

The Ground Segment of the EnMAP Mission: from Tasking to Product Download

E. Carmona¹, S. Engelbrecht², M. Habermeyer², H. Mühle², M. Pato¹, N. Pinnel², K. Wirth³ and the EnMAP Ground Segment Team

¹ Remote Sensing Technology Institute, DLR, 82234 Weßling, Germany

² German Remote Sensing Data Center, DLR, 82234 Weßling, Germany

³ German Space Operations Center, DLR, 82234 Weßling, Germany



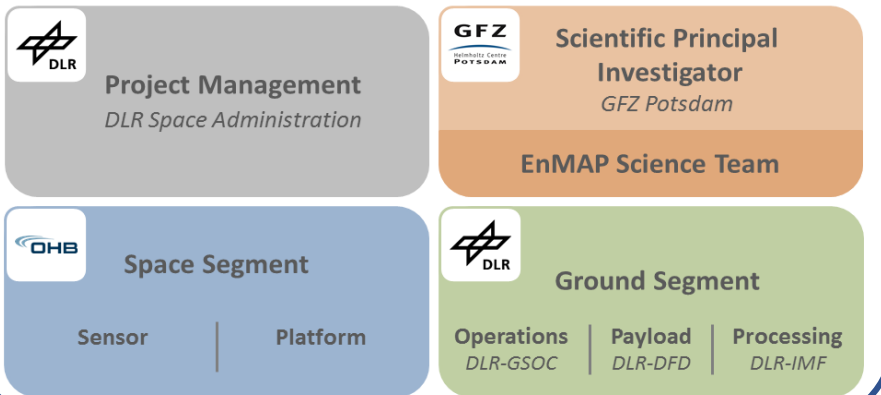
1st EnMAP User Workshop
10 – 11 October 2023

The EnMAP Ground Segment



- Under DLR responsibility and led by the Earth Observation Center (DFD and IMF institutes) and the German Space Operation Center (GSOC)

EnMAP Mission



The EnMAP Ground Segment



Ground Segment

Operations
DLR-GSOC

Payload
DLR-DFD

Processing
DLR-IMF

- Under DLR responsibility and led by the Earth Observation Center (DFD and IMF institutes) and the German Space Operation Center (GSOC)
 - **GSOC:** Mission operations, generate and send telecommands, receive telemetry, flight dynamics, mission planning



The EnMAP Ground Segment



Ground Segment

Operations
DLR-GSOC

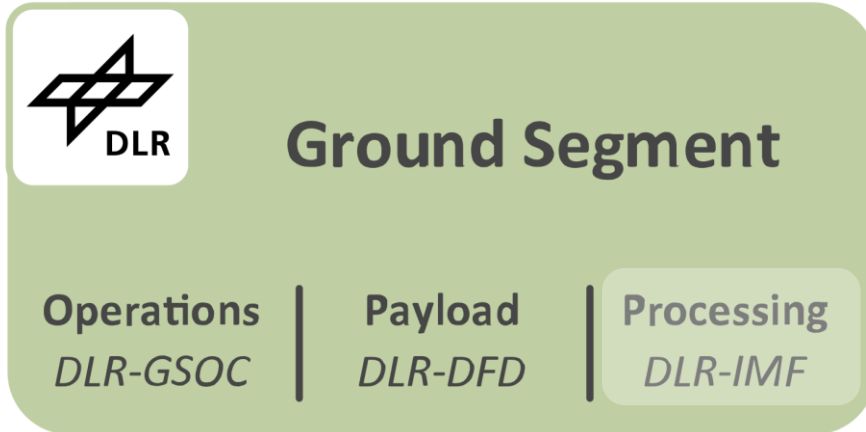
Payload
DLR-DFD

Processing
DLR-IMF

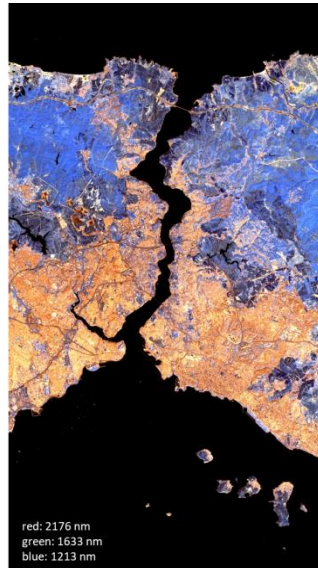
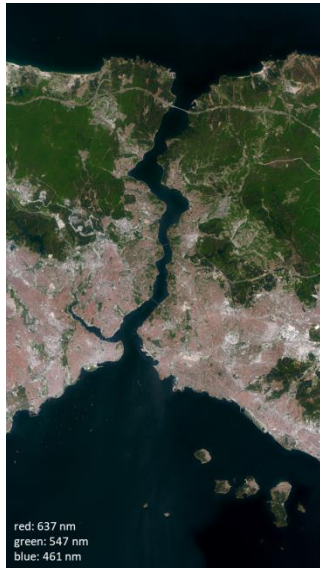
- Under DLR responsibility and led by the Earth Observation Center (DFD and IMF institutes) and the German Space Operation Center (GSOC)
 - **GSOC:** Mission operations, generate and send telecommands, receive telemetry, flight dynamics, mission planning
 - **DFD:** Payload data reception, data processing, data archiving and user interfaces (Instrument Planning and EOWEB)



The EnMAP Ground Segment



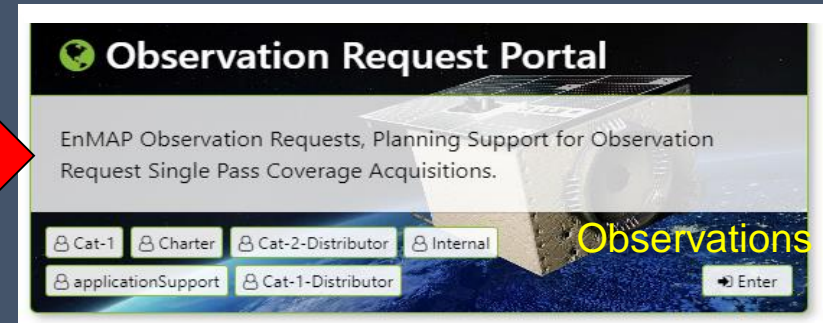
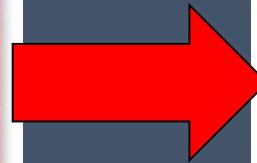
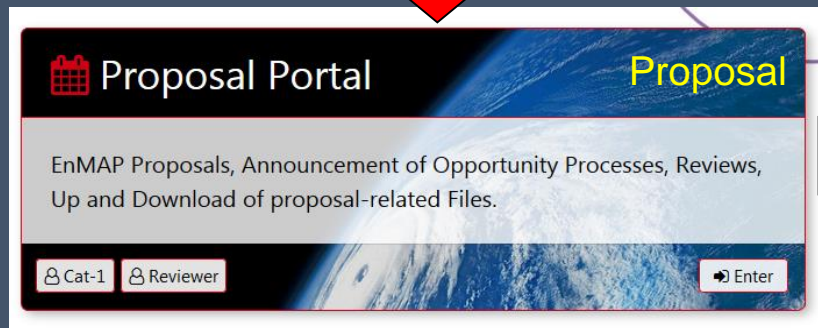
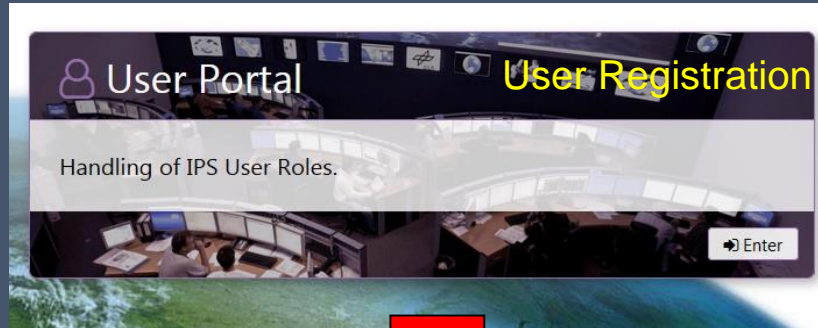
- Under DLR responsibility and led by the Earth Observation Center (DFD and IMF institutes) and the German Space Operation Center (GSOC)
 - **GSOC:** Mission operations, generate and send telecommands, receive telemetry, flight dynamics, mission planning
 - **DFD:** Payload data reception, data processing, data archiving and user interfaces (Instrument Planning and EOWEB)
 - **IMF:** Processor development, in-flight calibration and quality control (processed data and instrument)



How to register

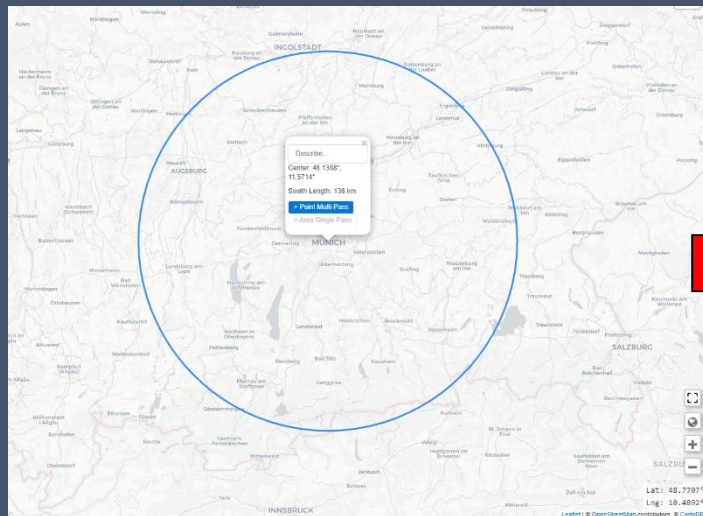
EnMAP Instrument Planning Portal <https://planning.enmap.org/>

Where users can **register**, submit proposals (necessary to task the instrument) and request future EnMAP acquisitions



How to plan an EnMAP acquisition

EnMAP Instrument Planning Portal <https://planning.enmap.org/>



Mode: POINT MULTI PASS

Datatake Parameters changeable for each datatake anytime before submission...

Start Date (UTC Time): 2023-07-04 End Date (UTC Time): 2023-07-23

Off Nadir Angle: -15° to +15° Path Direction: descending Swath Length (km): 47

Sunglint Default Parameters used for all datatakes...

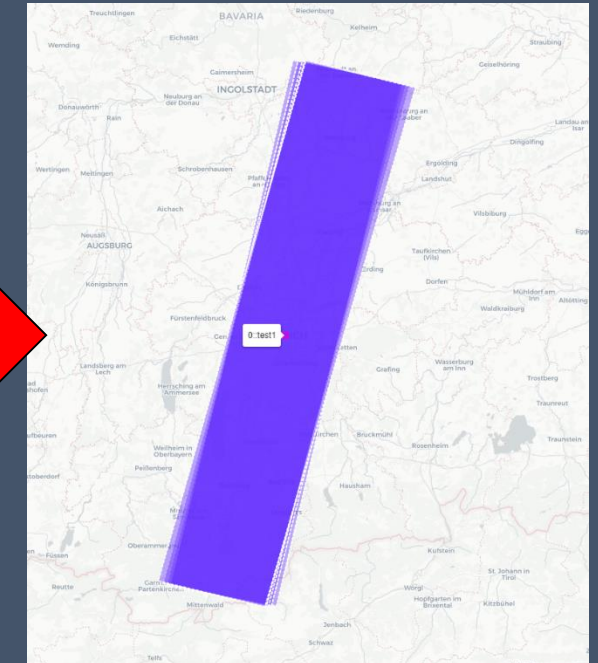
Model: union: predicted sun glitter... Preview Sunglint: do not return sunglint pixel... Windspeed(s): × 3 m/s × 8 m/s

Coverage Threshold: 100 % Intensity Threshold: 100 % Threshold Type: avoid interference

Cloud Coverage Default Parameters used for all datatakes...

Preview Clouds: do not return clo... Threshold Type: avoid interference Intensity Threshold: 100 % Coverage Threshold: 20 %

[Save & Calculate now](#)



Creating a request does not guarantee entering the satellite schedule. Tasking decision depends on cloud statistics and forecast, satellite restrictions (e.g. maneuvers), priority and quota and number of competing requests

How to get archived EnMAP data

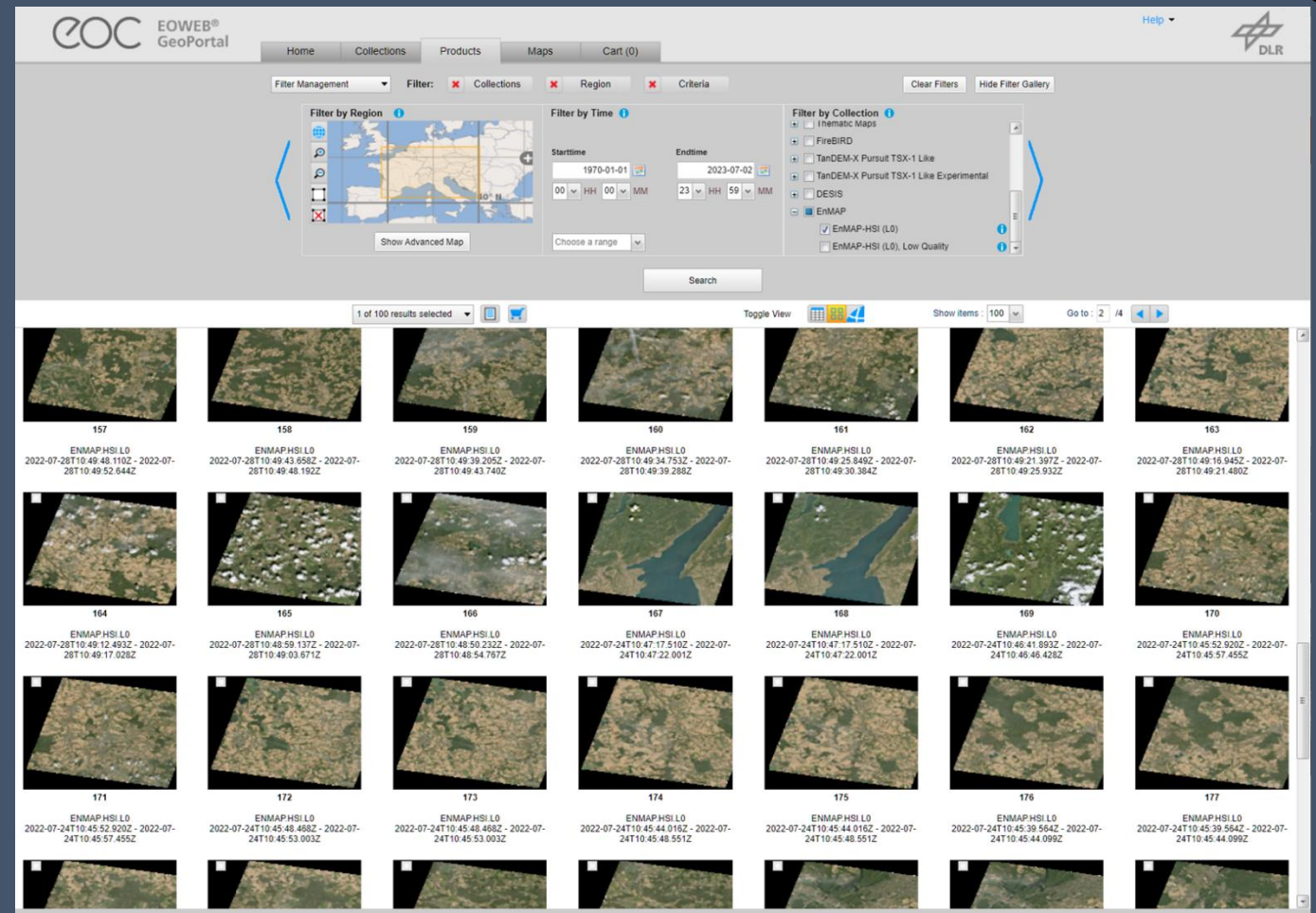
German Satellite Data Archive through EOWEB

<https://eoweb.dlr.de/egp/>

Where users can browse the EnMAP catalogue and order the products.

Products are processed on-demand, according to different processing options of their choice like:

- Processing level (L1B, L1C, L2A)
- Map projection
- Resampling options
- L2A processing mode (land, water, combined)
- Atmospheric correction parameters



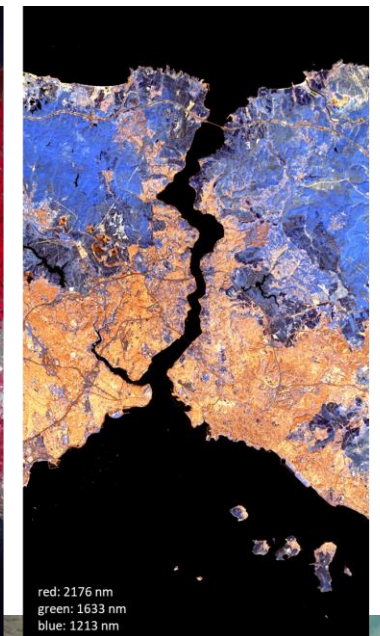
Timeline

LEOP 01.04.2022 –
15.04.2022 Commissioning 15.04.2022 – 01.11.2022

Launch
01.04.2022 First light,
27.04.2022



- 01.04.2022 EnMAP Launch
- Start LEOP Phase until 14.04.2022
- 15.04.2022 Start of commissioning Phase
- 27.04.2022 First light



Timeline



LEOP 01.04.2022 –

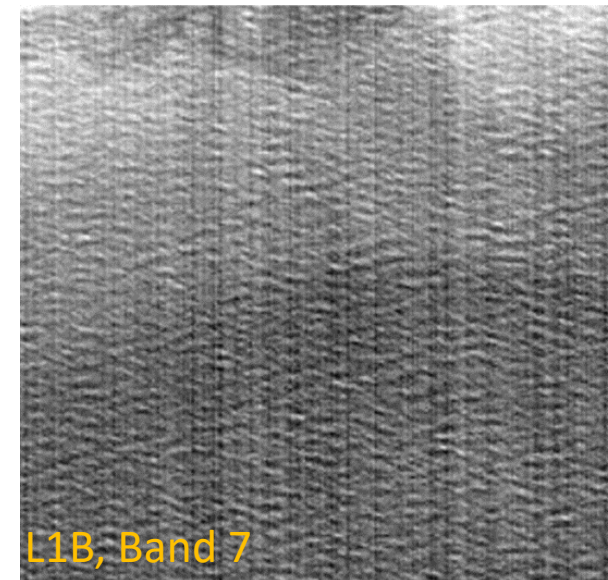
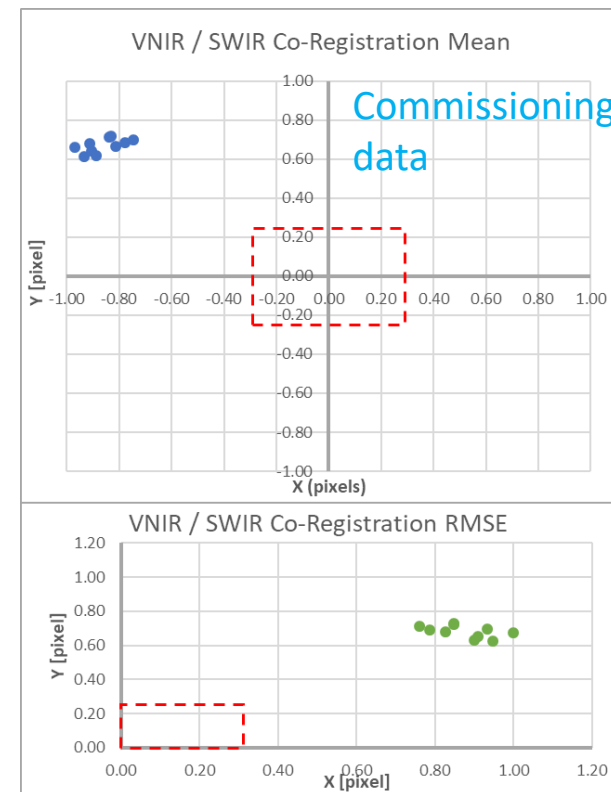
15.04.2022 Commissioning 15.04.2022 – 01.11.2022

Launch

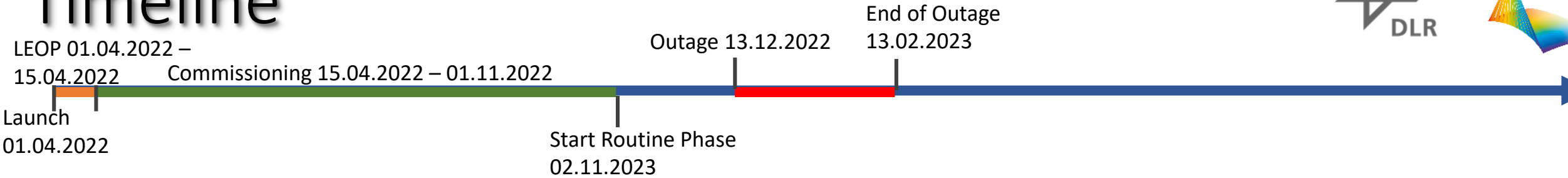
01.04.2022

Start Routine Phase
02.11.2023

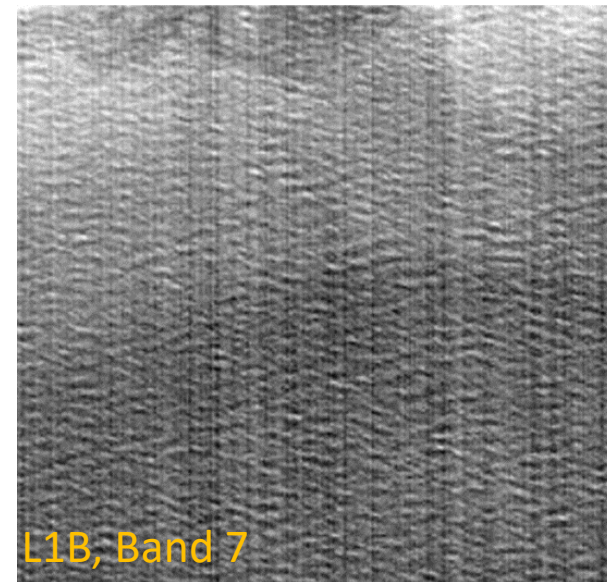
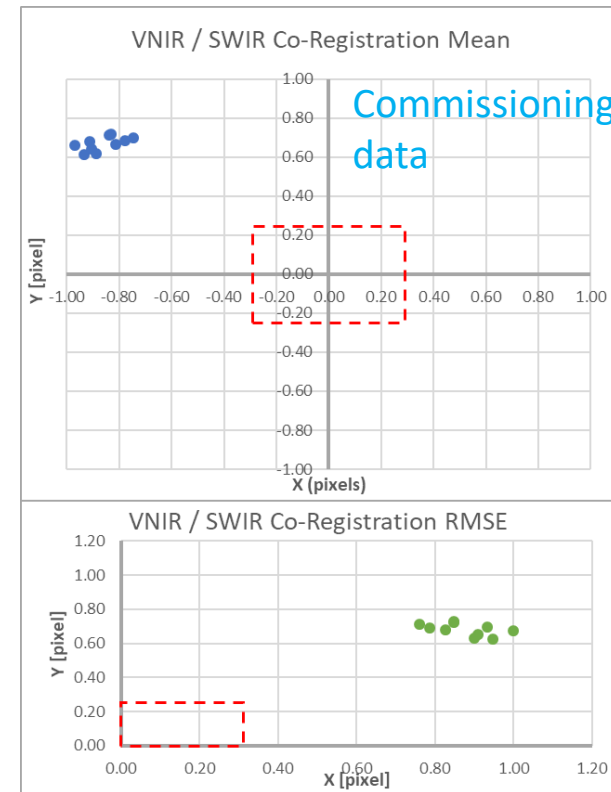
- Start routine phase after successful FQR
 - Data requirements satisfied, except for VNIR-SWIR co-registration (error ~0.7-0.8 pixel)
 - Request to improve image striping and mitigate effect of VNIR degradation



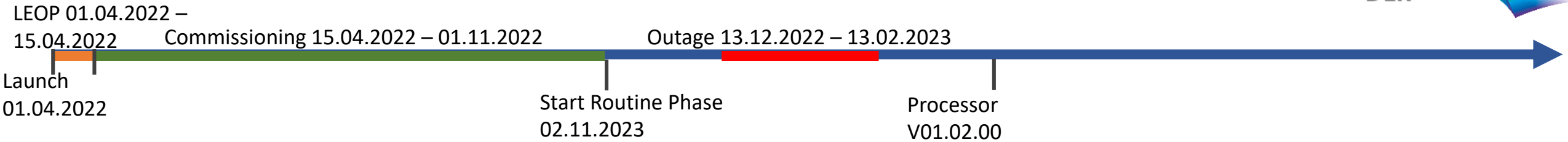
Timeline



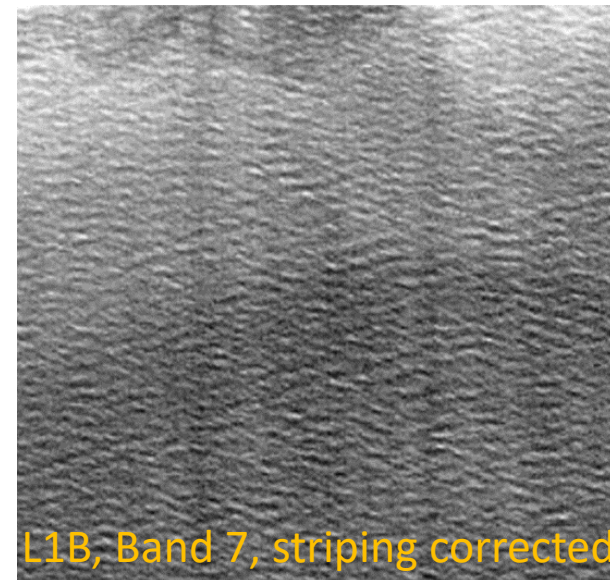
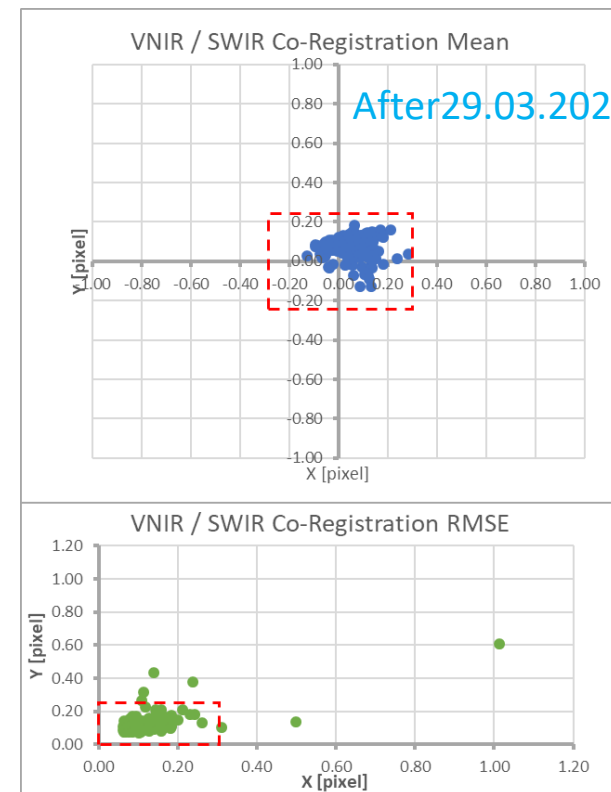
- Start routine phase after successful FQR
 - Data requirements satisfied, except for VNIR-SWIR co-registration (error ~ 0.7 - 0.8 pixel)
 - Request to improve image striping and mitigate effect of VNIR degradation
- Failure occurred at the end of a Sun calibration on 13.12.2022. Two months outage to update on-board software



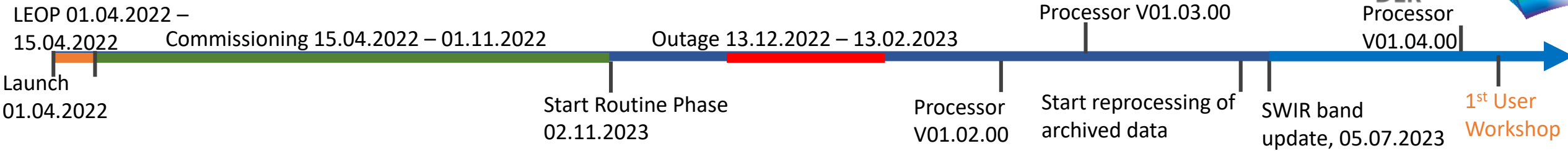
Timeline



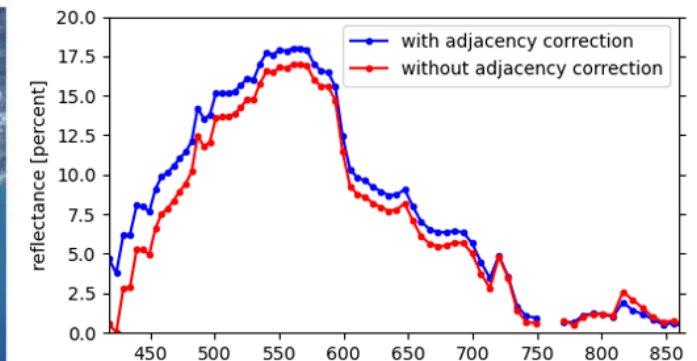
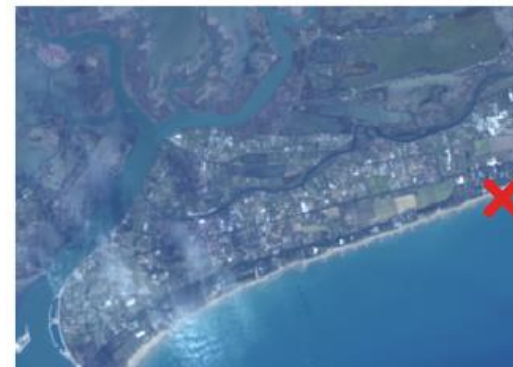
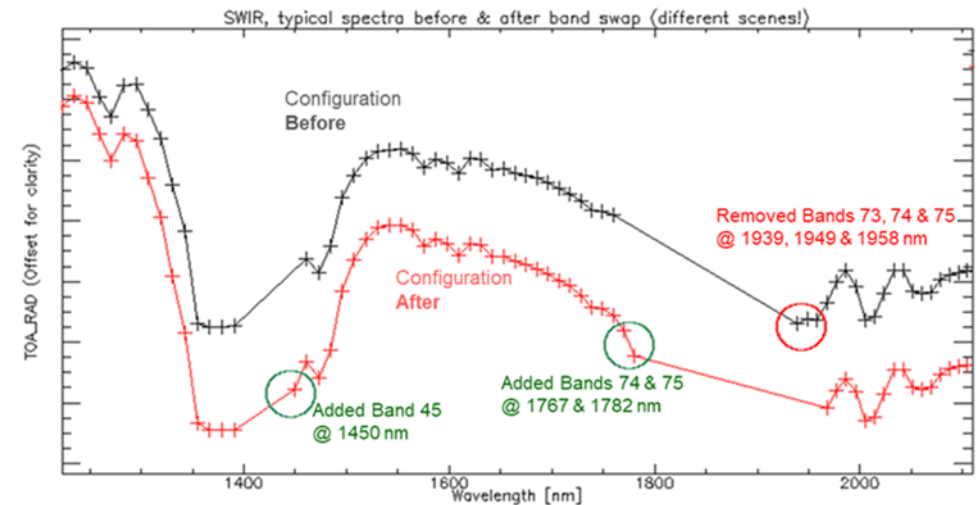
- Operations resumed on 13.02.2023. No consequences on mission functionality or data quality
- Processor update **V01.02.00** on 29.03.2023 with several improvements. Among them:
 - Improved VNIR-SWIR co-registration for newly archived products (<0.1 pixel)
 - De-stripping algorithm
 - Dynamic calibration coefficient
- VNIR degradation was reducing and by end of Q1 2023 had virtually disappeared



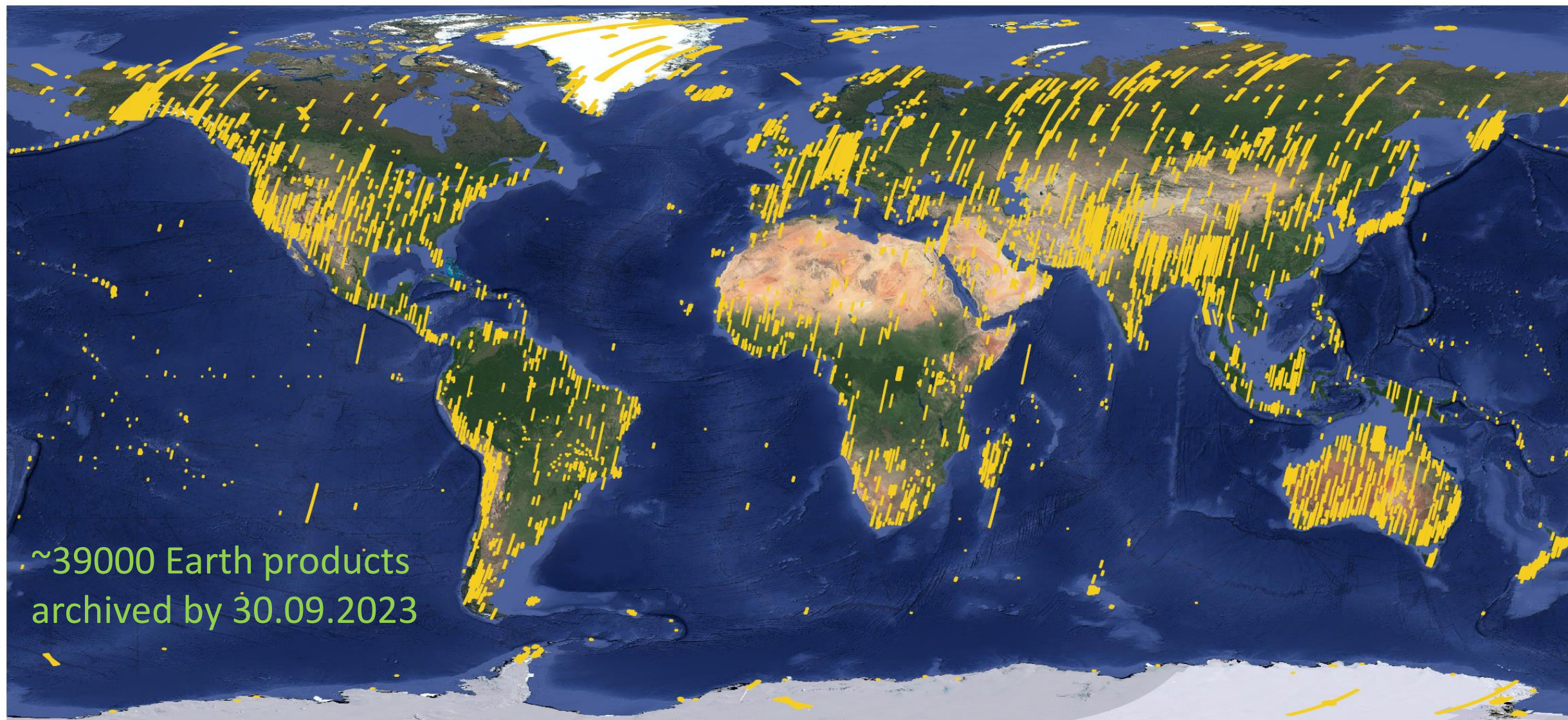
Timeline



- Processor update **V01.03.00** on 02.05.2023. Improved geometric accuracy along-track and other small improvements or bugfixes
- 27.06.2023, start archive re-processing:
 - New versions > **V01.03.00**
 - Highly recommended for commissioning data
- Update of SWIR band configuration on 05.07.2023
- Processor **V01.04.00** on 25.09.2023. Correction of L2A-water adjacency effect

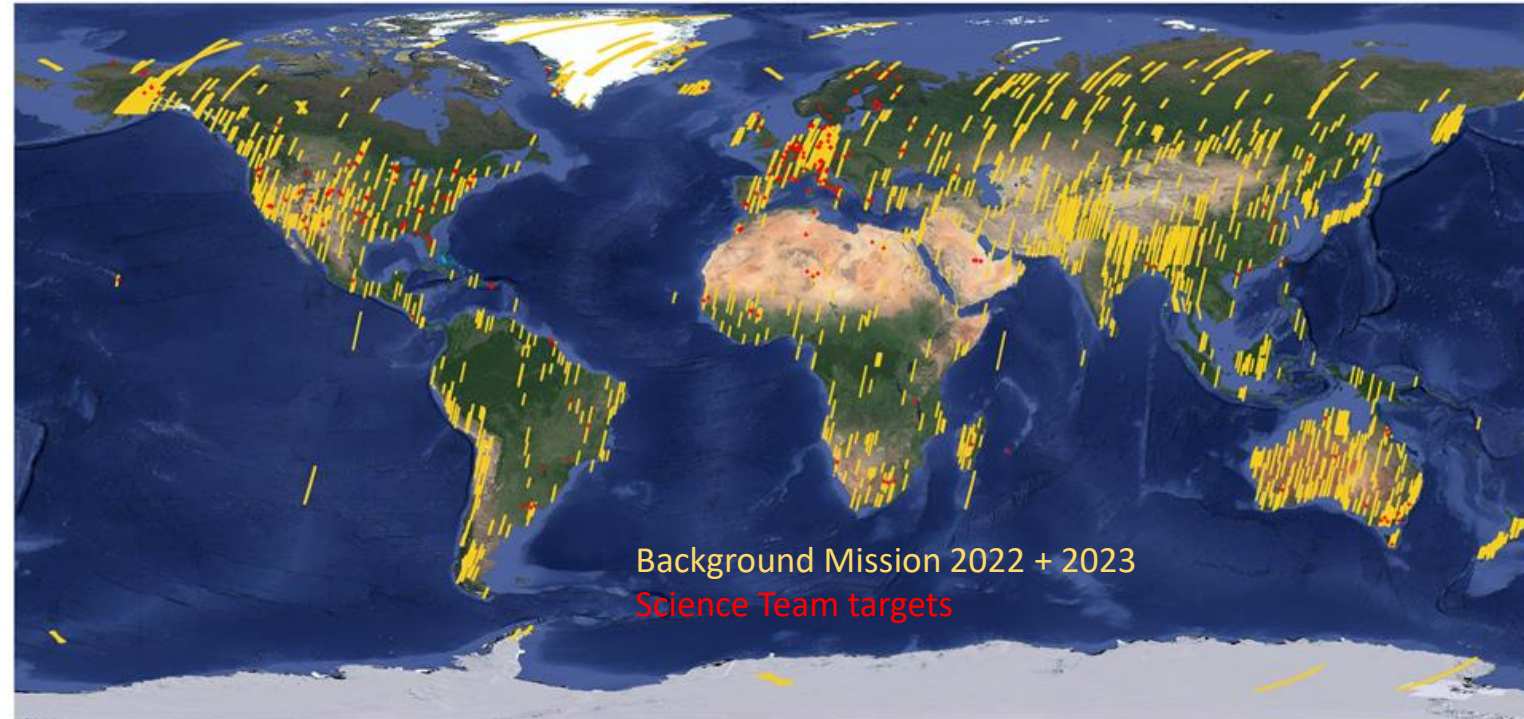


EnMAP acquisitions



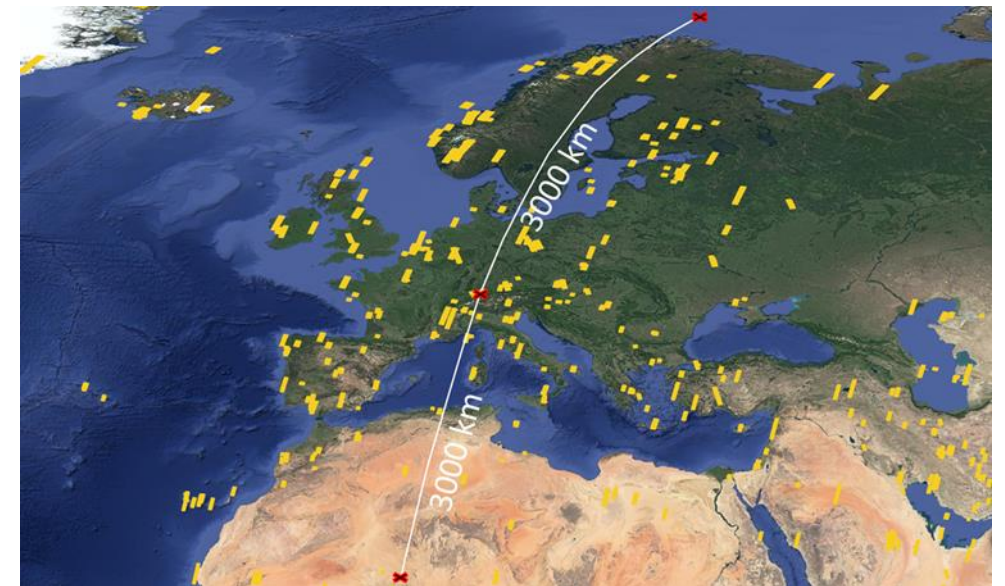
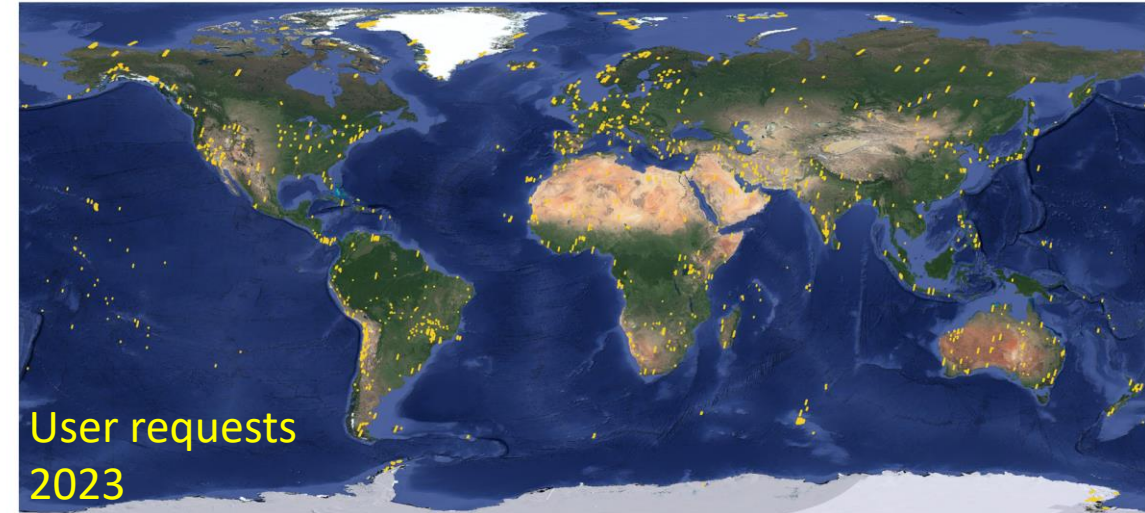
Background Mission

- The EnMAP Mission assigns high priority to user requests (priority 6 and 7 assigned to proposals)
 - Proposals that run out of quota get priority reduced
- Time not used by user requests is assigned to background mission
- BG mission acquisitions are typically longer but with lower priority than user requests, considering the input from the Science Team (list of targets)



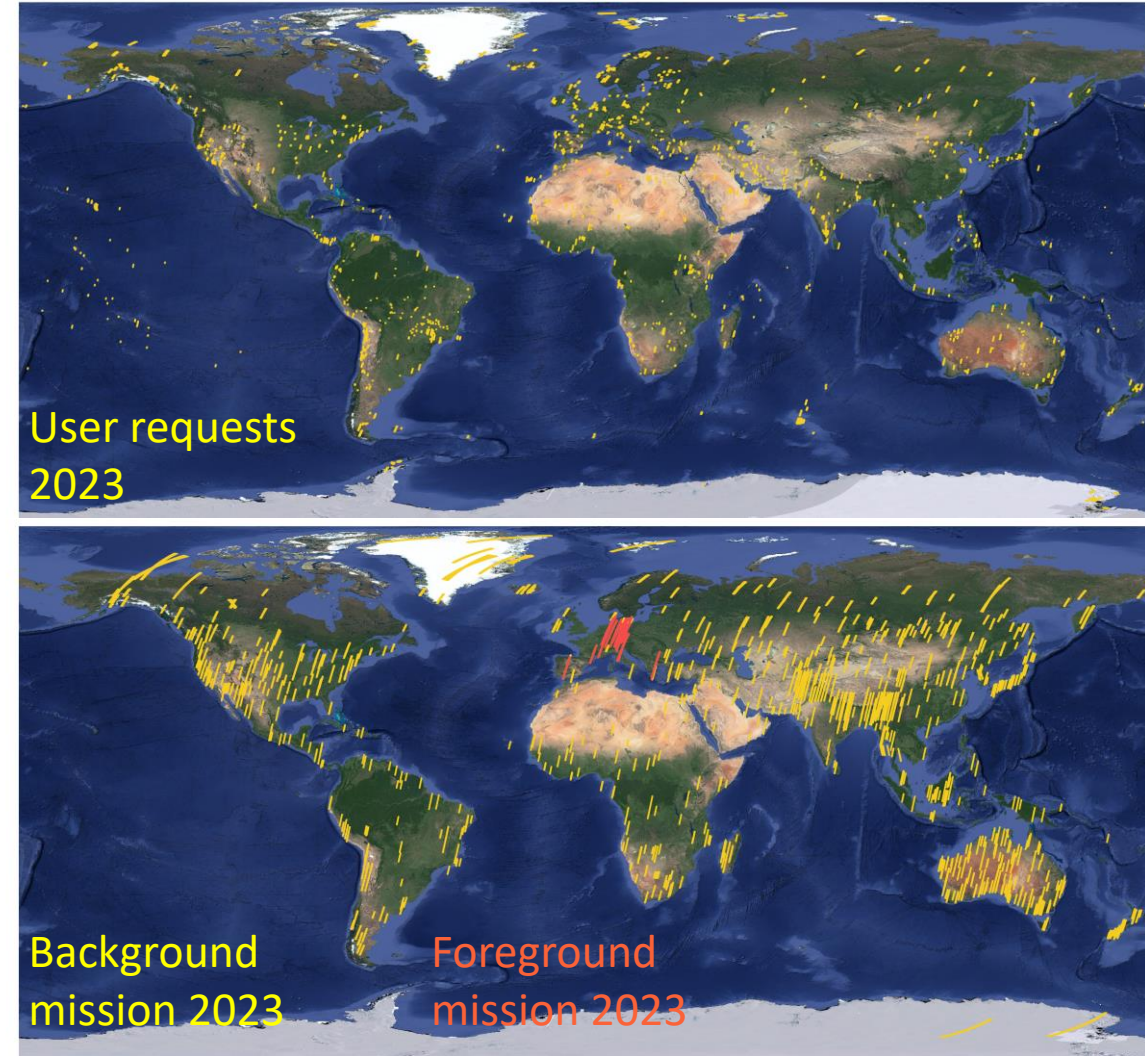
User acquisitions

- Typical user acquisitions are very small (1-3 tiles) and not geographically uniformly distributed. High demand over certain areas (e.g. Europe)
- EnMAP needs ~3000 km (7 minutes) between acquisitions, making the short requests very inefficient
 - Only 1 order gets a slot in the instrument timeline over areas highly requested. High competition between orders
 - Short requests reduce the data volume acquired over the highly demanded areas



User acquisitions

- Typical user acquisitions are very small (1-3 tiles) and not geographically uniformly distributed. High demand over certain areas (e.g. Europe)
- EnMAP needs ~3000 km (7 minutes) between acquisitions, making the short requests very inefficient
 - Only 1 order gets a slot in the instrument timeline over areas highly requested. High competition between orders
 - Short requests reduce the data volume acquired over the highly demanded areas
- Background mission acquisitions are longer, but with lower priority and don't compete with user requests
 - Temporary implemented “**foreground mission**” to take high priority long acquisitions over certain geographic areas
- Longer-term changes are under evaluation at Mission level



Getting information and news: www.enmap.org



- Main channel to get informed about mission status and news
- Contains additional useful resources for the EnMAP Users

A screenshot of the EnMAP website homepage. The header features the EnMAP logo and a navigation bar with links: Home, Data & Access, Mission, Science & Applications, Tools, and Events & Education. Below the header, there's a 'Welcome to EnMAP' section with a subtitle 'The German Spaceborne Imaging Spectrometer Mission'. To the left of this section is a sidebar with links to 'Data Access Portal', 'Science Plan', 'Brochure (english - 15H4B)', 'Brochure (german - 19H4B)', 'Flyer (english)', 'Flyer (german)', and 'Video (german)'. Below the welcome section is an 'IMAGE GALLERY' with a search bar. A large yellow box contains a warning message about user interest and acquisition requests. Below this is a 'News' section with three articles: '1st EnMAP user workshop - Agenda and late registrations', 'Reactivation of the adjacency correction for L2A water products', and '1st EnMAP user workshop'.

A screenshot of the EnMAP website news section. It displays a list of recent news items, each with a small image icon, a title, and a publication date. The news items include: 'New online course opened in HYPERedu course series 'Beyond the Visible'', '13th EARSeL Workshop on Imaging Spectroscopy - Call for Abstracts', 'EnMAP SWIR band configuration update', 'Re-processing of archived data', 'Flood mapping with EnMAP - Provision of crisis information in the frame of the International Charter "Space and Major Disasters"', and 'Introductory videos on the use of the EnMAP Data Access Portal now online'. At the bottom, there's a link to 'EnMAP for monitoring oil slicks offshore Brazil'.

Getting information and news: www.enmap.org



- Main channel to get informed about mission status and news
- Contains additional useful resources for the EnMAP Users
 - **Mission Quarterly Reports**
 - Mission Status and News
 - User and Data Statistics
 - Instrument calibration
 - Data Products quality

The screenshot shows the EnMAP website's 'Mission' page. At the top is a banner image of the EnMAP satellite in orbit over Earth. Below the banner is a navigation bar with links: Home, Data & Access, Mission, Science & Applications, Tools, and Events & Education. On the left is a sidebar menu with categories: Organization, Space Segment, Ground Segment, Mission Exploitation Program, RELATED DOCUMENTS (EnMAP Specifications, Glossary of Abbreviations, Glossary of Terms, EnMAP Spectral Bands), GROUND TRACKS (EnMAP Ground Tracks 2023, EnMAP Ground Tracks 2022), and QUARTERLY REPORTS (04 (01.04.2023-30.06.2023), 03 (01.01.2023-31.03.2023), 02 (01.10.2022-31.12.2022), 01 (01.04.2022-30.09.2022)). The main content area is titled 'Mission' and features a 3D model of the satellite. The text describes the mission's objectives: to provide high-quality, regional scale hyperspectral data to improve understanding of coupled environmental processes and assist in sustainable management of Earth's resources. It also mentions that EnMAP has clear potential to evolve into an operational service. Below this is the 'Mission Outline' section, which lists key features: a dedicated pushbroom hyperspectral imager, a broad spectral range from 420 nm to 1000 nm (VNIR) and from 900 nm to 2450 nm (SWIR), a 30 km swath width, a spatial resolution of 30 x 30 m, a nadir revisit time of 27 days, and a total of 5,000 km per day. The 'Status' section states that the mission is currently in its phase, with full readiness of the ground segment for in-orbit operations. A timeline diagram shows the mission phases: Mission Preparation Phase (Phase A, B, C, D) from 2022 to 2027, followed by the Operational Phase, and then the Decommissioning Phase. The 'Objectives' section lists the primary scientific goals: providing high-quality calibrated hyperspectral data, developing novel methodologies, and obtaining diagnostic geochemical, biochemical, and biophysical parameters.

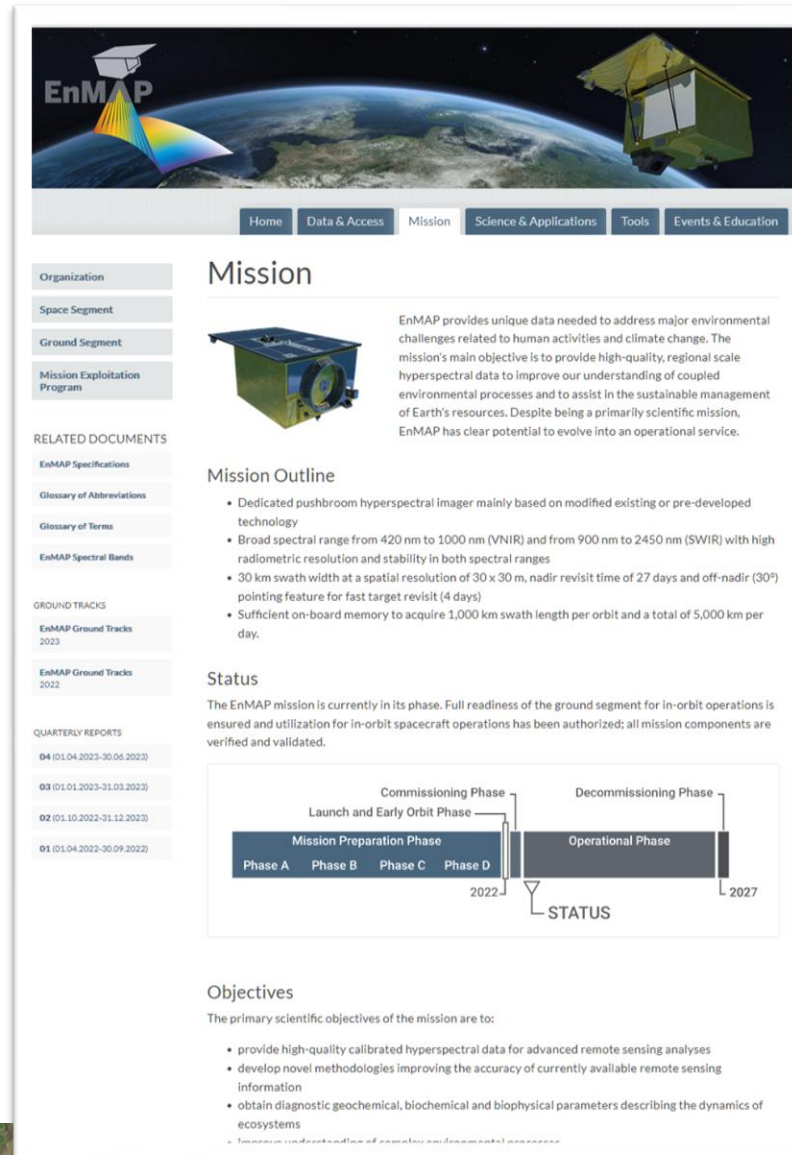
This screenshot shows the cover of the 'EnMAP Ground Segment Mission Quarterly Report #04' for the period 01.04.2023 to 30.06.2023. The report is published by the Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR) and is restricted to public use. It includes a table with the following information: Doc ID: EN-GS-RPT-1104, Issue: 1.0, Date: 16.08.2023, and Configuration Controlled: Yes. The EnMAP logo is prominently displayed in the center. At the bottom, the report is attributed to the German Remote Sensing Data Center (DFD), Remote Sensing Technology Institute (IWF), German Space Operations Center (GSOC), and German Research Centre for Geosciences (GFZ-Potsdam), all part of the German Space Agency at DLR. A disclaimer at the very bottom states that no part of the document may be reproduced without permission.

This screenshot shows the cover of the 'EnMAP Ground Segment Mission Quarterly Report #03' for the period 01.01.2023 to 31.03.2023. Similar to the previous report, it is published by DLR and is public. The table indicates: Doc ID: EN-GS-RPT-1103, Issue: 1.0, Date: 21.05.2023, and Configuration Controlled: Yes. The EnMAP logo is centered. The report is attributed to the German Remote Sensing Data Center (DFD), Remote Sensing Technology Institute (IWF), German Space Operations Center (GSOC), and German Research Centre for Geosciences (GFZ-Potsdam), all part of the German Space Agency at DLR. A disclaimer at the bottom states that no part of the document may be reproduced without permission.

Getting information and news: www.enmap.org



- Main channel to get informed about mission status and news
- Contains additional useful resources for the EnMAP Users
 - **Mission Quarterly Reports**
 - Mission Status and News
 - User and Data Statistics
 - Instrument calibration
 - Data Products quality
 - **Ground tracks (KML files)**



The screenshot shows the 'Mission' page of the EnMAP website. At the top, there is a header with the EnMAP logo and navigation links: Home, Data & Access, Mission, Science & Applications, Tools, and Events & Education. Below the header, there is a sidebar with a table of contents for the Mission page, including Organization, Space Segment, Ground Segment, Mission Exploitation Program, RELATED DOCUMENTS (EnMAP Specifications, Glossary of Abbreviations, Glossary of Terms, EnMAP Spectral Bands), GROUND TRACKS (EnMAP Ground Tracks 2023, EnMAP Ground Tracks 2022), and QUARTERLY REPORTS (Q4 (01.04.2023-30.06.2023), Q3 (01.01.2023-31.03.2023), Q2 (01.10.2022-31.12.2022), Q1 (01.04.2022-30.09.2022)). The main content area is titled 'Mission' and features a small image of the EnMAP instrument. The text describes the mission's objectives: to provide high-quality, regional scale hyperspectral data to improve our understanding of coupled environmental processes and to assist in the sustainable management of Earth's resources. Below this, there is a 'Mission Outline' section with a bulleted list of key features: Dedicated pushbroom hyperspectral imager, Broad spectral range (420 nm to 1000 nm VNIR and 900 nm to 2450 nm SWIR), 30 km swath width, and Sufficient on-board memory. The 'Status' section states that the mission is currently in its phase, with full readiness of the ground segment for in-orbit operations. A timeline diagram shows the mission phases: Mission Preparation Phase (Phase A, B, C, D) and Operational Phase, with a 'STATUS' indicator showing the current phase. The 'Objectives' section lists the primary scientific objectives: provide high-quality calibrated hyperspectral data, develop novel methodologies, and obtain diagnostic geochemical, biochemical, and biophysical parameters.

Mission

EnMAP provides unique data needed to address major environmental challenges related to human activities and climate change. The mission's main objective is to provide high-quality, regional scale hyperspectral data to improve our understanding of coupled environmental processes and to assist in the sustainable management of Earth's resources. Despite being a primarily scientific mission, EnMAP has clear potential to evolve into an operational service.

Mission Outline

- Dedicated pushbroom hyperspectral imager mainly based on modified existing or pre-developed technology
- Broad spectral range from 420 nm to 1000 nm (VNIR) and from 900 nm to 2450 nm (SWIR) with high radiometric resolution and stability in both spectral ranges
- 30 km swath width at a spatial resolution of 30 x 30 m, nadir revisit time of 27 days and off-nadir (30°) pointing feature for fast target revisit (4 days)
- Sufficient on-board memory to acquire 1,000 km swath length per orbit and a total of 5,000 km per day.

Status

The EnMAP mission is currently in its phase. Full readiness of the ground segment for in-orbit operations is ensured and utilization for in-orbit spacecraft operations has been authorized; all mission components are verified and validated.

Objectives

The primary scientific objectives of the mission are to:

- provide high-quality calibrated hyperspectral data for advanced remote sensing analyses
- develop novel methodologies improving the accuracy of currently available remote sensing information
- obtain diagnostic geochemical, biochemical and biophysical parameters describing the dynamics of ecosystems



Getting information and news: www.enmap.org



- Main channel to get informed about mission status and news
- Contains additional useful resources for the EnMAP Users
 - **Example Data Products**
 - 3 Scenes (Tyrol, Groningen and Nevada)
 - 3 processing levels for each scene (L1B, L1C, L2A)

EnMAP Example Data Products

Selected EnMAP data sets are provided to the user community as representative examples of the products available to EnMAP users. For details concerning the data format and content, please refer to the [product specification](#) and ATBDs of the different levels in the [data access page](#). The performance and characterization of the EnMAP instrument and processors have been reported in [Storch et al 2023](#) et.

We would like to point out that the EnMAP test data may be used under consideration of the license documents: [AUP](#), [Collaboration Contract](#), [Data License](#), [Data Protection Declaration](#).

Tyrol, Austria
12 June 2022 | 47.09°N, 10.81°E

This EnMAP tile shows the Alps in Tyrol, Austria. The L2A product was produced in "land mode", meaning land and water areas were processed using the atmospheric processing software for land (surface reflectance values for all pixels).

Processing details

- L1B: Default
- L1C: UTM projection, bilinear interpolation
- L2A: UTM projection, bilinear interpolation, land mode, no cirrus or haze removal, no terrain correction, summer season, ozone column 313 DU

[Download L1B](#)
[Download L1C](#)
[Download L2A](#)

Groningen, Netherlands
10 August 2022 | 53.43°N, 6.53°E

This EnMAP tile shows the North Sea coast close to the city of Groningen, Netherlands. The L2A product was produced in "combined mode", meaning land and water areas were processed using the atmospheric processing software for land and water respectively (surface reflectance values for land pixels and underwater reflectance values for water pixels).

Processing details

- L1B: Default
- L1C: UTM projection, bilinear interpolation
- L2A: UTM projection, bilinear interpolation, combined mode, no cirrus or haze removal, no terrain correction, summer season, ozone column 319 DU

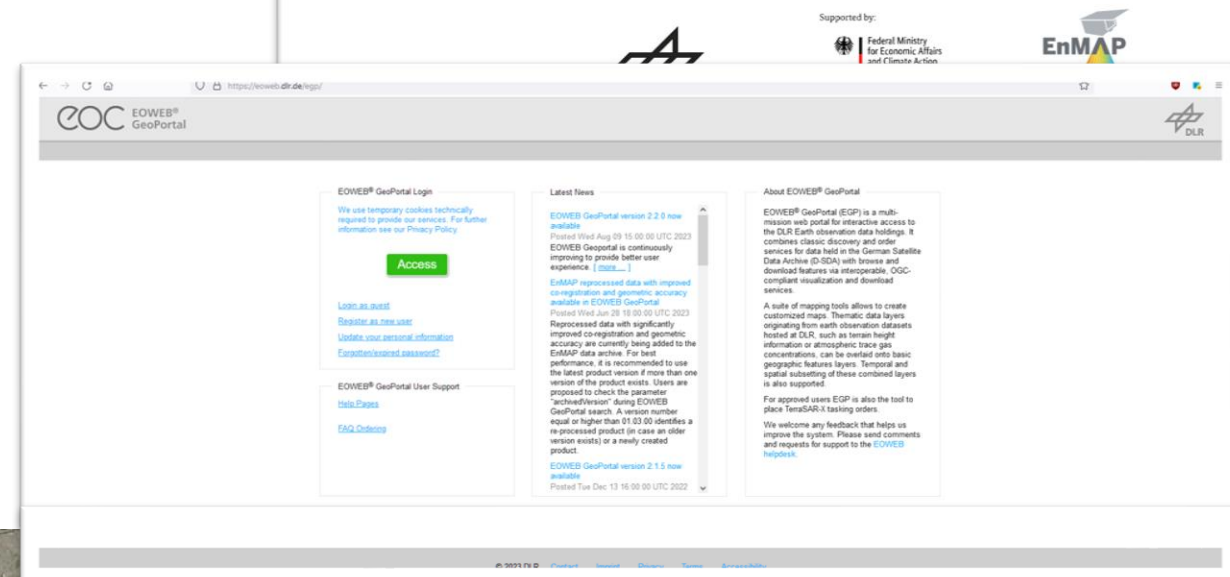
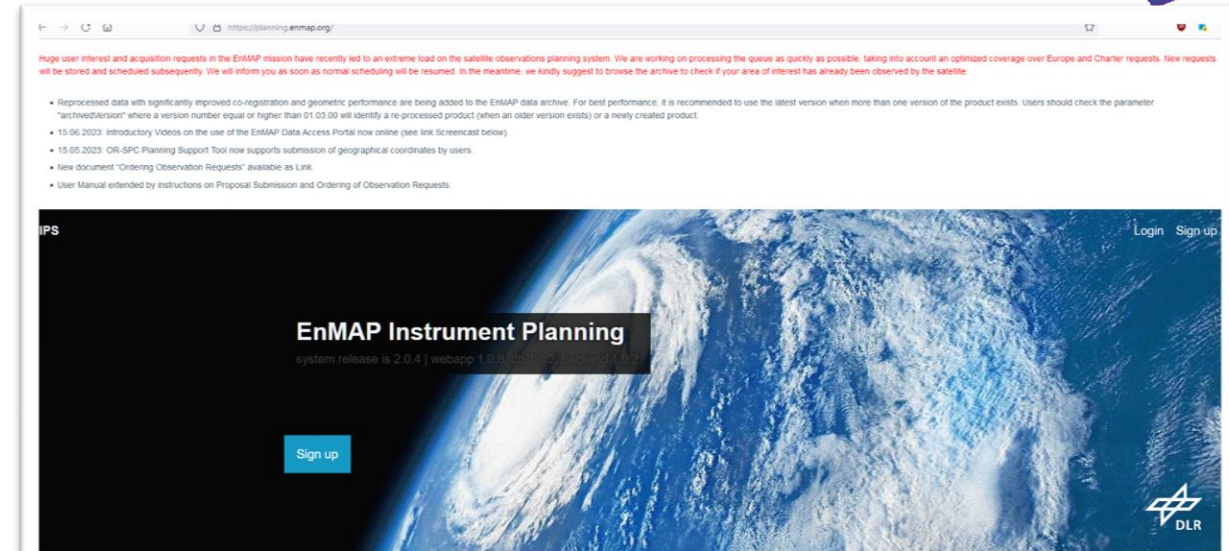
[Download L1B](#)
[Download L1C](#)
[Download L2A](#)

Getting information and news: www.enmap.org



- Main channel to get informed about mission status and news
- Contains additional useful resources for the EnMAP Users
- Additional important notices published at IPS and EOWEB sites

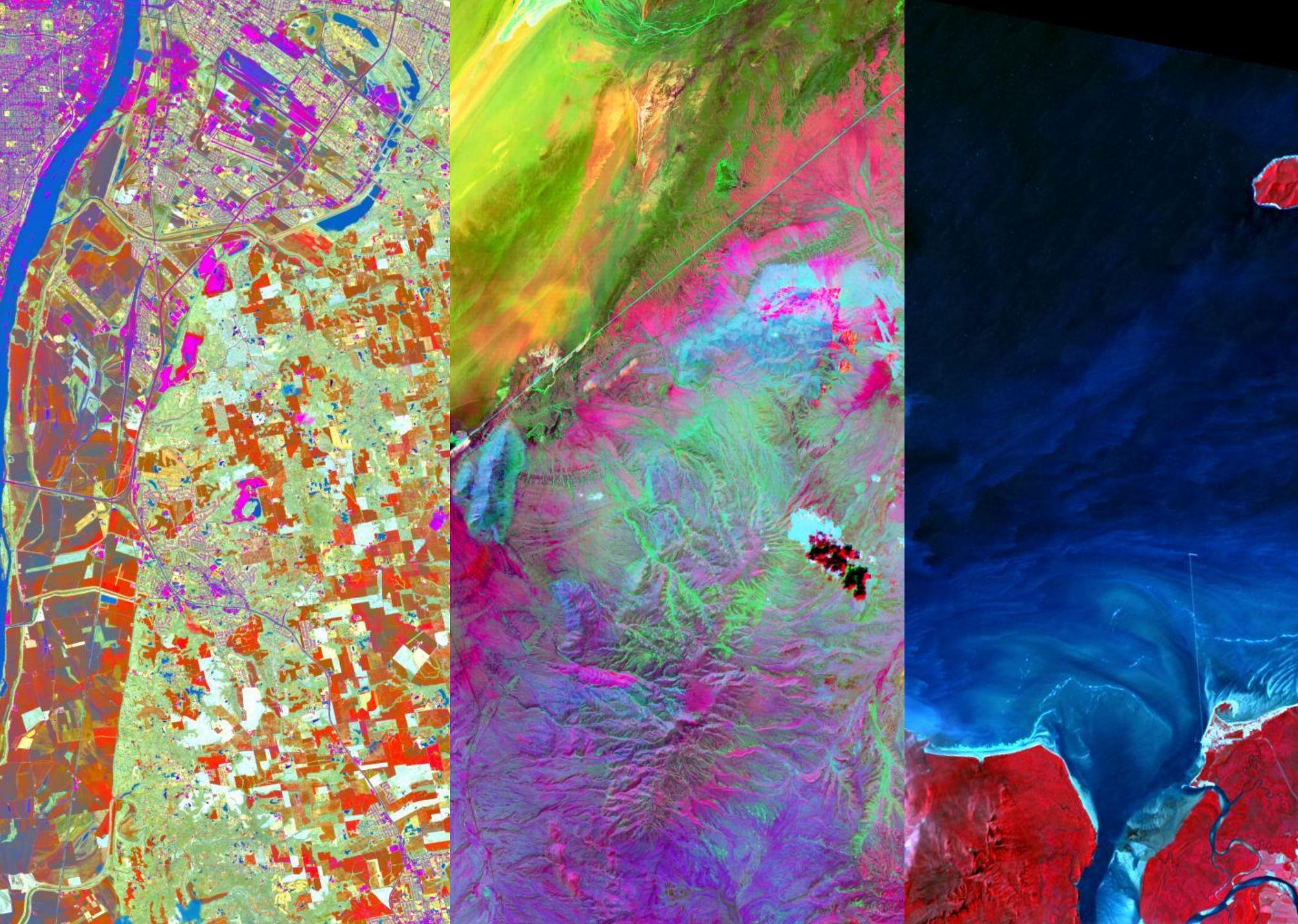
- <https://planning.enmap.org/>
- <https://eoweb.dlr.de/egp/>



Summary



- Improvements in Ground Segment services / data quality, specially during 1st year
 - Check when data were acquired (performance may differ)
 - When possible use re-processed data
- High demand of user acquisitions on certain geographic areas combined with minimum time between EnMAP acquisitions creates a queue of requests not fulfilled. Situation is very inefficient due to very short acquisitions with high priority. Adjustments are necessary to improve the situation for all users
- Check www.enmap.org news feed and Mission Quarterly Reports to get latest status of the EnMAP Mission



Thank you !

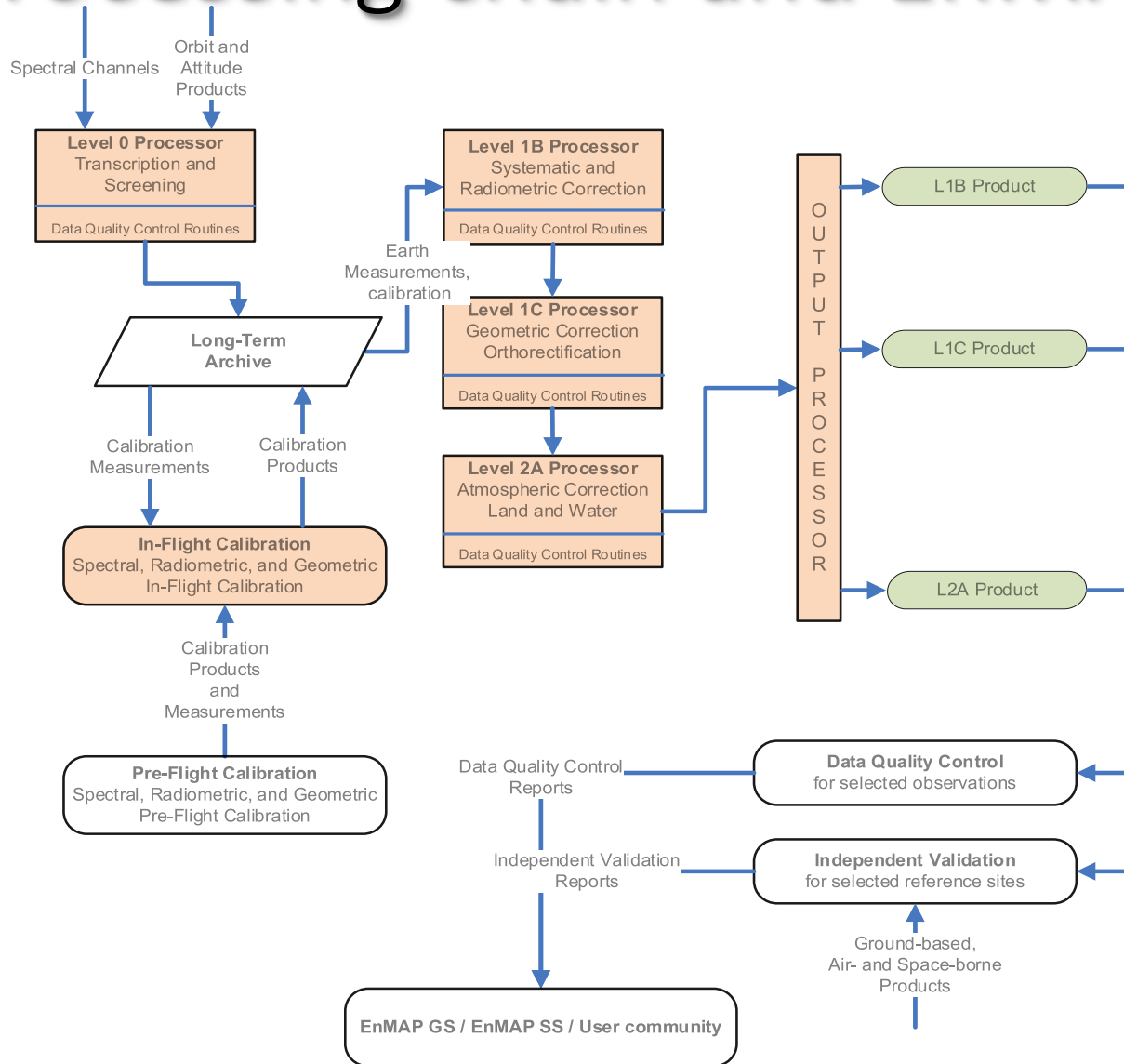
Funded by



Federal Ministry
for Economic Affairs
and Climate Action

Extra

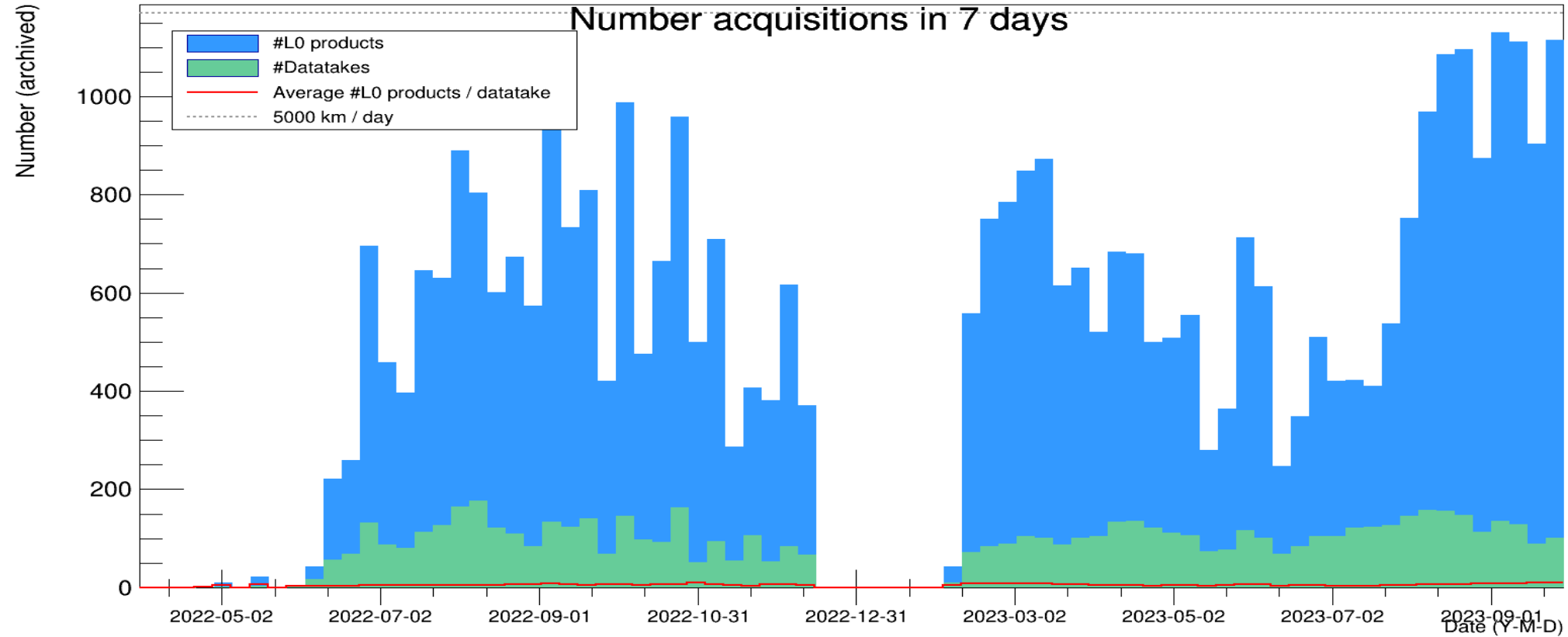
Processing chain and EnMAP Products



- In-flight calibration observations are processed to generate updated calibration tables
- Three level of users products can be ordered (L1B / L1C / L2A) from Earth observations. Dedicated L2A water processor (2 types of water products)
- User products annotated with quality information (metadata) plus periodic quality and validation reports
- Quality Control (GS) and Independent Validation (GFZ) performed on user products
- EnMAP L2A data complaint with CEOS CARD4L at threshold specification

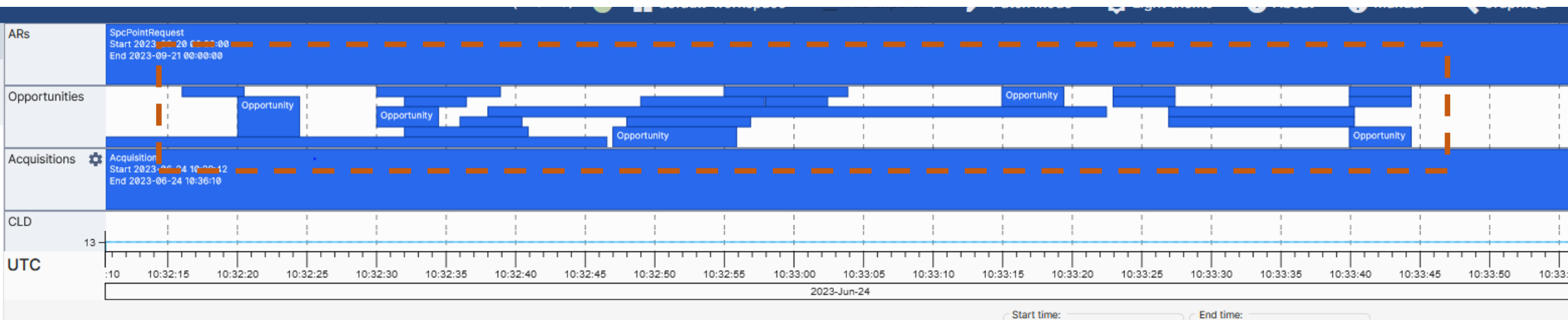
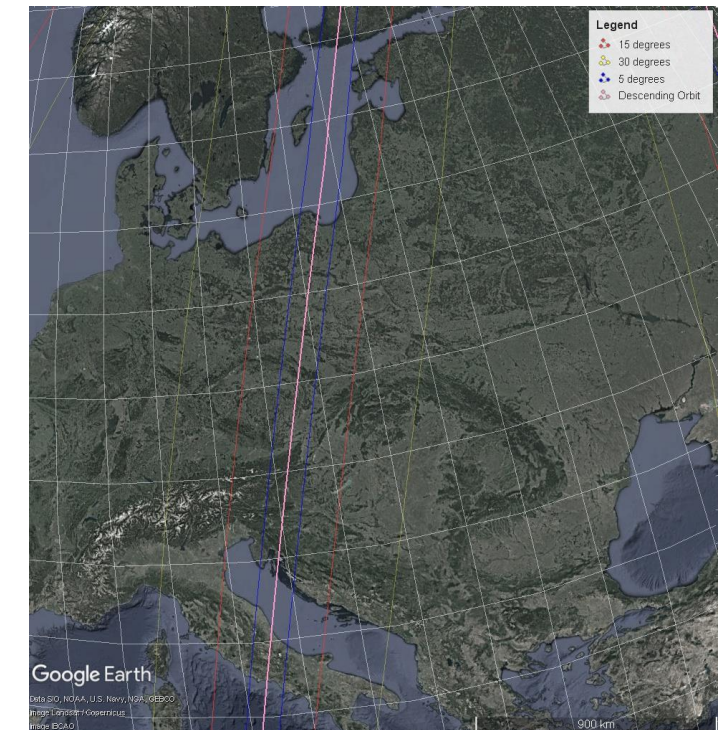


EnMAP Acquisitions over time



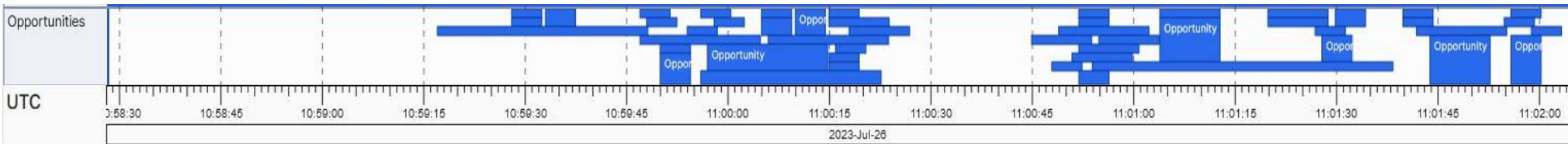
How bad is competition between user requests?

- Example 24.06.2023 between 10:32:10 and 10:33:55 (105 seconds, ~750 km on ground)
- Bottom graph shows 22 opportunities in the system. Only **one** can be acquired
- From the 22 opportunities, 15 of them overlapping in 55 seconds
- Moreover, the bottom graph also shows the size of users acquisitions (~4.5 seconds = 1 tile) which create Problem-2
 - 12 are 1-tile requests, 6 are 2-tiles requests, 2 are 3-tiles requests

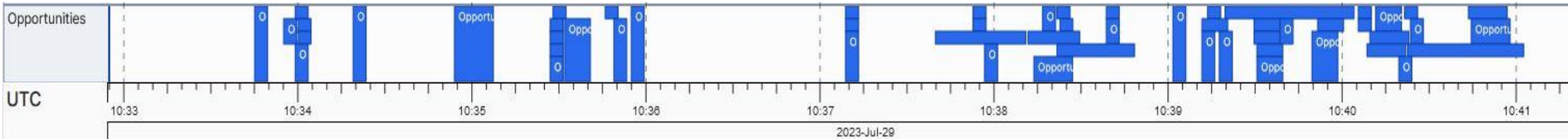


More examples of observation requests

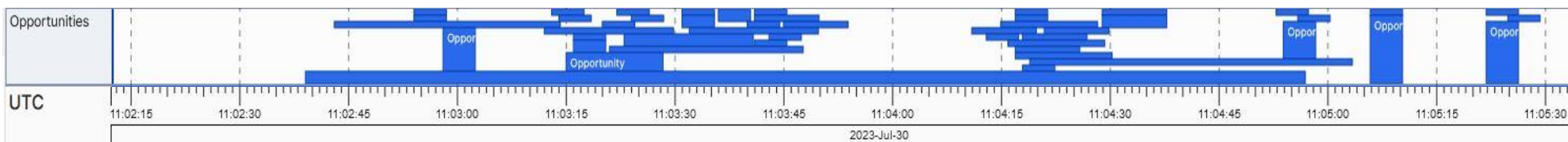
26 July 2023: 48 requests for 3 minutes time window 26 are 1 tile acquisitions



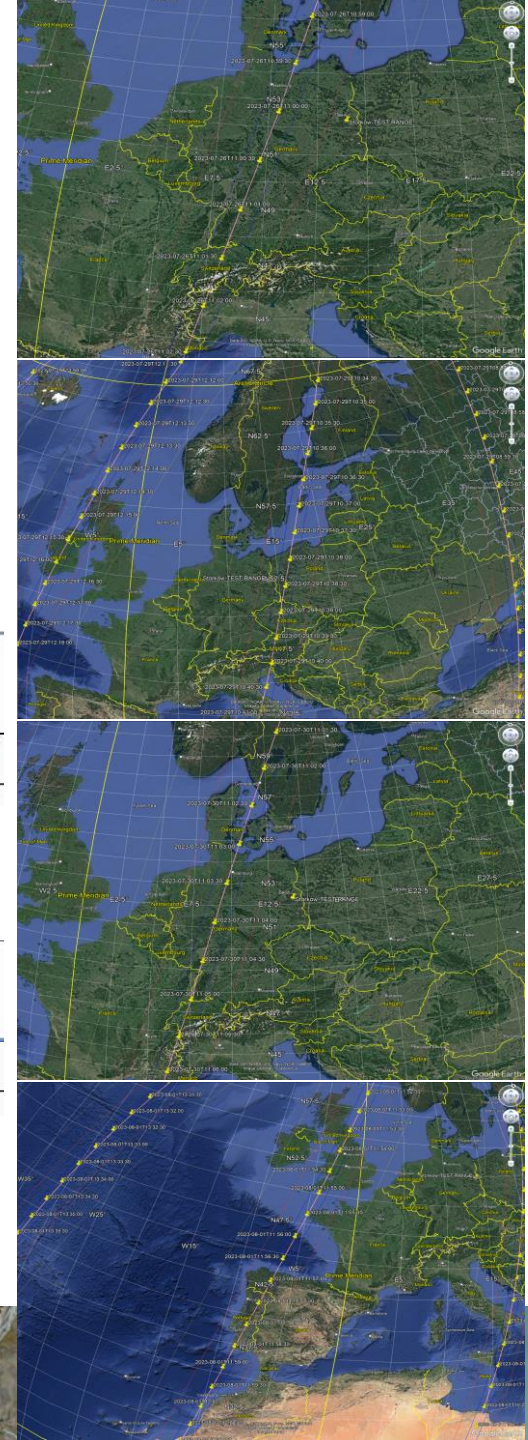
29 July 2023: 55 requests for 7 minutes time window 36 are 1 tile acquisitions



30 July 2023: 48 requests for 3 minutes time window 27 are 1 tile acquisitions



01 August 2023: 17 requests for 7 minutes time window 6 are 1 tile acquisitions



Getting information and news: www.enmap.org



- Main channel to get inform about mission status and news
- Contains additional useful resources for the EnMAP Users
 - **Portal User Manual**
 - **Algorithm Theoretical Baseline Documents**
 - **EnMAP L1B, L1C and L2A Product Specification**

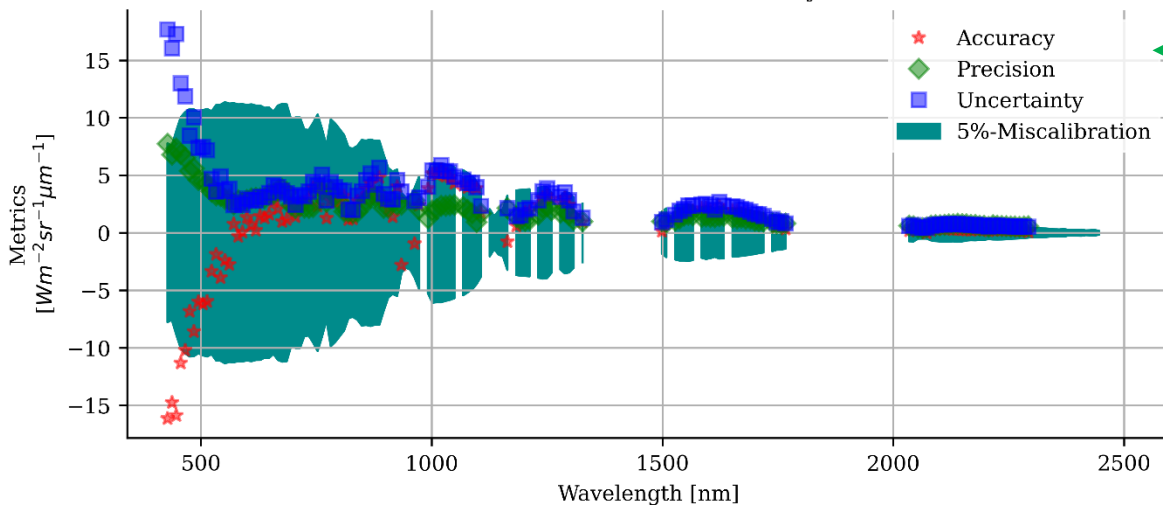
A screenshot of the 'Data & Access' section of the EnMAP website. The page has a navigation bar with links: Home, Data & Access, Mission, Science & Applications, Tools, and Events & Education. The main content area is titled 'Data & Access' and includes a 'Data Access Portal' link. It features a 'SCREENCASTS' section with links to 'How to register and assign to user roles', 'How to submit a data proposal', 'How to plan and request future observations', and 'How to search and download data from the archive'. There is also a 'RELATED DOCUMENTS' section with links to 'Portal User Manual' and 'Level 1B, Level 1C, Level 2A Product Specification'. The 'ALGORITHM THEORETICAL BASELINE DOCUMENTS' section lists 'Level 1B', 'Level 1C', 'Level 2A land', and 'Level 2A water'. The 'LICENCE' section includes links for 'ADP', 'Collaboration Contact', 'Data License', and 'Data Protection Declaration'. The main text describes the Data Access Portal (DAP) and provides information on how to request acquisitions through the EnMAP Instrument Planning Portal (IPP) and the EOWEB® GeoPortal. It also mentions that users can access EnMAP data using two different options: through the IPP or through the EOWEB® GeoPortal. A diagram shows the data flow from 'Orbit and Attitude Products' and 'Raw data' through 'CAL tables' to 'Level 0 Processing', then through 'Level 0 Processor', 'Level 1B Processor', 'Level 1C Processor', and 'Level 2A Processor' to 'OUTPUT'. A 'Long Term Archive L0 Data' is also shown. The 'Product Levels' section lists the following EnMAP data products available to the user community: Product Level 1B, 1C, and 2A. It notes that raw data and subsequent Level 0 products are not available to the user community. A detailed description can be found in Gunter et al. (2015) and Kaufmann et al. (2016). The 'Level 1B Processor (ENMAP.HSIL1B)' section describes the systematic/radiometric correction processor that converts raw image pixels values to at-sensor radiance physical values. The 'Level 1C Processor (ENMAP.HSIL1C)' section describes the geometric correction processor that orthorectifies images using different methods and performs the resampling of the image (with and without automatically extracted GCPs). The 'Level 2A Processor (ENMAP.HSIL2A)' section describes the atmospheric correction processor that produces reflectance values for land and water.

A collage of four documents related to the EnMAP Ground Segment. The top-left document is the 'EnMAP Ground Segment Portals User Manual', dated 13 December 2022. The top-right document is the 'EnMAP Ground Segment EnMAP HSI Level 1 / Level 2 Product Specification Document', dated 04.10.2022. The bottom-left document is the 'EnMAP Ground Segment Level 2A Processor (Atmospheric Correction over Land) ATBD', dated 07.09.2023. The bottom-right document is the 'EnMAP Ground Segment Level 1B Processor (ENMAP.HSIL1B)', dated 07.09.2023. All documents are published by the German Remote Sensing Data Center (GRS) and the German Space Operation Center (GSOC).

In-Orbit Validation

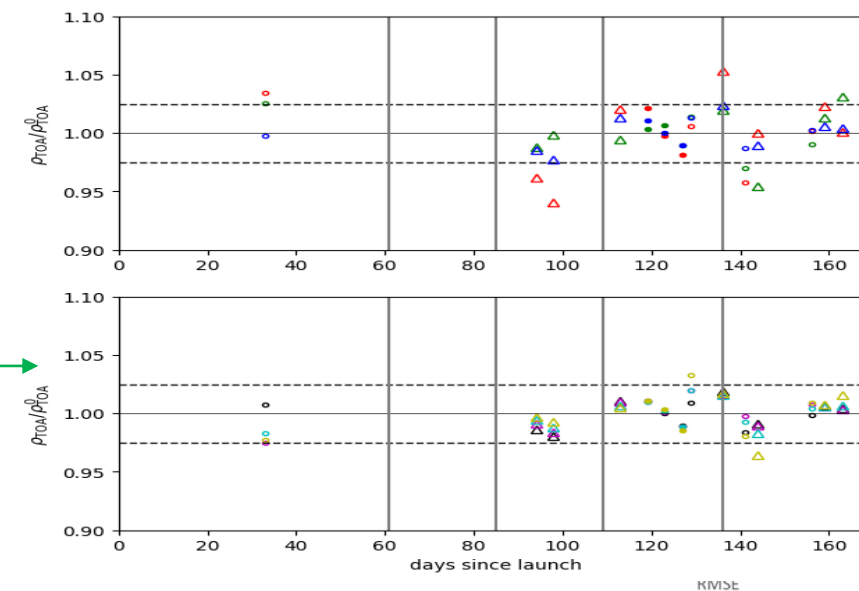


TOA Radiance Uncertainty

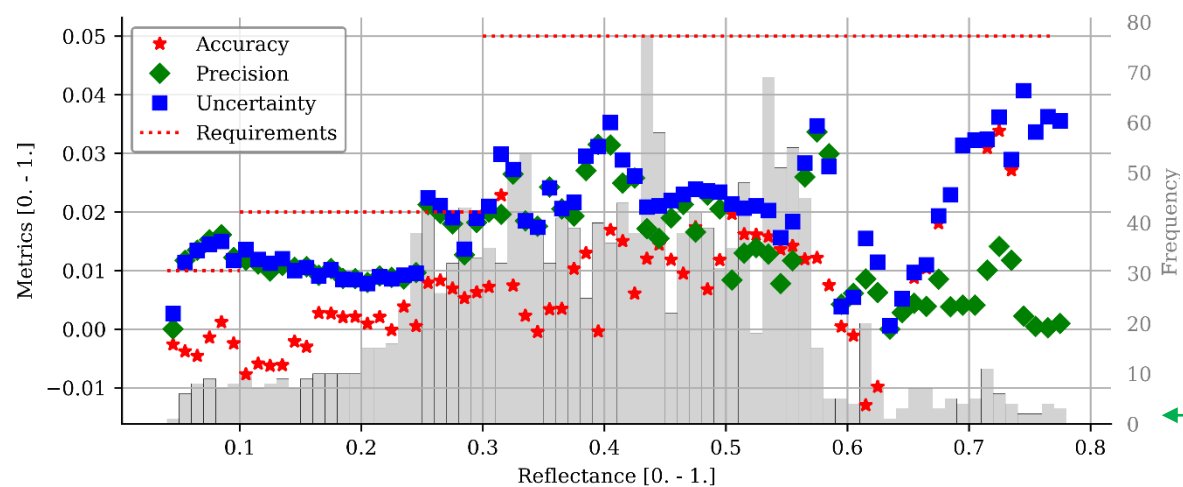


Radiometric Validation

Radiometric Stability



Reflectance Uncertainty



Geometric Performance

Reflectance Validation

