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Abstract
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Status of EnMAP processor and calibration activities

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Challenge

The Environmental Mapping and Analysis Program (EnMAP) mission, launched on April 1, 2022, has been acquiring high-quality hyperspectral measurements since the successful completion of the commissioning phase and start of operations in November 2022. EnMAP imagery for Earth observations consists of 30x30 km^2 tiles with a spatial resolution of 30 m and covers the full reflective range 418–2445 nm with 224 spectral channels of bandwidths between 5 nm and 12 nm. The correct processing and high quality of these data are ensured by the EnMAP Ground Segment (DLR) through the Processor and Calibration team, whose main operational tasks include the maintenance of the processing chain, in-flight calibration, data quality control and instrument monitoring. In this contribution, we give a detailed account of our activities since the beginning of the operational phase with a special focus on the improvements of relevance to users of EnMAP data.

Methodology

The EnMAP payload consists of two push-broom spectrometers covering the visible and near infrared (VNIR) and the short-wave infrared (SWIR) spectral ranges with requirements on radiometric accuracy and stability of 5% and 2.5% respectively and spectral accuracy of 0.5 nm for VNIR and 1 nm for SWIR. This performance is possible in EnMAP due to the extensive in-flight calibration equipment, which enables different calibration types: relative radiometric (white Spectralon®), absolute radiometric (Sun diffuser), spectral (doped Spectralon®), linearity (focal plane LEDs), deep space and dark frames (closed shutter). The EnMAP Ground Segment regularly schedules the calibration measurements in order to continuously calibrate and monitor the instrument. The EnMAP processing chain then incorporates the latest calibration tables to generate the Earth observation user products at three levels: L1B (top-of-atmosphere radiances), L1C (orthorectified top-of-atmosphere radiances) and L2A (orthorectified bottom-of-atmosphere reflectances). The processing chain is under active maintenance and is frequently updated to improve the delivered products. The radiometric, spectral and geometric quality of EnMAP products of all levels is controlled regularly and reported in the publicly available mission quarterly reports. The same report also includes a comprehensive overview of the life-limited items and other instrument parameters monitored.

Results

We briefly present selected results from the commissioning phase, which validated the products delivered by the EnMAP processing chain. At the start of the operational phase, three main EnMAP processing and calibration issues remained:

- VNIR degradation. A rapid sensitivity decay of the VNIR instrument was noticed soon after the first calibration acquisitions. The decay slowed down during 2022 and stopped in 2023 (see figure below). The issue was mitigated in March 2023 by applying dynamic coefficients between radiometric calibrations.
- Across-track striping. This effect was visible in both VNIR and SWIR, hampering the use of EnMAP data for certain applications. After thorough investigation, an image-based destriping algorithm developed by GFZ was implemented in March 2023 at L1B level. The algorithm is very effective in reducing striping in most situations.
- VNIR/SWIR co-registration. At the end of commissioning, the alignment between VNIR and SWIR images amounted to 0.7–0.8 pixels, above the requirement of 0.3 pixels. This was sequentially improved to 0.06 pixels by March 2023 through two geometric calibrations and a processor update.

All three issues have been solved and can be retroactively fixed in past scenes by re-ordering the products. Other issues fixed include L2A snow spectra (July 2023) and the adjacency correction in L2A water products (September 2023). In addition, a new SWIR band configuration in the instrument was uplinked in July 2023.

Outlook for the future

The EARSeL workshop in April 2024 will mark the second anniversary of EnMAP in orbit. During these two years, EnMAP has gradually acquired, delivered and archived tens of thousands of hyperspectral image products, filling an important gap in the needs of the global remote sensing community. The Processor and Calibration team within the EnMAP Ground Segment has routinely performed its operational tasks and in parallel solved the main issues affecting the quality of the end-user products. Additional minor issues (e.g., SWIR along-track striping and VNIR/SWIR radiometric consistency in overlapping spectral range) are being investigated at the moment. In this respect, the feedback provided by users (as well as by EnMAP Space Segment and Science Segment) remains crucial to improve the delivered products during the EnMAP mission lifetime and beyond.

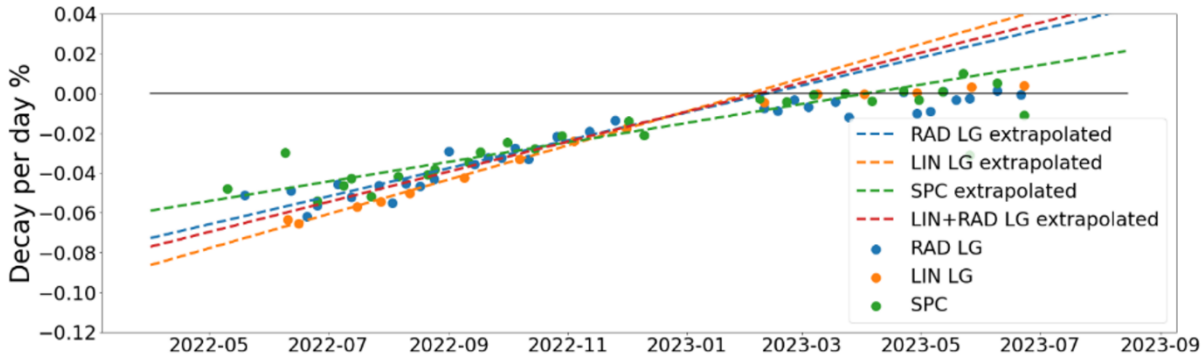

Figure VNIR degradation effect as a function of time. The decay rate was fast after launch, but it has gradually slowed down and essentially stopped by March 2023.