

Operational Lessons from the EnMAP Foreground Mission during the ESA CARMA 2025 Campaign

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Abstract
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Challenge

Launched on 1 April 2022, the Environmental Mapping and Analysis Program (EnMAP; www.enmap.org) has been providing high-quality spaceborne imaging spectroscopy data to the international scientific community for nearly four years. Since the start of routine operations in November 2022, user demand has grown rapidly, with more than 4,400 active users worldwide. Acquisition requests are spatially highly heterogeneous, with particularly strong demand over Europe. As a result, overlapping requests within individual orbits are common, limiting the feasibility of user-defined acquisitions and complicating the generation of consistent hyperspectral time series and spatial-temporal multi-sensor matchups. These challenges became especially apparent during coordinated campaign activities such as the ESA CARMA 2025 campaign, which required frequent, cloud-free acquisitions and close synchronization with field and airborne measurements.

Methodology

To address these challenges, EnMAP introduced the Foreground Mission (FGM) in March 2024 as a general acquisition concept for regions with persistently high user demand. The FGM prioritizes the regular acquisition of extended, high-priority flight lines of up to ~990 km over selected areas in Europe. These flight lines are typically acquired quasi-nadir ($\pm 5^\circ$ off-nadir) at intervals of approximately 27 days during the vegetation period (March–November), enabling systematic spatial coverage and the generation of consistent hyperspectral time series.

Complementary to the regular foreground acquisitions, EnMAP provides high-priority tasking to support large field and airborne campaigns. This includes coordinated acquisitions with in-situ measurements, other imaging spectroscopy missions such as PRISMA and DESIS, as well as with Sentinel-2 and airborne overflights. Acquisition plans are updated on a daily basis and dynamically adapted to cloud conditions, field activities and competing mission priorities. Planned foreground acquisitions are published in advance via the EnMAP website (https://www.enmap.org/data_tools/foreground_mission/), while successfully acquired data are typically available to registered users within approximately six days via the EOWEB Geoportal (<https://eoweb.dlr.de>).

In 2025, a total of 876 Foreground Mission and campaign-related orders were submitted by the ground segment. Some orders were cancelled due to high cloud coverage or scheduling conflicts, 606 orders were ultimately commanded; approximately 70 % of these commanded acquisitions supported campaign activities. The ESA CARMA 2025 campaign represents a prominent example of such targeted support. For this campaign, an initial strategy of twice-monthly acquisitions proved insufficient to reliably

obtain cloud-free monthly time series and spatio-temporal matchups under typical European weather conditions. Consequently, the acquisition strategy was adapted to allow multiple high-priority acquisition attempts per month, with the objective of achieving at least one cloud-free observation per month between March and November 2025. This campaign-specific approach required a high degree of flexibility in mission planning, ground-segment operations, and field logistics.

Study area and data

The Foreground Mission primarily targets high-demand regions across Europe, with a particular focus on Germany. As a representative case study, the ESA CARMA campaign conducted in 2025 near Puch, close to Munich (Germany), illustrates both the operational capabilities and practical limitations of coordinated time-series acquisition. This campaign integrated EnMAP data with extensive in situ measurements, airborne multi-, hyperspectral and radar observations, and acquisitions from other spaceborne sensors, producing a unique multi-sensor data set for time-series analysis and inter-mission comparison accessible to the entire user community.

During the campaign, EnMAP attempted a total of 17 acquisitions over the CARMA Test site in Puch; however, cloud-free conditions (defined as less than 20% cloud cover) were achieved in only eight instances. This highlights the challenges of maintaining consistent, high-quality time series in regions with variable weather and underscores the need for flexible, adaptive mission planning to optimize campaign support and multi-sensor matchups.

Discussion and Conclusions

The ESA CARMA 2025 campaign highlights that flexible and responsive mission planning is essential for effective campaign support and reliable time-series generation in regions characterized by high cloud variability and intense user demand. Although achieving spatial-temporal matchups across multiple missions remains operationally challenging, the EnMAP Foreground Mission has enabled the generation of time series and high-quality multi-sensor data sets that are valuable to the broader user community.

Looking forward, the Foreground Mission will continue in 2026, with a focus on high-demand regions in Europe during the vegetation period and selected global targets during the winter months. In this role, EnMAP serves as an important precursor mission, providing operational experience and best practices for coordinated hyperspectral acquisitions, consistent time-series generation, and enhanced multi-mission interoperability.

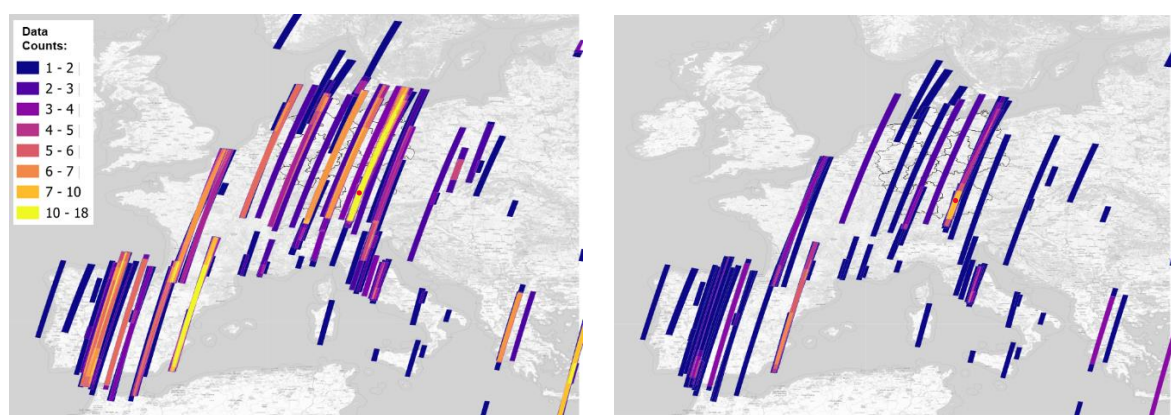


Figure 1: Frequency of EnMAP high-priority foreground mission and campaign flightlines over Europe in 2025, shown for scenes with 100% cloud coverage (left) and less than 20% cloud coverage (right). The red dot in the center indicates the approximate location of Puch in southern Germany, near Munich.