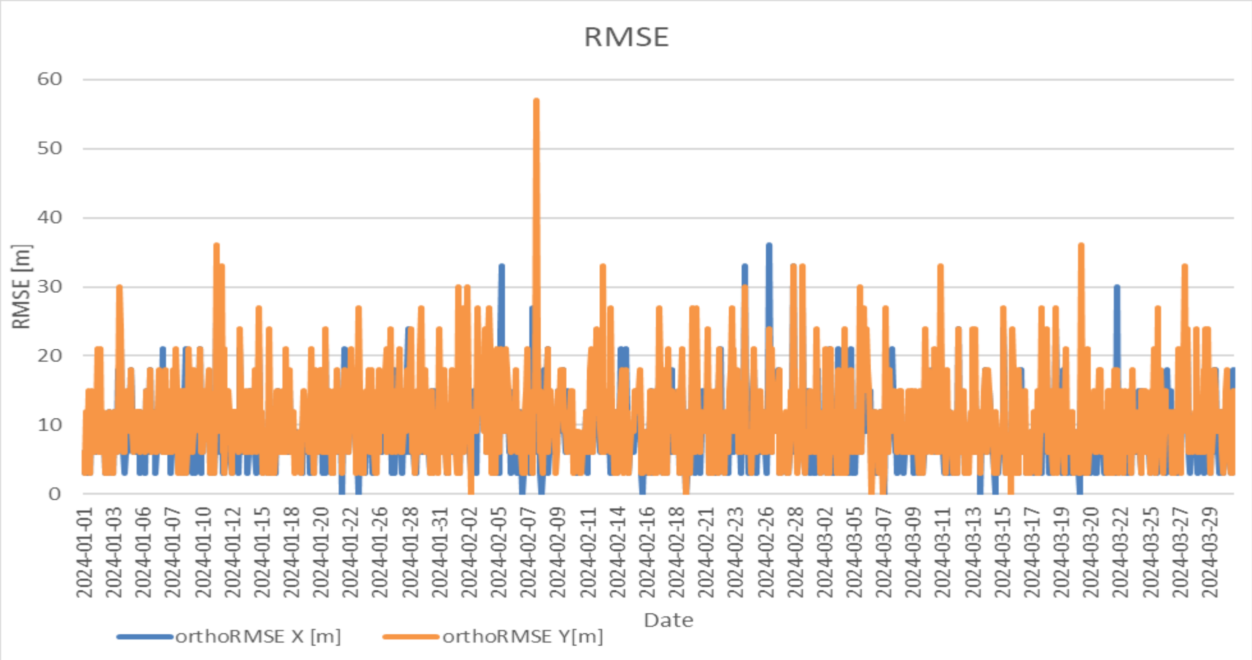


Figure 7-25 Assessment of RMSE values, calculated based on found ICPs, for all datatakes where ICP could be found

In x-direction, 4 datatakes (~0.4%) had an RMSE value above 30 m (1 GSD), whereas in y-direction, 9 datatakes (~0.8%) are above this threshold. For most of those datatakes, only very few GCP and ICP could be found during processing, making the results less reliable. The mean values are 8.58 m in x-direction and 10.68 m in y direction. This shows a very high geolocation accuracy for the datatakes where matching was possible. The requirement GRD-PCV-0155 is thus fulfilled.

The average boresight angles, which can be interpreted as the correction and thus the error of the scene if no GCPs could have been found, correspond to approximately -4 m in x direction with a standard deviation of approximately 22 m and -46 m in y direction with a standard deviation of approximately 20 m on ground. It is reasonable to assume that the scenes where no GCPs could be found are in the same accuracy range and thus well within the requirement of 100 m (GRD-PCV-0150). Note that the x and y direction mentioned in this report are not in the image coordinate system but in UTM, as the evaluation is done on L1C products.

7.6.3.1 Geometric accuracy

EnMAP L1C products are matched against a reference image (Sentinel-2 data, if not stated otherwise) by using image matching techniques to assess the geometric accuracy. At the obtained checkpoints (CP), statistics are calculated to provide mean and RMSE values (Figure 7-26) for each scene. Note that the obtained accuracy in the analysis is always w.r.t. the reference image. This report covers EnMAP data from 01.01.2024 to 31.03.2024. A random sample of 453 L1C tiles was selected based on visual inspection of the catalogue quicklooks (e.g. to avoid cloudy images).

The requirement GRD-PCV-0155 shall be fulfilled:

The geolocation accuracy at nadir look direction of level 1C and 2A products shall be better than 1 GSD (1 sigma) in each direction with respect to reference images provided that reference images are available and sufficient similarity.

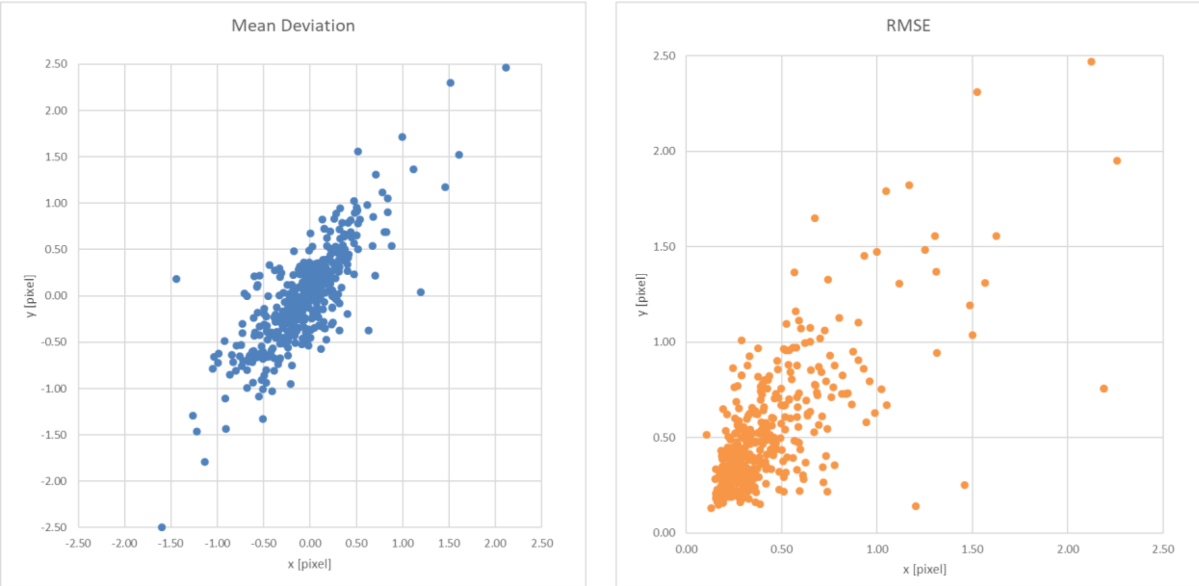


Figure 7-26 Mean deviation of EnMAP L1C products in pixel (left). RMSE value for EnMAP L1C products in pixel (right)

Note, that during processing the boresight angles and the geometric accuracy related quality flags are calculated on datatake level while in the figures and tables above, the accuracy is assessed per tile. The mean values over all 453 L1C tiles are -0.06 and -0.02 pixel in mean deviation with a standard deviation of 0.41 and 0.51 pixel while the mean RMSE values are 0.42 and 0.50 pixel, all in x and y direction respectively. The data show, that for the vast majority of scenes the accuracy wrt. reference image is better than one pixel and thus the requirements are fulfilled. Compared to the last geometric QC report, the values are very stable.

7.6.3.2 Co-registration accuracy

In this chapter, the co-registration accuracy is checked against the Space Segment requirement SRDS-PIM-0050 (EN-KT-RFW-003 is also to be considered here):

*The HS-Imager shall be designed such, that the geometric co-registration is ≤ 20 % of the nominal Ground Sampling Distance (0.2 * GSD linear displacement in both directions).*

For the assessment of co-registration accuracy, the SWIR data of EnMAP L1C products are matched against the corresponding VNIR data and the mean deviation values shown in this section (Figure 7-27).

This report covers EnMAP data from 01.01.2024 to 31.03.2024. A random sample of 457 L1C tiles was selected based on visual inspection of the catalogue quicklooks (e.g. to avoid cloudy images).

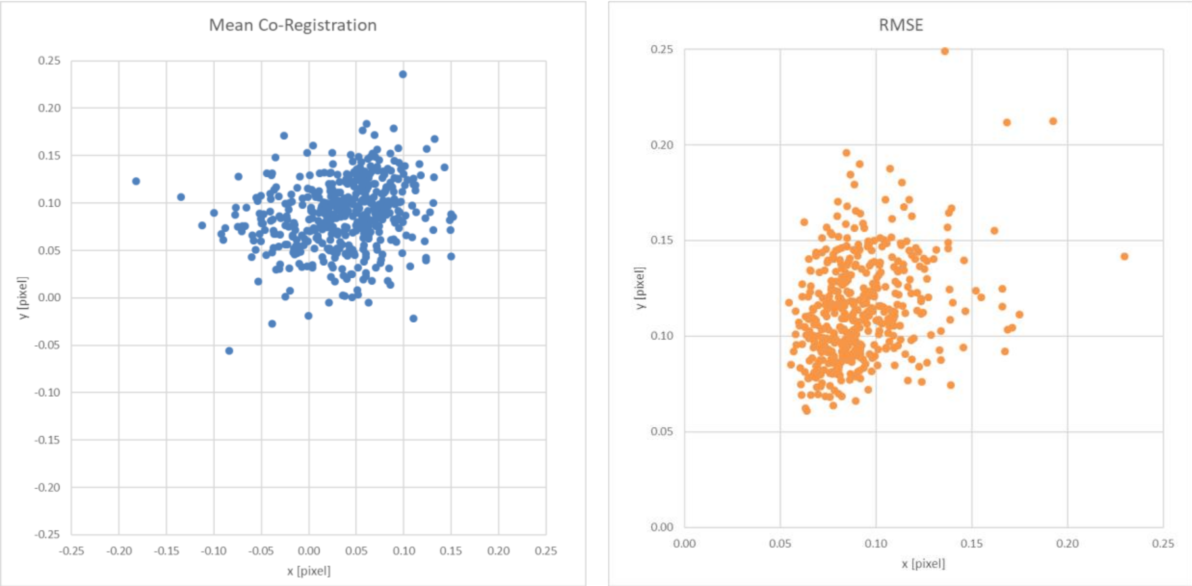


Figure 7-27 Mean deviation in pixel between VNIR and SWIR data of EnMAP L1C products (left). RMSE in pixel between VNIR and SWIR data of EnMAP L1C Products (right)

The data show, that the mean co-registration is well within the requirement. Note that the theoretical accuracy of the used matching algorithm is 0.1 pixel, and as can be seen in the RMSE values, still some mismatches were not removed by the blunder detection techniques that were applied. The mean deviation over all analyzed tiles are 0.03 pixel in x-direction with a standard deviation of 0.05 pixel and 0.09 pixel in y direction with a standard deviation of 0.04 pixel. Compared to the results in the previous geometric QC report, the values are very stable.

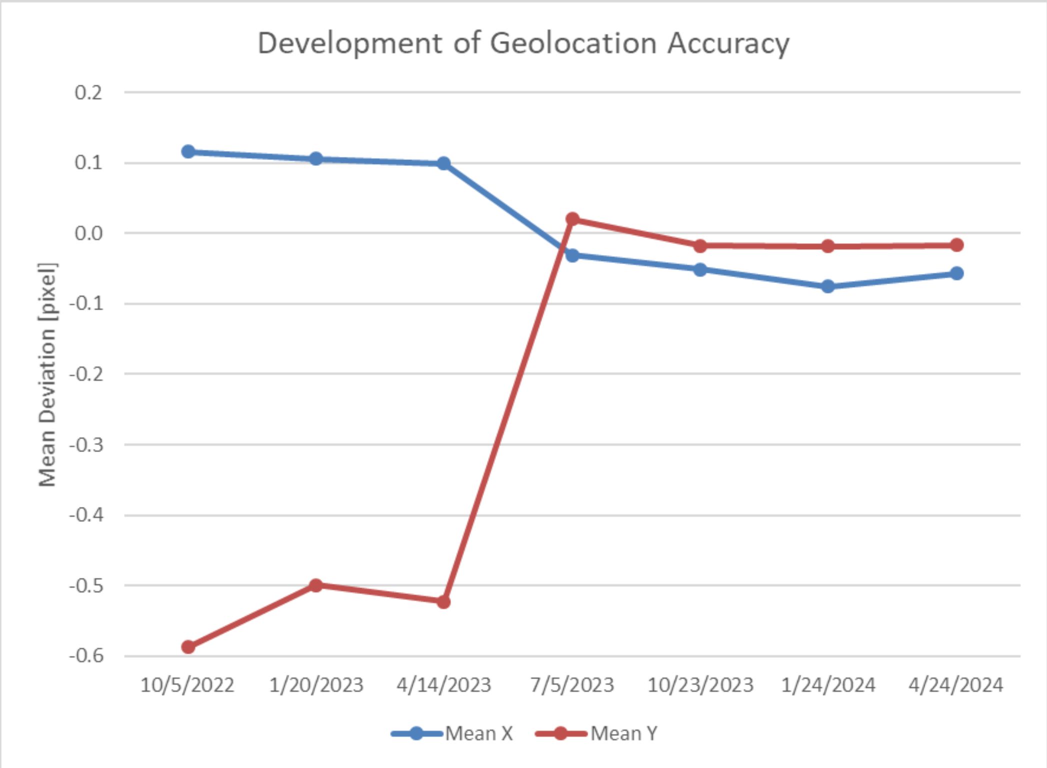
7.6.3.3 Development of geometric performance

Since the launch of EnMAP on April 1st 2022, the geometric performance has been improved significantly. This was achieved by different geometric calibrations and processor updates. Table 7-25 shows the measures performed, their date and their effect.

Date	Measure	Effect
01.08.2022	Fix of attitude processing	Improvement of absolute geolocation (w/o matching)
20.09.2022	Boresight Calibration	Improvement of absolute geolocation (w/o matching)
03.11.2022	1st Geometric Calibration	Improvement of absolute geolocation (w/o matching) Improvement of VNIR/SWIR co-registration (~0.8 pix -> ~0.4 pix)
11.02.2023	2nd Geometric Calibration	Improvement of VNIR/SWIR co-registration (~0.4 pix -> ~0.15 pix)
29.03.2023	Processor update (v01.02.00)	Improvement of VNIR/SWIR co-registration (~0.15 pix -> ~0.06 pix)
05.05.2023	Processor update (v01.03.01)	Improvement of geolocation accuracy

Table 7-25 Improvement of geometric performance

Figure 7-28 shows the development of the co-registration accuracy, measured as described in previous section. Again, after a significant improvement since commissioning phase, over the last report periods the accuracy has been very stable.



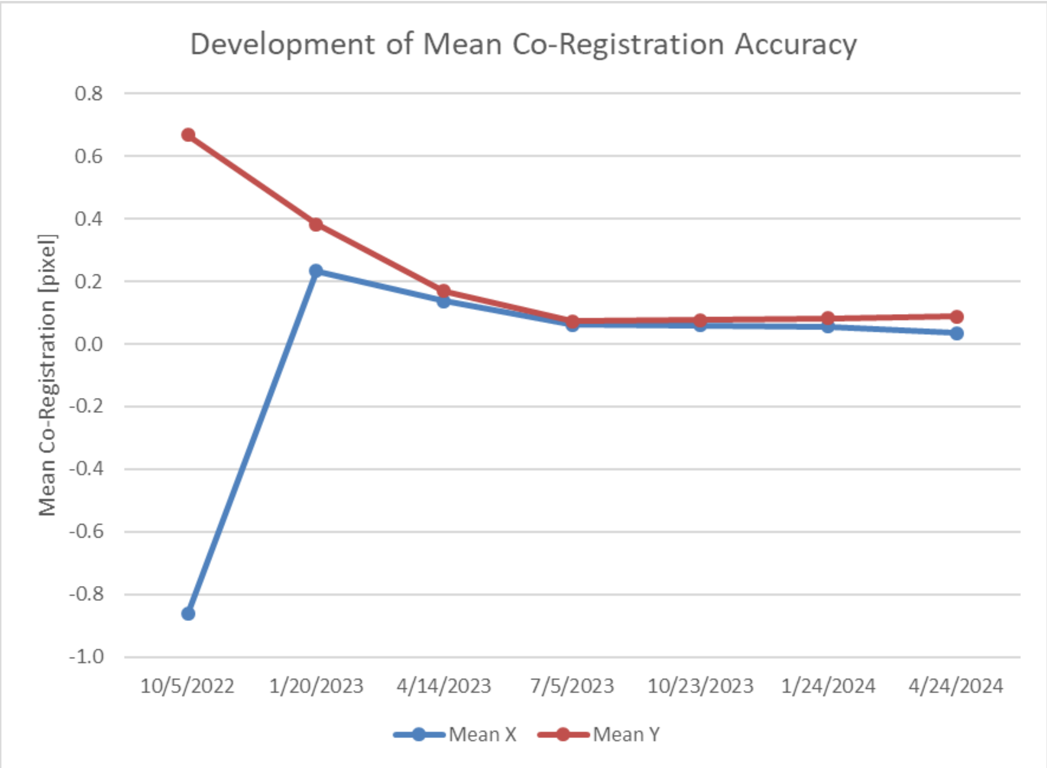


Figure 7-28 Development of co-registration accuracy based on the previous geometric QC reports

As most of the geometric processing – especially the matching against a reference image – is done on datatake level during L0 processing, the geometric accuracy and co-registration of data acquired earlier during the mission is not automatically improved when higher level products (L1B, L1C, L2A) are processed with the current processor version. However, during the currently ongoing L0 reprocessing of the whole archive, the geometric processing is executed with the latest processor version and geometric calibration table to make sure that the best geometric quality and co-registration is reached also for the reprocessed data. Users can recognize reprocessed data by checking the metadata tag **archivedVersion**: if the version is 01.03.00 or higher, then the geometric performance should be as analyzed in this report.

7.6.4 Level 2A

7.6.4.1 Validity of generated L2A "water" data

7.6.4.1.1 Analyzed scenes

The following scenes were taken into consideration:

DataTake - ID	Tile - ID	Location	L2A Option	Cirrus / Haze Removal	Overall Quality
35856	2	Lake Hume	Water mode, water type "clear"	Cirrus	Nominal
33417	2	Lucinda	Water mode, water type "clear"	Cirrus	Nominal
33232	2	Lake Hume	Water mode, water type "clear"	Cirrus	Nominal
28137	2	Lucinda	Water mode, water type "clear"	Cirrus	Nominal
23601	2	Lucinda	Water mode, water type "clear"	Cirrus	Nominal

The below listed parameters were checked for above mentioned scenes by EOMAP:

Parameter	Check
Masking (Land, Water, Clouds, etc.)	No issues found.
Adjacency correction	No issues found.
Retrieval of atmospheric properties	No issues found.
Cirrus – correction	No issues found.
Retrieval of water leaving reflectance	No issues found.
Quality Mask	No issues found.

In the following the scene **23601**, covering the area around Lucinda (Figure 7-29), is used to show some examples of the data checked here.

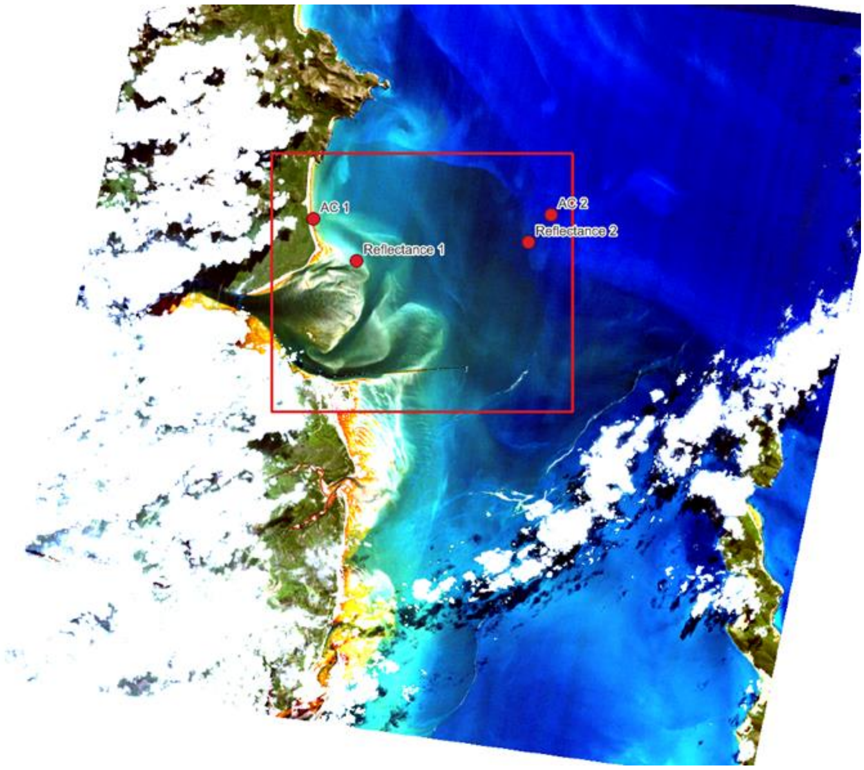


Figure 7-29 RGB - Quicklook of scene-ID 23601; The labeled dots show sample – locations for the following analysis; Red square surrounds the AOI for further analysis; Wavelengths for RGB: 611.02nm – 550.69nm – 463.73nm

The **coordinates** (WGS-84) for the sample – locations, shown in Figure 7-29, are as follows:

AC 1: -18.46802746 N, 146.32948828 E

AC 2: -18.46685842 N, 146.41821123 E

Reflectance 1: -18.48301608 N, 146.34553030 E

Reflectance 2: -18.47659345 N, 146.40973423 E

7.6.4.1.2 Data Checks

- **Masking**

First, the water mask is checked. The water body and the clouds, as well as shadows, are correctly masked (see Figure 7-30).

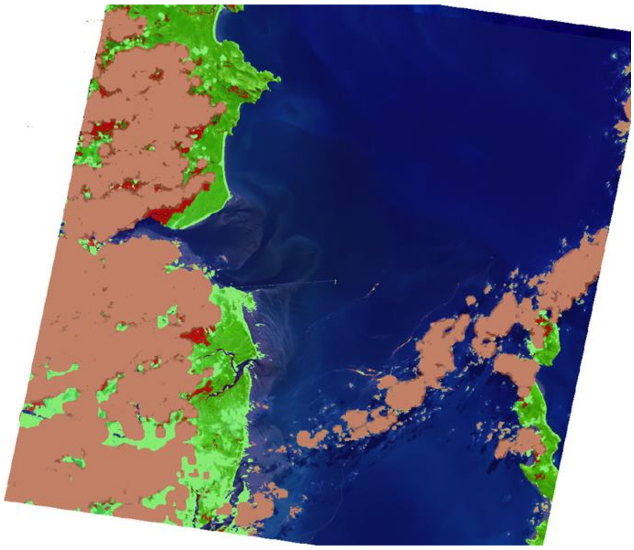


Figure 7-30 Geomask of scene-ID 23601; Land in green, shadow in red, clouds in brown, water in blue

- **Adjacency Correction**

Next, we check for the adjacency correction using the two sites 'AC1' and 'AC2' showed in Figure 7-29. In Figure 7-31, the influence of this correction on the spectrum is depicted. The adjacency effect is small, but noticeable in the sample-location AC1 (left image in Figure 7-31) close to the shore. For the location offshore the correction has almost no effect, as the two lines are practically on top of each other, as one would expect. Summing up, the adjacency correction works as expected.

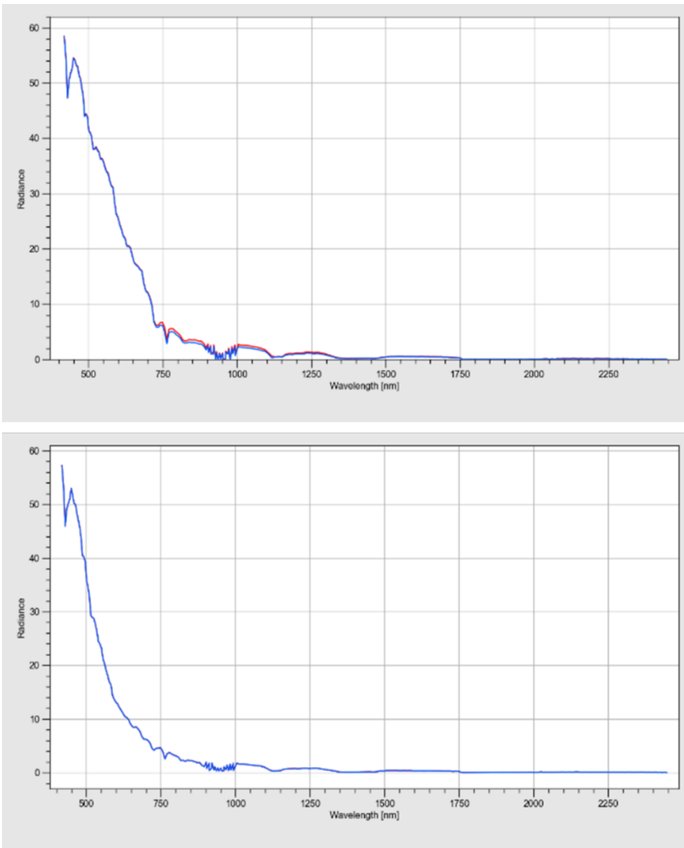


Figure 7-31 Red is the radiance without adjacency correction, blue corresponds to the spectrum after correction of scene-ID 23601; Upper: AC 1, Lower: AC 2

- **Quality Mask**

In Figure 7-32, the quality mask for the AOI within the scene is depicted. Note, that only those areas are shown, which were found to be of total quality of zero. In this scene, the calculated slope – values of around -3 are mainly responsible for the total quality value to be zero. Since within this scene, the AOT is found to be very low, at about 0.06, the mathematical effect of the slope is completely diminished. Thus, we would suggest updating the calculation of total quality in a way, so that in case of comparable low AOT – values, the minimum quality value for slope is > 0, e.g. 0.3. In doing so, we would ensure, that the value of total quality reflects the actual conditions, leading to such low AOT – values, but it is not set to zero just based on the slope.

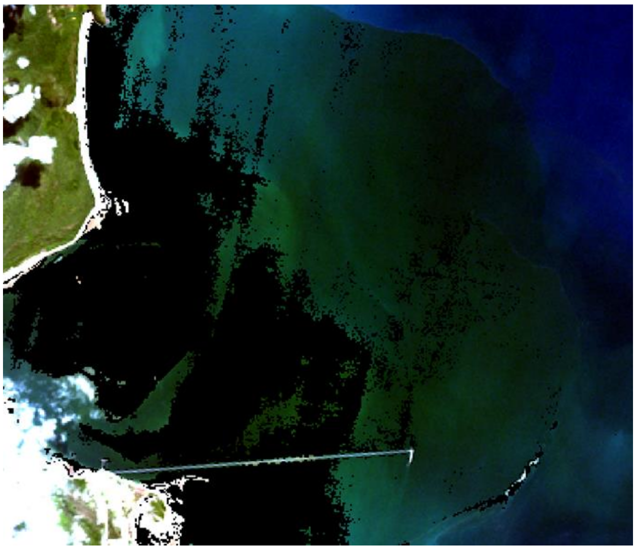


Figure 7-32 Quality mask of scene-ID 23601 for the AOI; Black are areas with total quality equals 0

- Reflectance Product

To get a better impression of the product water leaving reflectance as the final one, Figure 7-33 shows the reflectance using the RGB channels 611.02nm, 550.69nm and 463.73nm.

Figure 7-33 Water Leaving Reflectance of scene-ID 23601 for the AOI; Wavelengths for RGB: 611.02nm – 550.69nm – 463.73nm

For the two labeled locations in Figure 7-33, you can find the corresponding spectra in Figure 7-34.

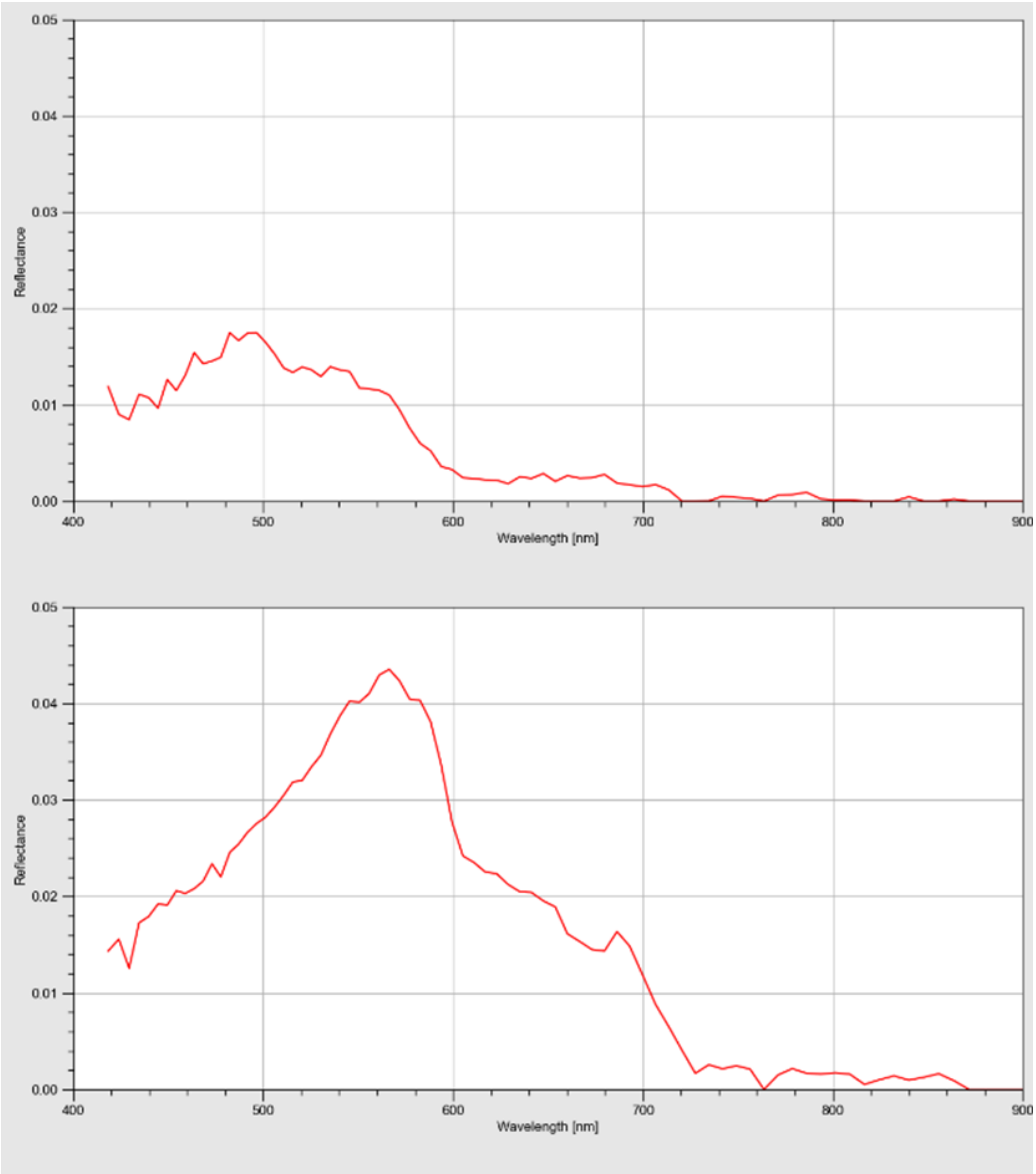


Figure 7-34 Water leaving reflectance of scene-ID 23601 for locations 'Reflectance 1' on the upper and 'Reflectance 2' on the lower

The upper plot depicts a spectrum sampled from a point located in the - more turbid water area (location Reflectance 1 in Figure 7-29). The contribution of the turbidity can be seen in the spectral region around wavelengths from 535.42nm to 588.17nm. Also, there is still some signal in the infrared region reflecting the shallow water column. The bottom plot shows a curve characteristic for more clear and deeper water (location 'Reflection 2' in Figure 7-29).

Overall, though the atmospheric conditions are challenging, the atmospheric correction, as well as the retrieval of the water leaving reflectance work as expected.

7.6.4.1.3 Resolved issues and details for the known issues

- **Solved | Signal Peaks in the blue spectral region**

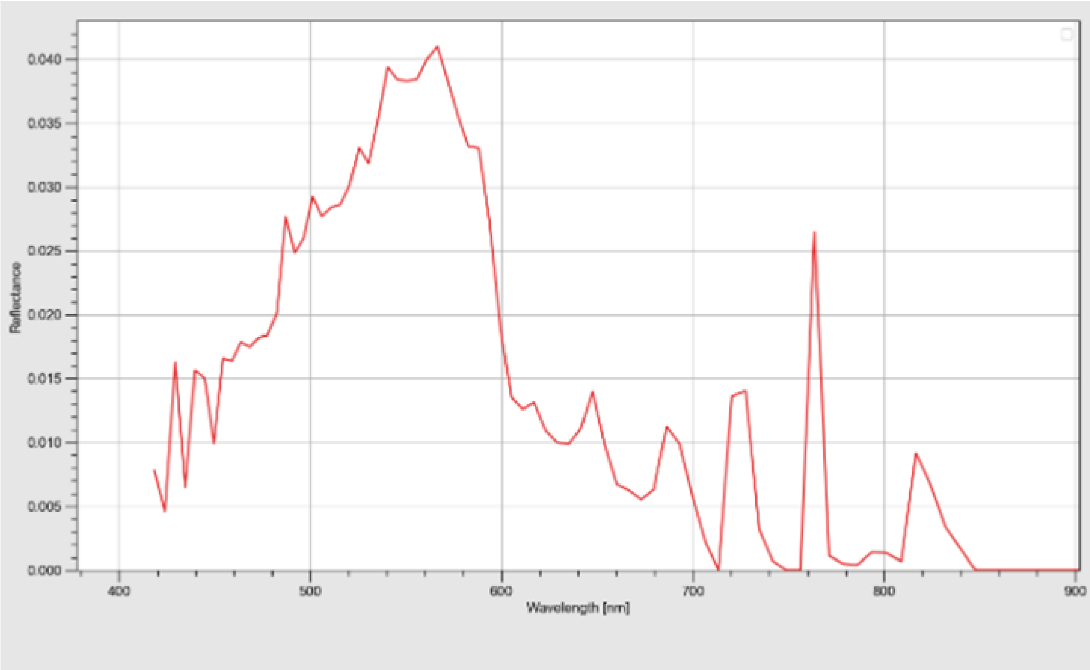


Figure 7-35 Water leaving reflectance for scene-ID 48673, checked in the previous report, and location "Reflectance 1" in Figure 7-29

Figure 7-33 shows the water leaving reflectance, sampled at location Reflectance 1 in Figure 7-29, based on the scene-ID 48673. Details to this plot were already described and discussed within the report of quartal 4, 2023. Important here are the peaks around the wavelengths 429.46nm, 439.76nm, 487.09nm, and 501.24nm. In the most recent processor version, the identified problem (see previous report) is solved and therefore, we were able to reduce the amplitude of those peaks distinctly (see Figure 7-34 for reference).

- **Solved | Glint – Quality band**

To evaluate the bug-fix in context of the sun-glint band of the quality mask, the scene with ID 49784 was chosen for further analysis.

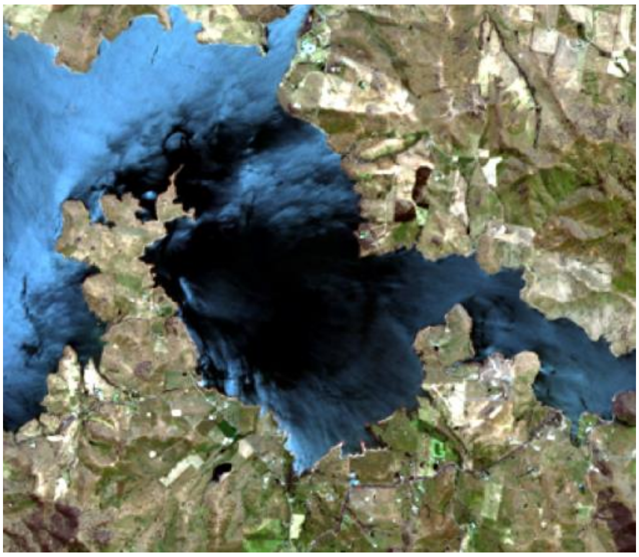


Figure 7-36 Quicklook for scene-ID 49784; Wavelengths for RGB: 611.02nm – 550.69nm – 463.73nm

Figure 7-36 depicts a RGB – Quicklook of this scene. Obviously, sun-glint is present in most of the water areas. The most recent version of the MIP – processor implements an update to fix known problems in context of masking areas, affected by the effect of sun-glint.

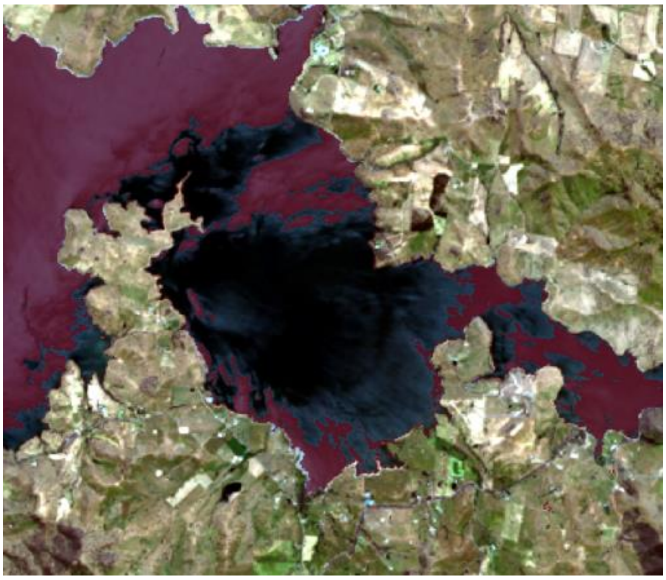


Figure 7-37 Masked areas affected by sun-glint; Mask in red

Figure 7-37 shows the resulting mask, applying the mentioned updated version of the sun-glint detection within MIP. As can be seen, the masking now works as we expect it to in detecting areas where sun-glint hampers any further analysis of the respective signal.

- **Clarification | Cirrus Detection and Correction**

Since some users raised questions about the functionality of detecting cirrus clouds through MIP, the following is intended to clarify those.

For this purpose, we choose the scene with ID 29863 for further analysis.

Figure 7-38 Quicklook for scene-ID 29863; Wavelengths for RGB: 611.02nm – 550.69nm – 463.73nm

Figure 7-38 depicts a sub – area of the chosen scene, clearly showing the dense cover of the water areas with cirrus clouds, thus appropriate for testing and explaining.

As initial input, the masking procedure takes the mask, already created by the land-processor (PACO) holding information not only about land – areas, but also from those covered by cirrus clouds. This information is then combined with the water – areas to define those, which are covered by cirrus clouds and are actual water - areas.

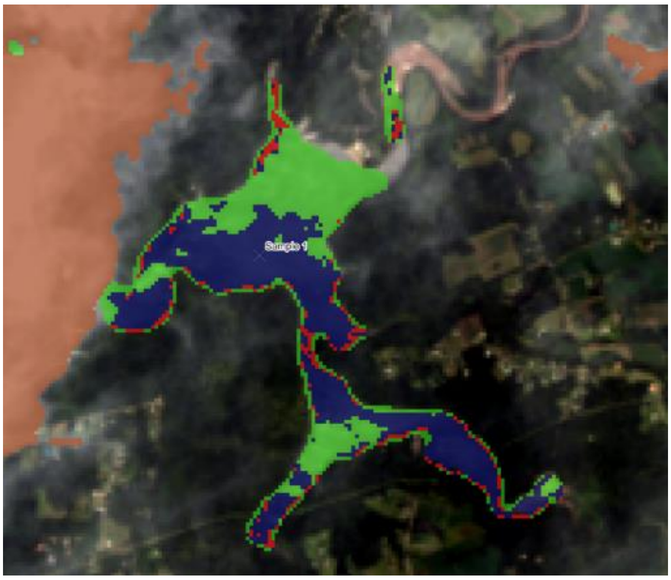


Figure 7-39 Mask holding information about clouded and water areas; blue: water, green: land, red: shadow

The identified areas are then used to calculate the effects, the clouds do have on the signal.

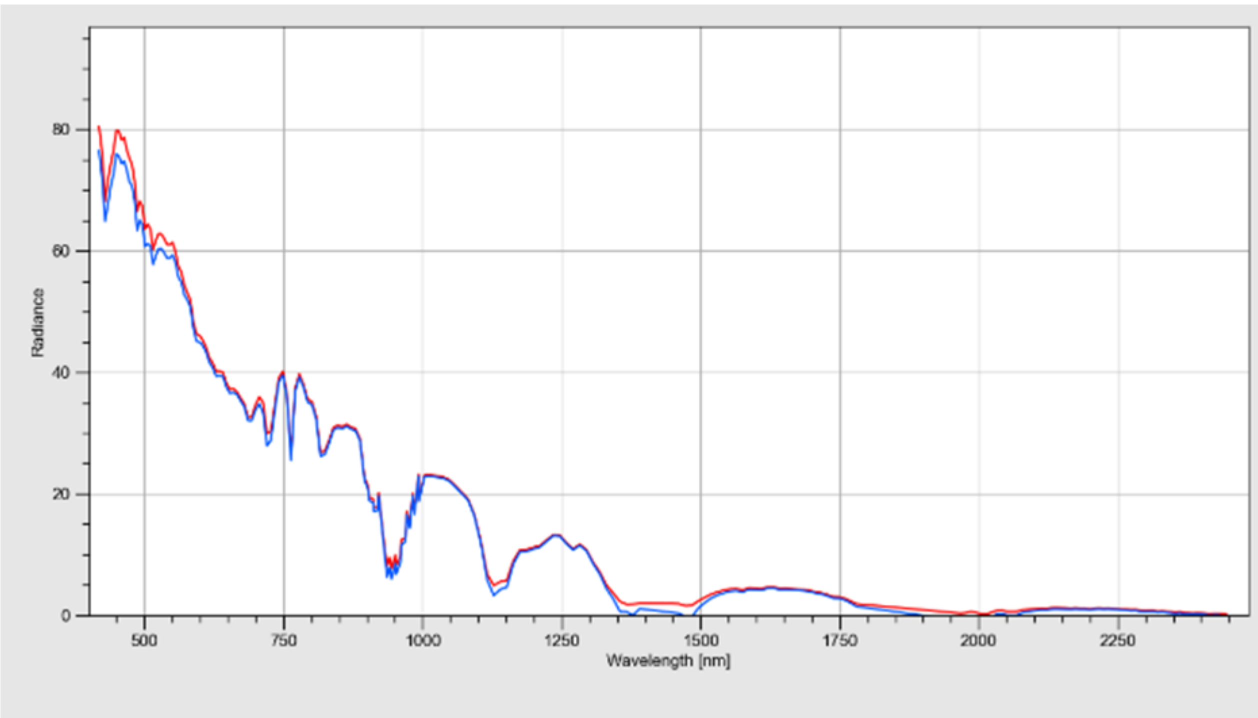


Figure 7-40 Spectra, showing the effect of cirrus – correction for the locations depicted in Figure 7-39 ; Location: Sample 1; Red: Original, Blue: Corrected

This enables MIP to correct for those effects. Important to note is, that MIP applies the respective correction on all the water pixels. The effect of the correction procedure on the spectrum is shown in Figure 7-40. The sample – location for this plot is placed within the water – area and therefore is corrected for the effect of the cirrus clouds. For a detailed description of the whole correction process, please take a look at the following document: https://www.enmap.org/data/doc/EN-PCV-TN-6008_Level_2A_Processor_Atmospheric_Correction_Water.pdf

7.6.4.2 **Validity of generated L2A "land" data**

7.6.4.2.1 Analyzed scenes

Within the time interval between 2024-01-01 and 2024-03-31, an interactive in-depth analysis has been conducted for the following scenes:

datatakeID	tileID	date	location	L2A option	cirrus and haze removal	processor version	Overall Quality	Quality Atm
64582	16	10.03.2024	Somalia	Land	No	V010402	Nominal	Nominal
54653	09	21.12.2023	Spain	Combined	No	V010401	Nominal	Reduced
54653	10	21.12.2023	Spain	Combined	No	V010401	Nominal	Reduced
01034	09	10.06.2022	Argentina	Combined	No	V010401	Nominal	Low

Table 7-26 Datatake ID of analyzed land products

For the selection of L2a data, care was taken to ensure a high degree of variety with respect to the geographical location of the data, external conditions (cloud cover) during the data take and processing parameters.

7.6.4.2.2 Data Checks

- **Checking cloud & cloud shadow masks, as well as BOA_ref spectra**

As shown in Figure 7-41 for the DT64582, the bigger clouds are masked correctly, while smaller and thin clouds are missing in the mask, especially when over bright surfaces. Nevertheless, these problems with small and thin clouds are as expected due to the conservative selection of the thresholding to avoid false positives. The cloud shadow mask includes the shaded areas of additional clouds, and is thus correct.

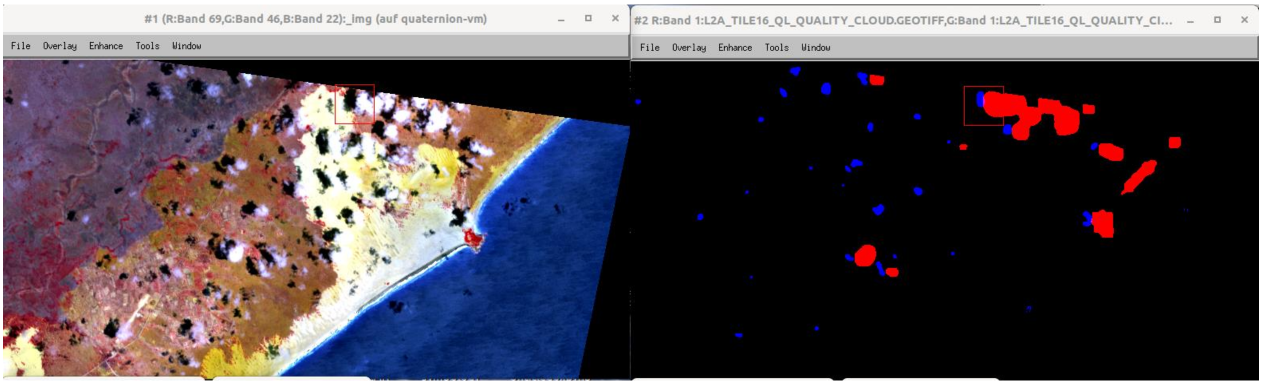


Figure 7-41 Left side: EnMAP L2A CIR composite of scene DT64582. Right side: cloud mask in red, cloud shadow mask in blue.

The retrieved BOA_ref spectra for this scene are depicted in Figure 7-42, showing the expected shape and magnitude of the various surface materials. The depicted water spectrum at the shoreline is overall atypically high, but it is worth pointing out that this is turbid water at a bright beach, and the L2A was run in land mode only. Also as shown in the figure, the overlapping region between VNIR and SWIR is spiky - as expected; this issue of the EnMAP radiometry is under investigation.

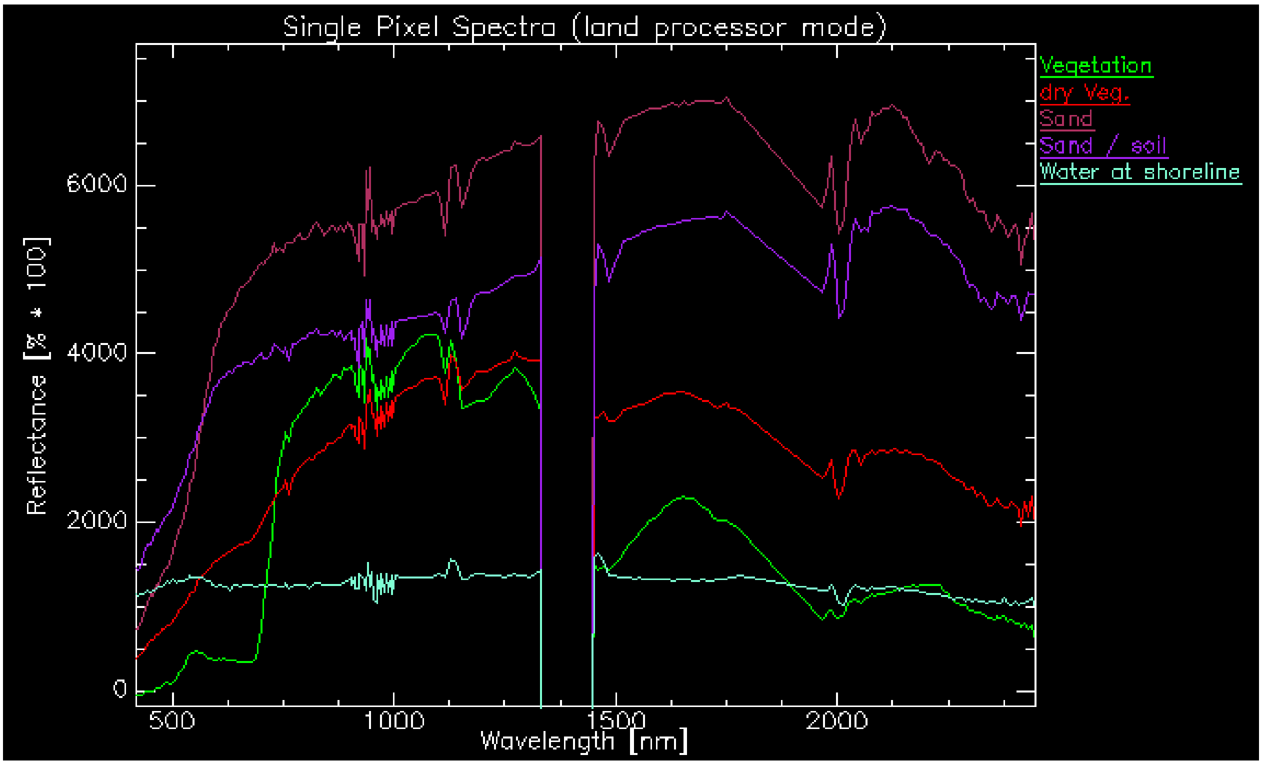


Figure 7-42 Image spectra from scene DT64582

- **Checking cloud & cloud shadow masks, as well as BOA_ref spectra, atm.quality reduced**

Also for the DT54653 tile 09 with a “reduced atm. Quality” rating, the same tests are conducted. The cloud and cloud shadow mask as depicted in Figure 7-43, showing some undetected cloud shadows. Due to the rough mountainous terrain (extension of the Sierra Nevada mountain range) having a large terrain shadowing influence, this can be partially explained. Some bright urban areas are masked as cloud, which is also as expected. The BOA_ref spectra in Figure 7-44 all show the typical shape and magnitude, also including the know issue of the VNIR-SWIR overlap region as well as residual CO2 features around 2000 nm.

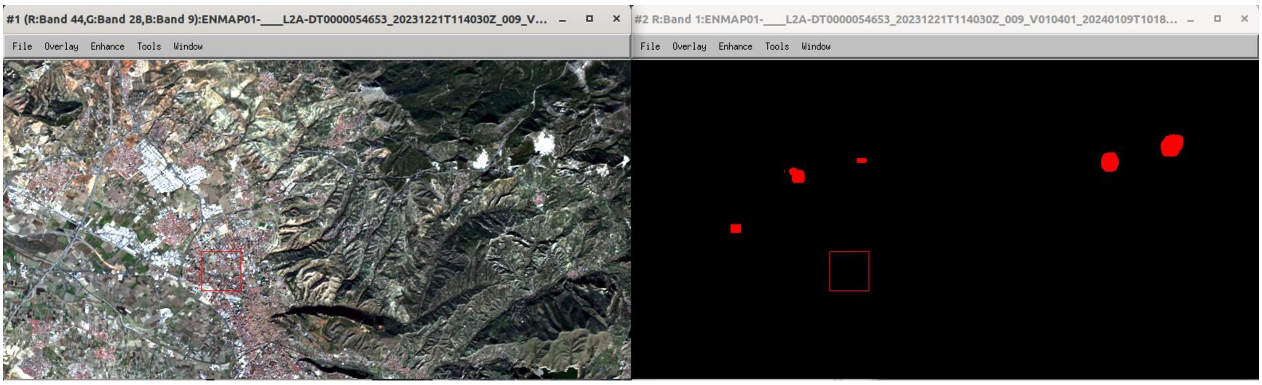


Figure 7-43 Left side: EnMAP L2A True Color composite of scene DT54653_09. Right side: cloud mask in red, cloud shadow mask in blue.

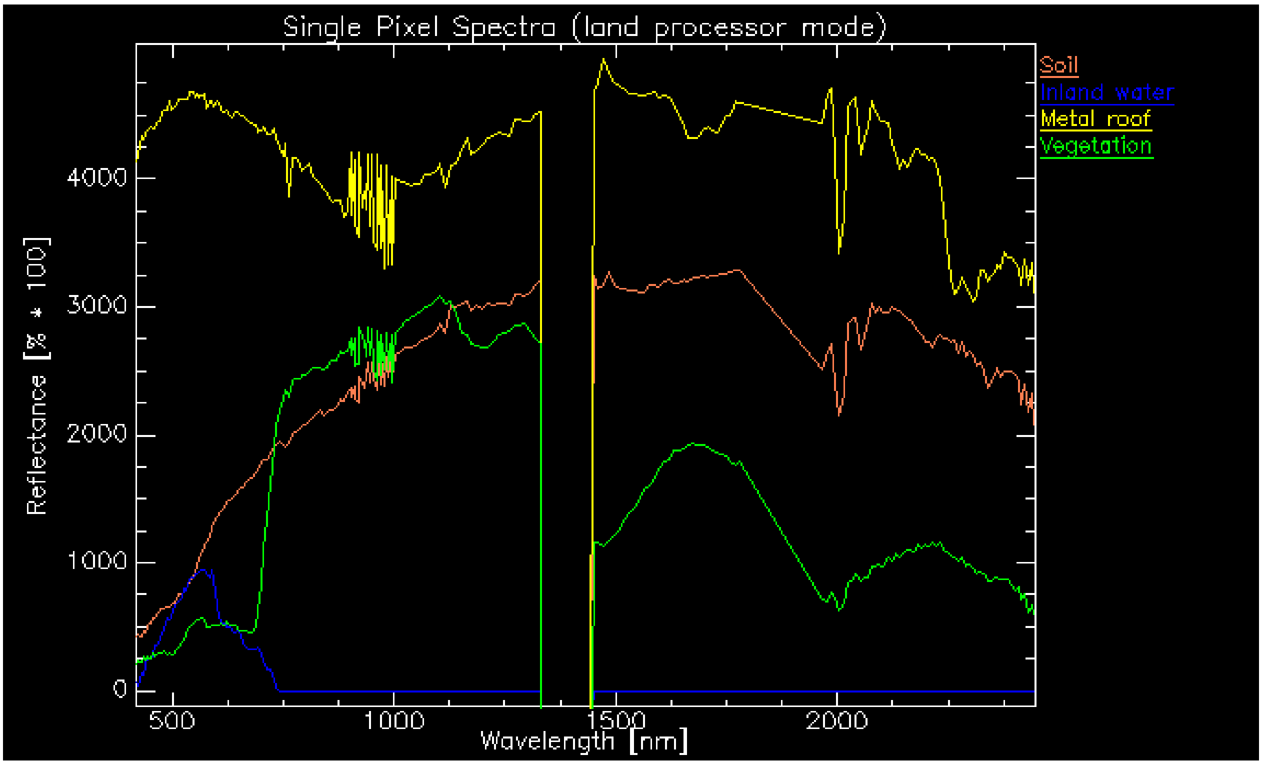


Figure 7-44 Image spectra from scene DT54653_09

- **Checking cloud & cloud shadow masks, as well as BOA_ref spectra**

The consistency in these results is given for the adjacent tile 10 of DT54653. As shown in Figure 7-45, for this scene all clouds are correctly masked and no additional image parts are included in the mask. Also the shape and magnitude of the image spectra (Figure 7-46) are as expected, with the same known shortcomings in the VNIR-SWIR overlap and the CO2 feature present as described before.

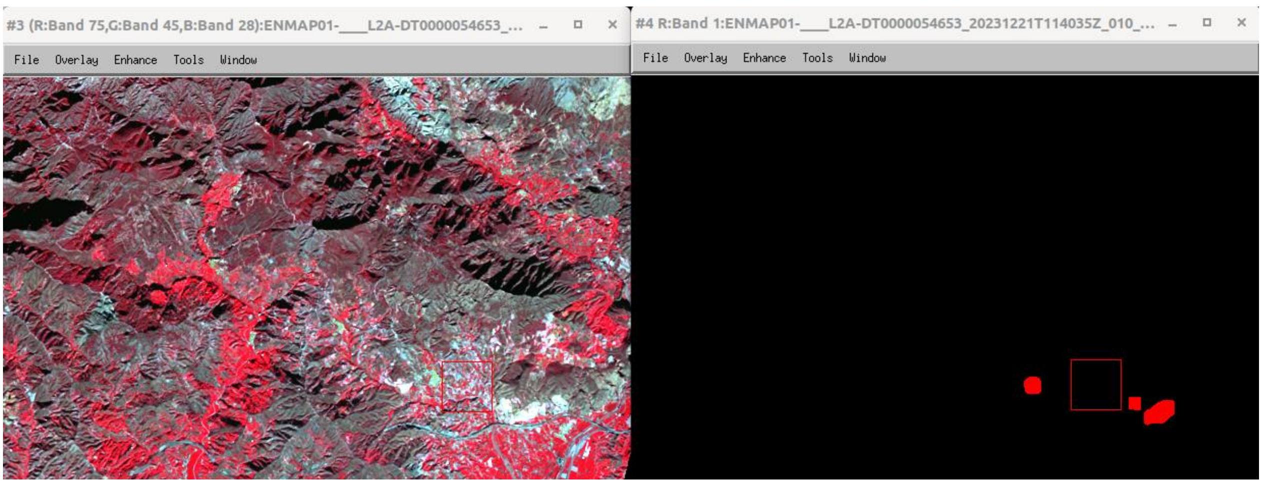


Figure 7-45 Left side: EnMAP L2A CIR composite of scene DT54653_10. Right side: cloud mask in red, cloud shadow mask in blue.

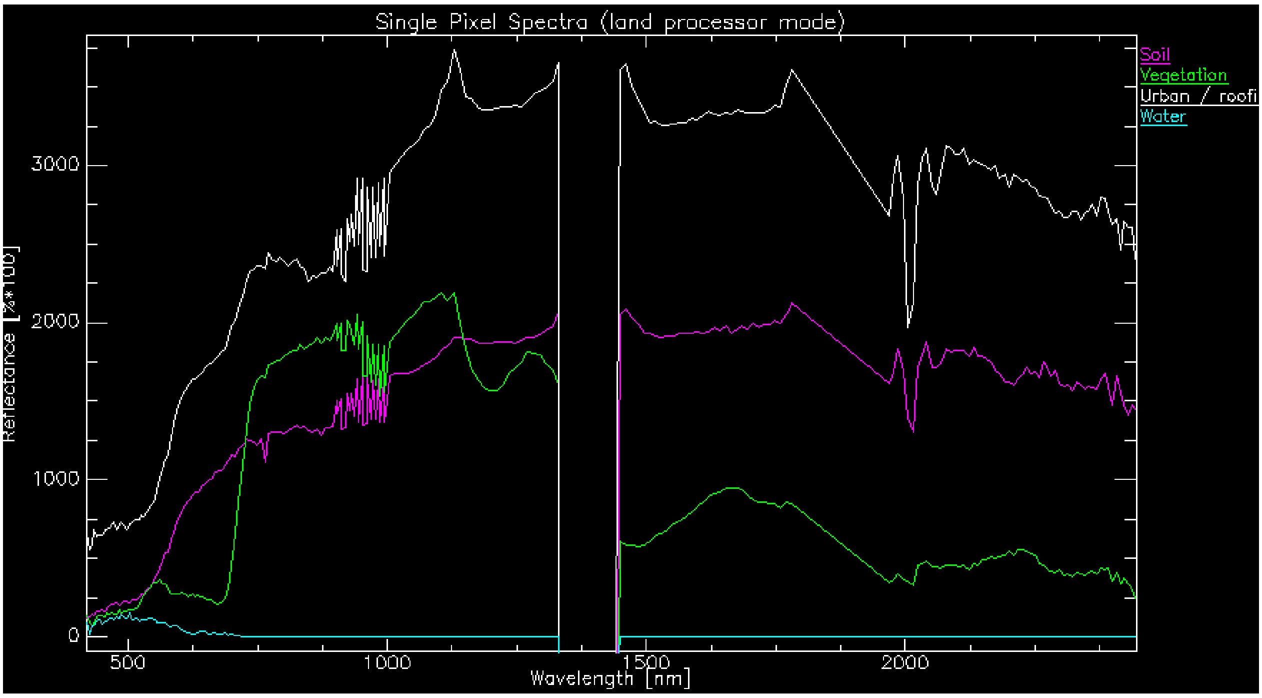


Figure 7-46 Image spectra from scene DT54653_10

- **Checking consistency in BOA_ref spectra in neighboring tiles**

For both tiles 09 and 10 of the DT54653 (Figure 7-47), also the consistency in BOA_ref is investigated. Depicted in Figure 7-48 are BOA_ref spectra from both tiles located close to the overlapping region, and originating from similar land cover types. Thus these spectra are expected to be similar, but are not expected to be identical. As shown in Figure 7-48, all sample spectra are quite similar in shape and magnitude, as well as in the previously described known issues. The conclusion is thus that the L2A processing is consistent across adjacent tiles.

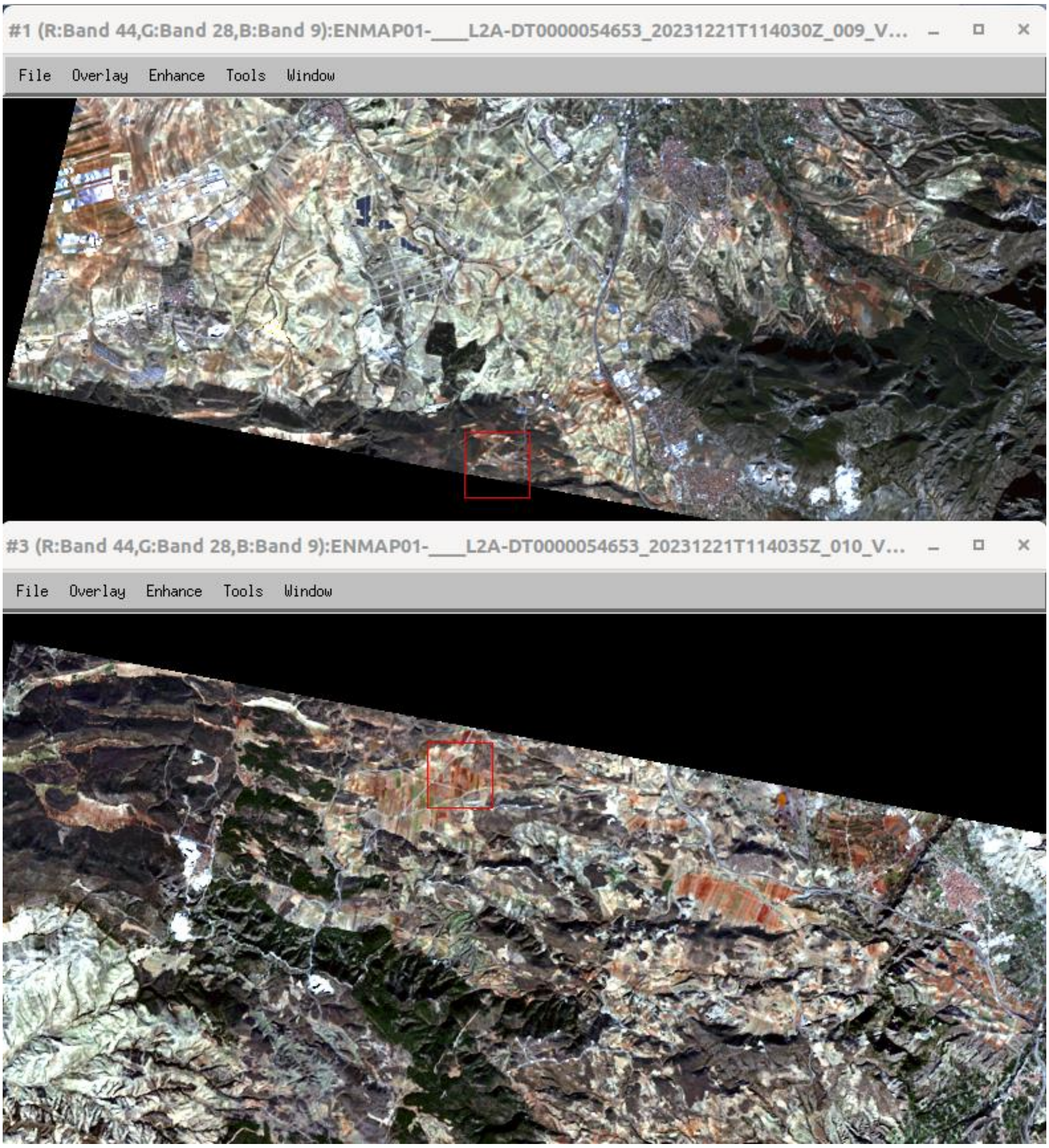


Figure 7-47 Top: true Color composite of scene DT54653_09; Bottom: True Color composite of adjacent tile DT54653_10

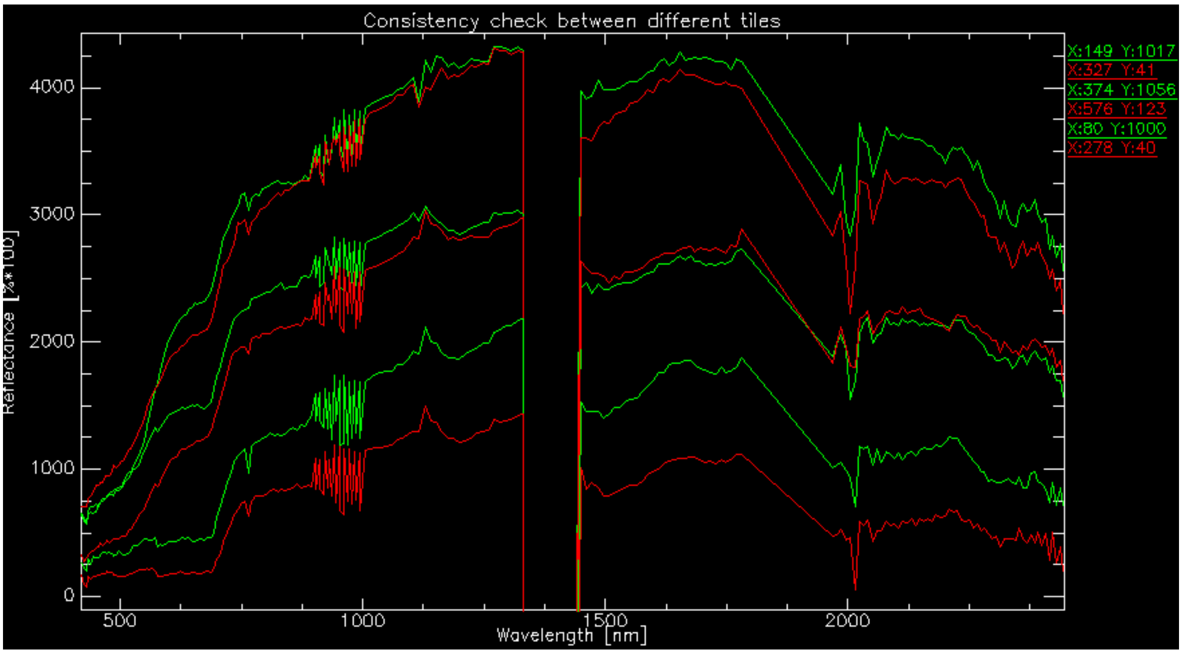


Figure 7-48 Image spectra from adjacent tiles 09 (green) and 10 (red) of scene DT54653 Note: spectra were acquired close to tile borders and for similar land cover classes, so these are not from identical pixels.

- **Check for high reflectance targets reg. artefacts in the first VIS bands possibly introduced by L2A and/or L1B**

The background of these checks was user feedback regarding the shape of the first VIS bands for high reflectance targets. I.e., that the shape of the BOA_ref spectra was too high. Thus an existing salt lake scene DT01034 (Figure 7-49) is used to check for artefacts and for the variability in these first bands. Note that due to these atypical and extreme scene content and atm. conditions, the atmospheric quality rating is "low".

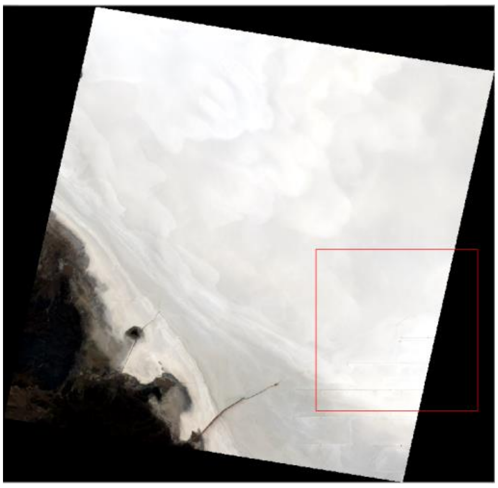


Figure 7-49 EnMAP scene DT01034, True Color composite, non-linear stretch

As shown in Figure 7-50, as expected the known artefacts show up: for spectra close to saturation, spikes appear in the range of the SWIR sensor. For unsaturated pixels no spikes are present so the data is generally valid. Next, in the region of VNIR-SWIR overlap, the well-know artefacts occur only for low and medium reflectance targets, but not for high reflectance targets, which is in line with the assumption of non-linearities at lower radiance levels. Finally, as within this scene no DDV pixels are present and thus a default AOT is used, an overcorrection for aerosols occur, leading to slightly negative reflectance values in the first bands which are most influenced by aerosols. Also this behavior is well known and as expected, and is documented by the atm. Quality rating of “low” in the metadata.

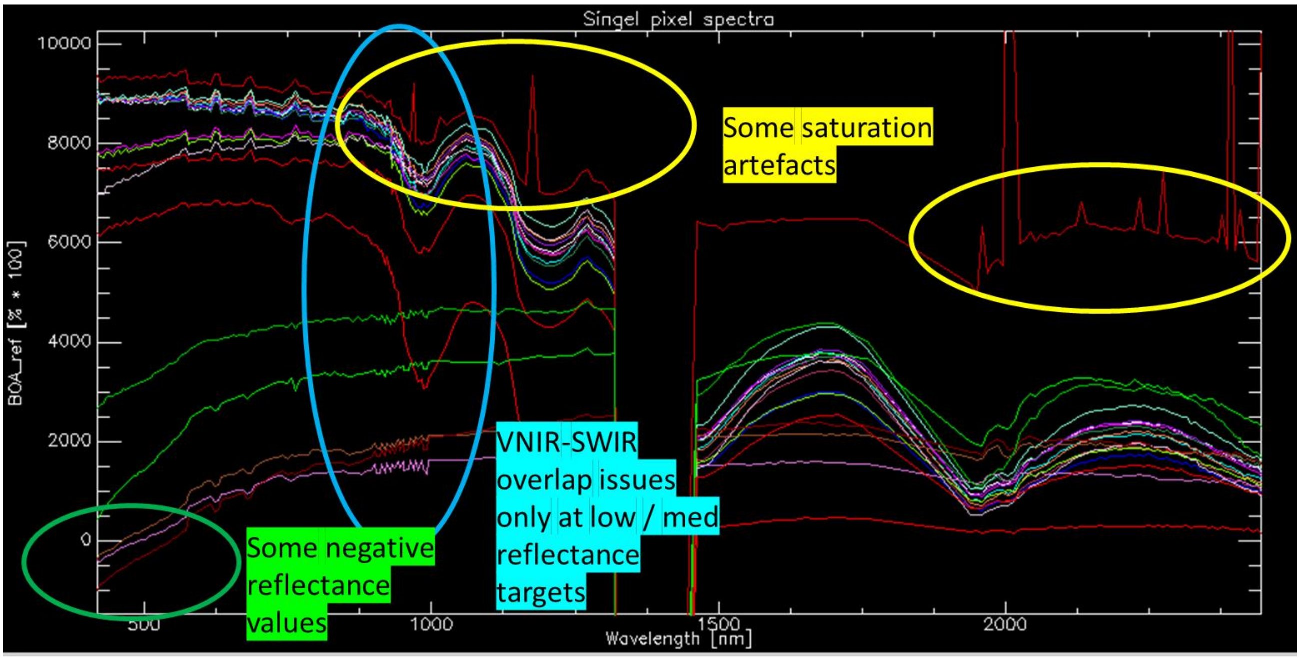


Figure 7-50 Image spectra from scene DT01034 including expected artefacts

As a final test regarding the shape in the first VIS bands, different targets in spatial proximity where chosen (Figure 7-51). The shape of these spectra varies from flat to a more or less increasing shape with longer wavelengths. One can conclude that in case of an incorrect radiometric correction, such expected variability would not occur. So no indication for calibration shortcomings was found.

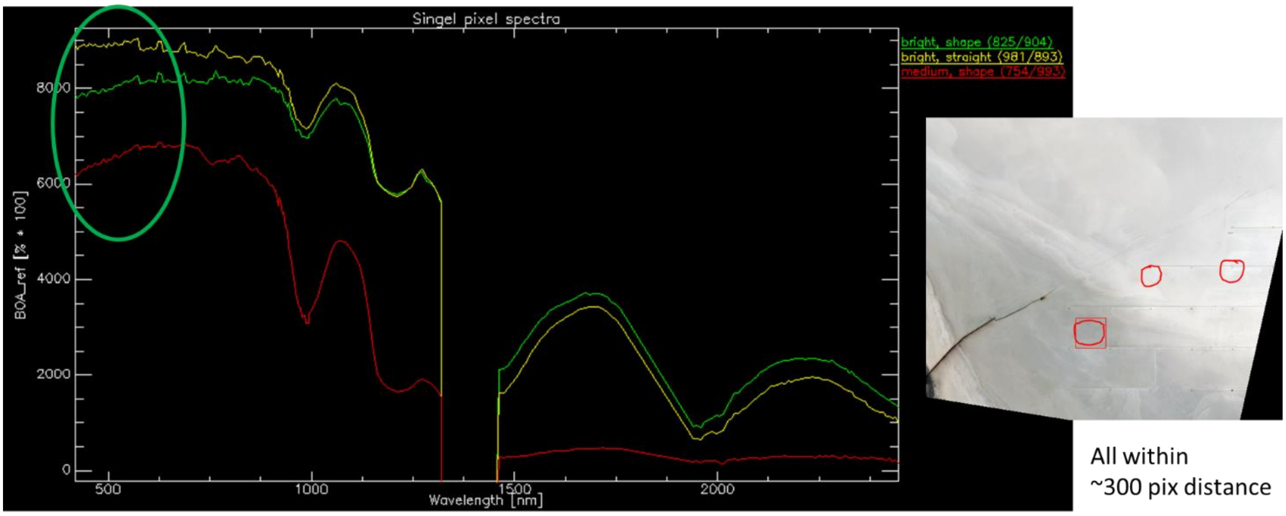


Figure 7-51 Check if radiometric calibration affects first bands of the VIS range – as expected, shape does vary within a spatial proximity, so no indication for such shortcomings in radiometric calibration.

8 External Product Validation

All standard quality parameters were monitored by default since no special events or anomalies occurred during the reporting period. EnMAP products from the latest available processor and archiving versions were validated. Five in-situ matchups not integrated in the last quarter were completed, and new ones were coordinated, further enhancing the significance of the independent validation efforts.

8.1 Level 1B

The following validation scenarios were performed to validate about 210 Level 1B products in the reporting period:

- TOA Radiance
- Spatially coherent radiometric miscalibration (striping artifacts; along- and across-track)
- Signal-to-Noise Ratio (SNR)
- Cross-matchups with EnMAP, EMIT, and PRISMA

The latest TOA Radiance comparisons confirmed that the radiometric mismatch is still < 5% RMSE. No significant changes based on earth datatake validation were indicated.

Also, VNIR and SWIR across-track radiometric miscalibration are on a level that does not influence most applications. Only some slight residual low-frequency across-track undulations can be detected for homogeneous scenes. All mentioned artifacts are well within the mission requirements of < 5 %.

The update of the SNR assessment included nine additional scenes and confirmed that the SNR achieved from earth datatakes is stable. The mission requirements (VNIR > 343:1 @495 nm SSD 4.7 nm; SWIR > 137:1 @2200 nm & SSD 8.4 nm) were still fulfilled.

Keystone was not checked during this reporting period.

The cross-validation between PRISMA, EMIT, and EnMAP was extended with five more matching scenes, which confirmed the initial validation from the last MQR. The TOA reflectance fit between the missions is within <10% TOA reflectance. The edges of the strong atmospheric absorptions show more significant deviations. Additional matchups will consolidate the statistics and the relative evaluation of EnMAP compared to the other systems in the future.

8.2 Level 1C

The following Level 1C validation scenarios have been performed:

- VNIR-to-SWIR spatial co-registration
- Absolute spatial accuracy

The geometric co-registration between VNIR-to-SWIR for archived versions >= 01.04.00 has reached a stable level with an RMSE around 3.5 m in X and Y direction well inside the mission requirements of < 30 % of a pixel.

No significant changes compared to the last MQR have been recognized for the absolute spatial accuracy validation.

8.3 Level 2A

During the reporting period, five in-situ matchups were added to the L2A land and water quality assessment.

Land

The additional measurements stabilized the monitoring trend for the respective validation and confirmed that the RMSE is generally still within the mission requirements for BOA reflectance. For shorter wavelengths (< 500 nm) and greater wavelengths (> 2250) nm, the RMSE is > 5%. This is due, on the one hand, to many sites without DDV and an associated fallback to a standard atmospheric AOT value in the EnMAP atmospheric correction. On the other hand, there is a tendency towards very low reflectance levels in these wavelength domains. However, the in-situ measurements also show more significant uncertainties overall in these wavelength ranges, and thus, the requirements have to be set into context in this regard.

Water

Also, several L2A normalized water leaving matchups were generated and analyzed, and all confirmed that the mission requirements were still fulfilled. Since the atmospheric correction did not distinguish between clear, turbid, and high-turbid waters until the update to version 01.04.02 on 16.03.2024, most images are still processed for the same optical water type, resulting in slightly higher residuals between 450-550 nm. This was fixed at the end reporting period and will be analyzed in more detail in the next period.

8.4 Summary of External Product Monitoring

All validation and quality monitoring efforts during the reporting period indicated that the product quality is stable and all respective mission requirements are fulfilled.

9 Others

EnMAP Mission Operations and Status Publications:

EnMAP Mission Operations and Status Presentations:

- Martin Bachmann, und Miguel Pato, und Emiliano Carmona, (2024) EnMAP Mission Status and Updates. ESA TRUTHS Mission Advisory Group, 2024-01-17 - 2024-01-18, Noordwijk & Online. https://elib.dlr.de/202399/
- Nicole Pinnel, EnMAP overview at ISSI Working Group Meeting in Bern, 7.02.2024.
- Emiliano Carmona, EnMAP Operation Status at EnSAG Meeting, 16.01.2024.