RADIOMETRIC AND SPECTRAL CALIBRATION AND VALIDATION ACTIVITIES FOR ENMAP

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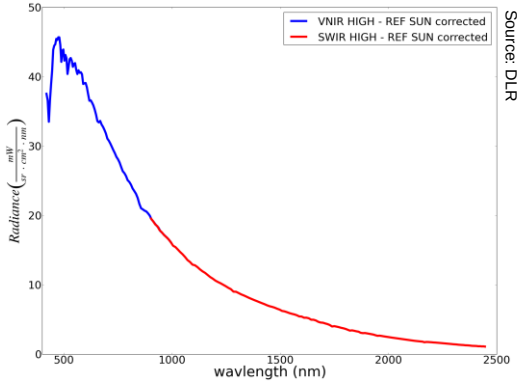
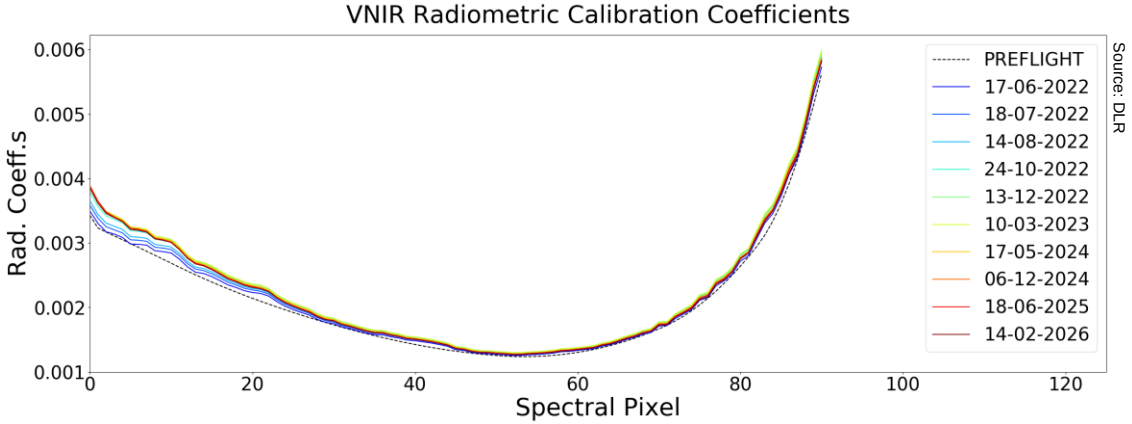
CALIBRATION ACTIVITIES

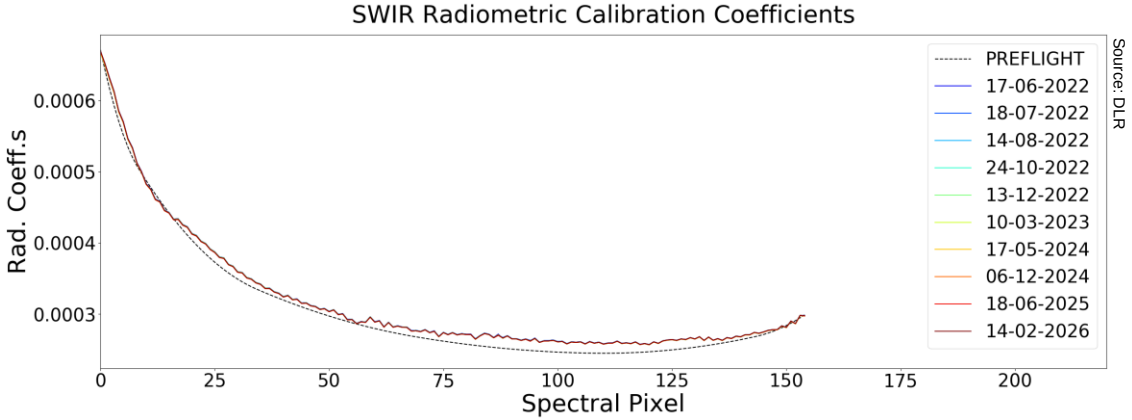
Enmap.org, Mizen Head, Cork, Ireland

Absolute Radiometric Calibration

- The Absolute Radiometry is calibrated using solar diffuser observations
- Since launch, there have been 35 calibration updates.
- Currently updated every 2 months
- The VNIR and SWIR Radiometry changed after launch
- VNIR Radiometry has changed during the mission: quickly at first during the commissioning phase and more slowly since February 2023

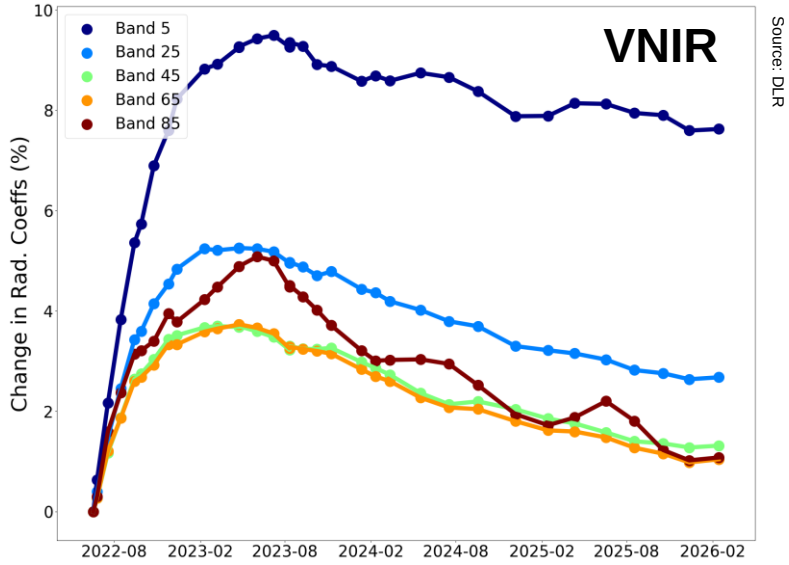


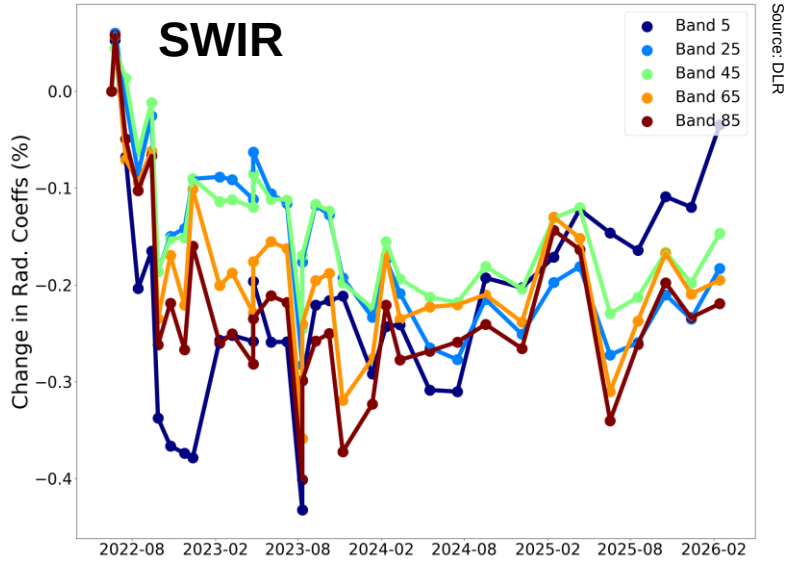




Absolute Radiometric Calibration – Long term

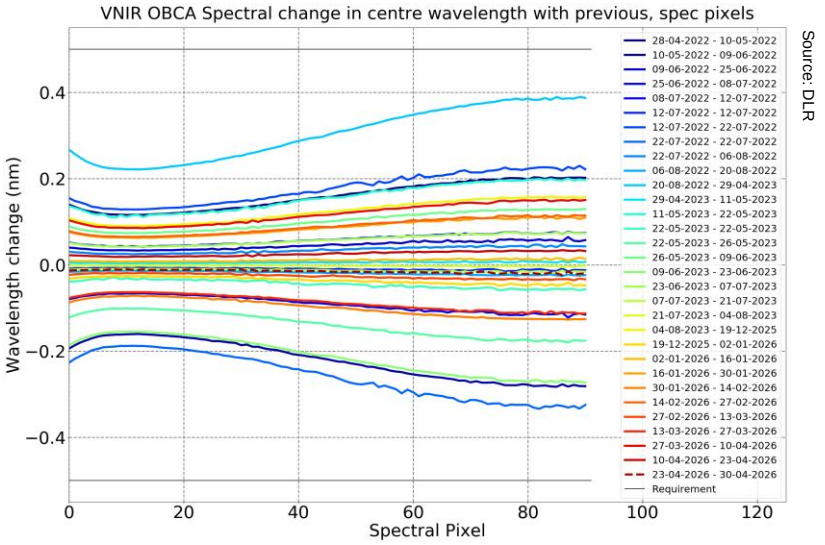
- VNIR Radiometry increased by up to 10% (band dependent) to compensate for changes in the measued signal and are still slowly changing
  - Frequent calibration updates ensure that changes do not affect the data quality
- SWIR Radiometry has been very stable since the end of the Commisioning Phase

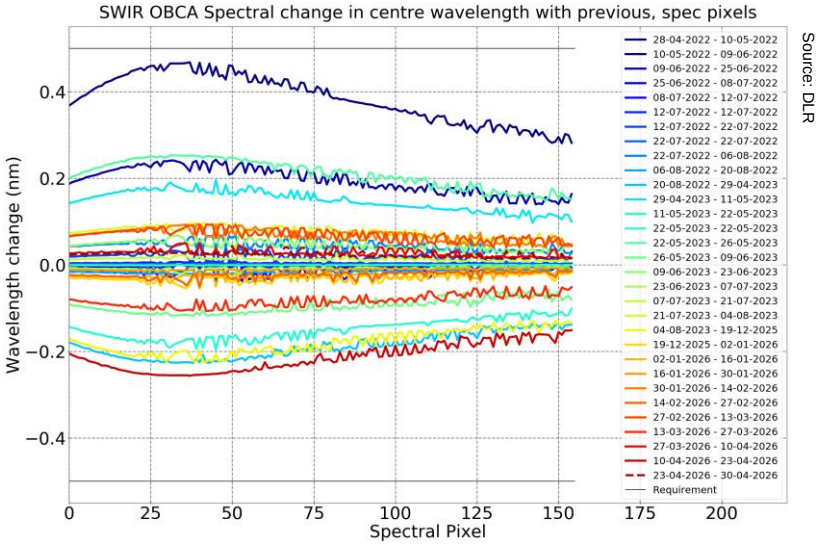




Spectral Calibration

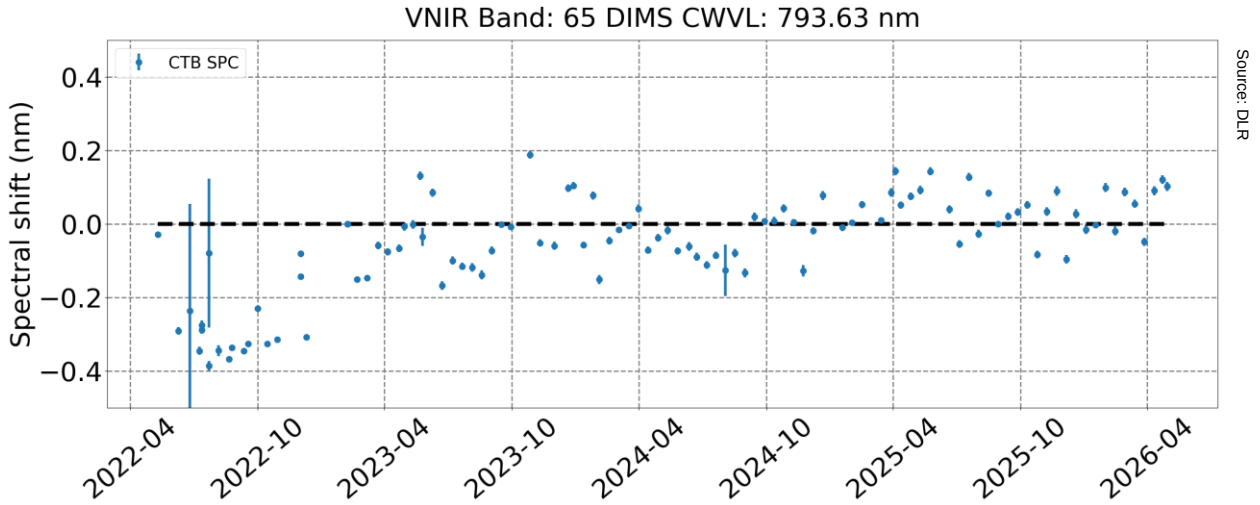
- New central wavelengths are calculated for each calibration measurement by shifting the spectrum so that the difference between the measured and reference spectrum is minimised
- Since launch, there have been 6 calibration updates.
- Spectral calibration is assessed every two weeks
- Both sensors are well within the requirements since February 2023 (40 months)
- The spectra smile is well characterised and stable

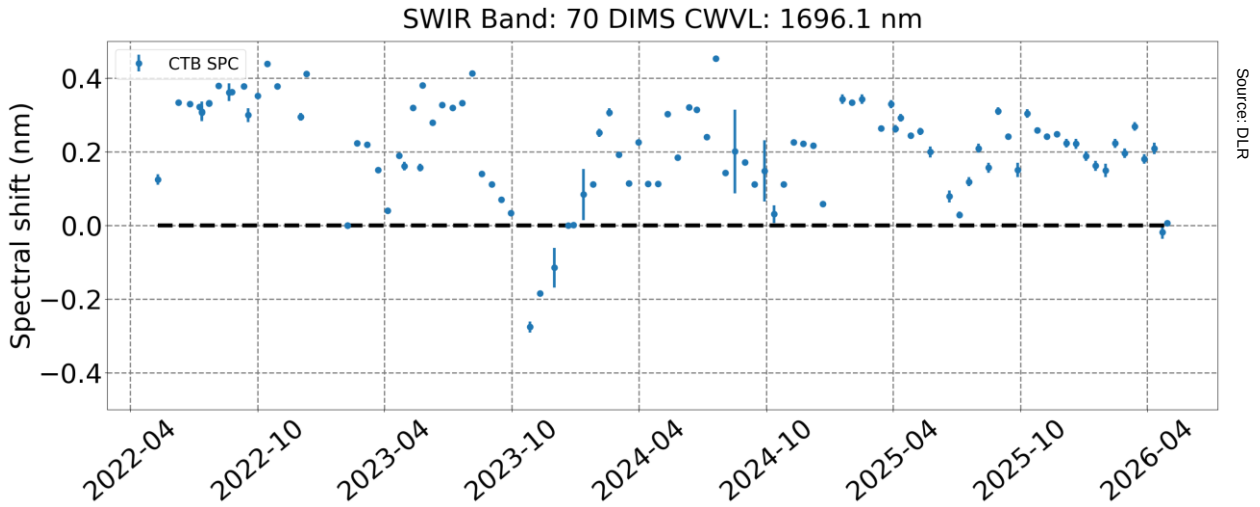




Spectral Calibration – Long term trends

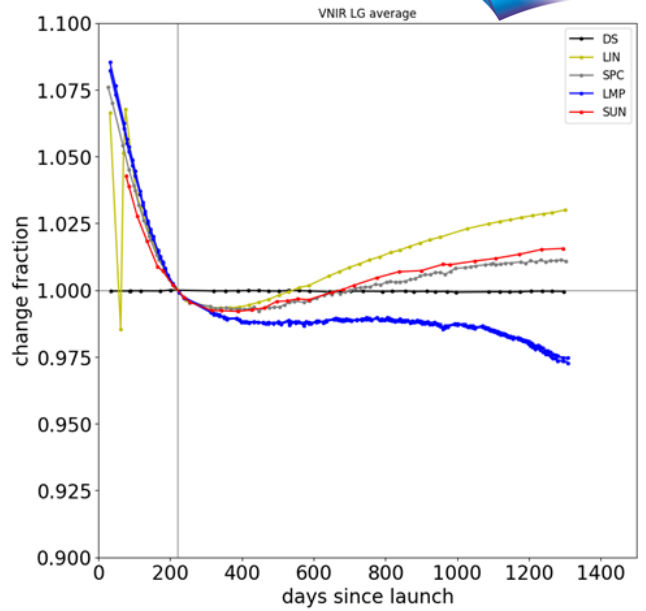
- Global spectral shifts are less than the 0.5 nm requirement
- VNIR spectral shifts are within 0.2 nm and average close to zero
- SWIR spectral shifts over time suggest that there is a +0.2 nm bias
  - Although small, within requirements and at the limits of the mission design, this small shift will be corrected for in a planned future update
- See Poster 9 by M. Bachmann et al – Data Quality for EnMAP



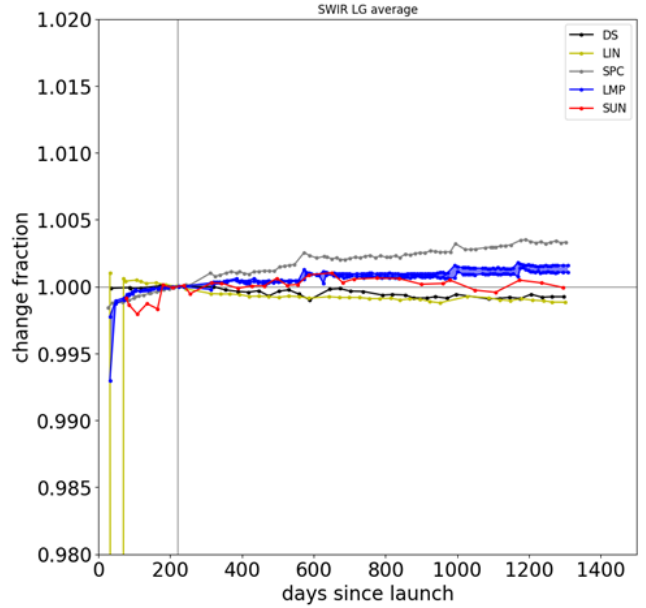


All Calibration Systems – Long term trends

- The VNIR signal degraded during first year (the root cause is unknown but contamination has been discarded) but stabilised in early 2023
- The sensor signal is now recovering and the onboard lamp signal is degrading
- The SWIR calibration measurements are very stable over the mission lifetime
- Dark signal is very stable throughout mission



Source: DLR



Source: DLR

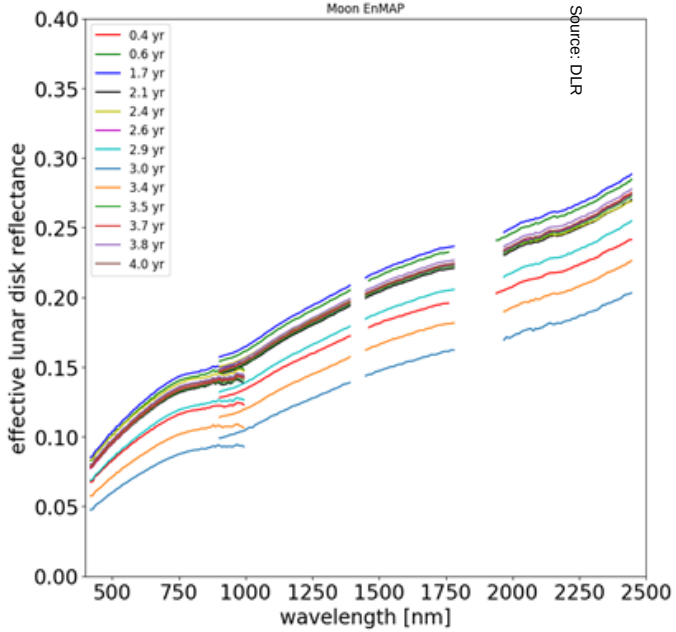
VALIDATION ACTIVITIES

Enmap.org, Playa Nazabal, Cuba

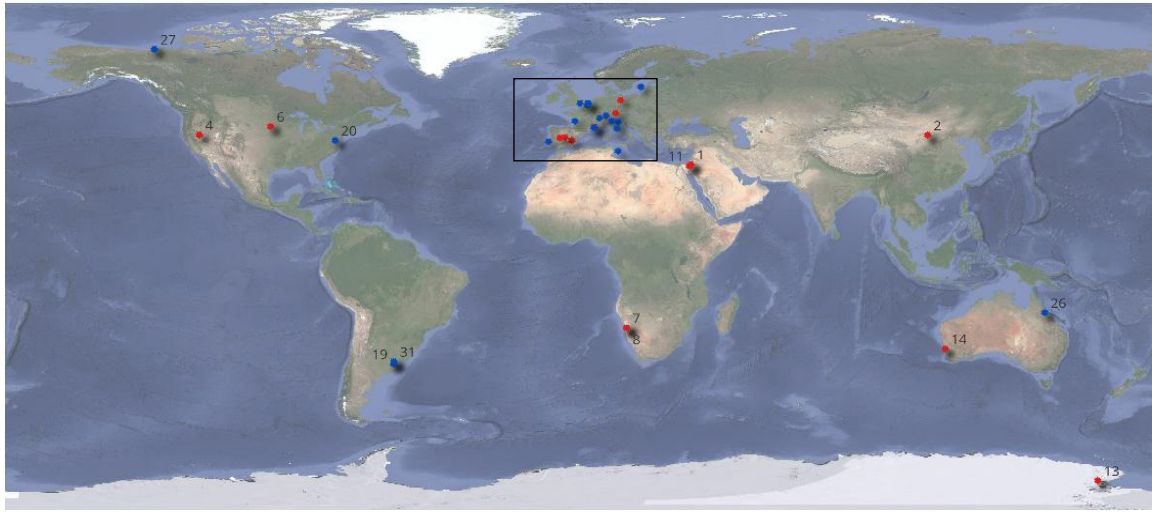
Moon Observations

Source: DLR

- Moon observations are not part of the routine operations but are useful for Cal/Val activities
- Fourteen observations have been performed so far and committed to acquiring one every 2 months
- These measurements are useful for the VNIR-SWIR mismatch investigation, alternative radiometric validation approaches and diffuser aging assessment
- See earlier presentation by M. Pato et al – EnMAP Moon Observations



TOA radiance and BOA reflectance validation sites

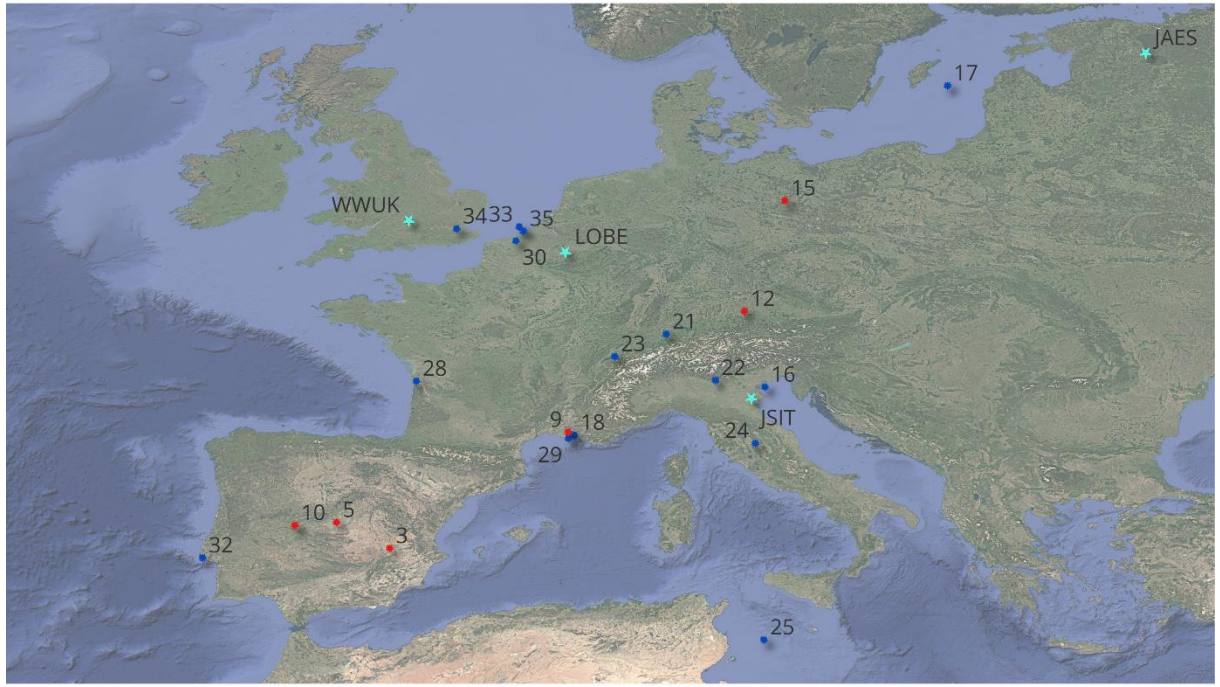


Land Sites

1 – Amiaz Plain
2 – Baotou Sand (BSCN)
3 – Barrax
4 – Black Rock Playa
5 – Camarena
6 – Sioux Falls
7 – Gobabeb RadCalNet (GONA)
8 – Gobabeb HYPERNETS (GHNA)
9 – La Crau (LCFR)
10 – Majadas del Tietar
11 – Makhtesh Ramon
12 – Munich North Isar
13 – Nansen Ice Shelf
14 – Pinnacles
15 – TXL Airfield

Water Sites

16 – AAOT
17 – Alkor
18 – Berre
19 – Chascomus
20 – Chesapeake Bay
21 – Greifensee
22 – Lake Garda
23 – Lake Geneva
24 – Lake Trasimeno
25 – Lampedusa
26 – Lucinda Jetty
27 – Mackenzie_campaign
28 – Magest
29 – Mesurho
30 – Oostende
31 – Rio De La Plata
32 – Tejo_estuary
33 – Thornton
34 – Wraysbury
35 – Zeebrugge



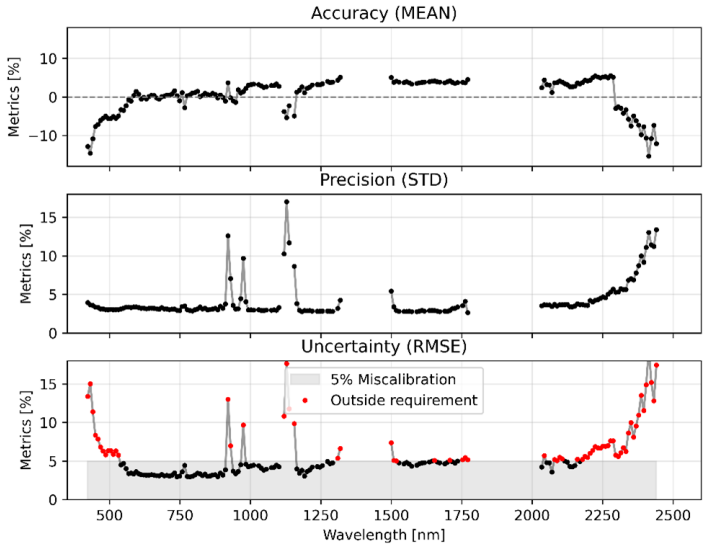
New HYPERNETS sites

Jarvselja, Estonia (JAES)
Jolanda di Savoia (FE), Italy (JSIT)
Lonzee, Belgium (LOBE)
Wytham Woods, UK (WWUK)

New in situ data from the LANDHYPERNET network for the sites GHNA, JAES, JSIT, LOBE and WWUK are currently being integrated.

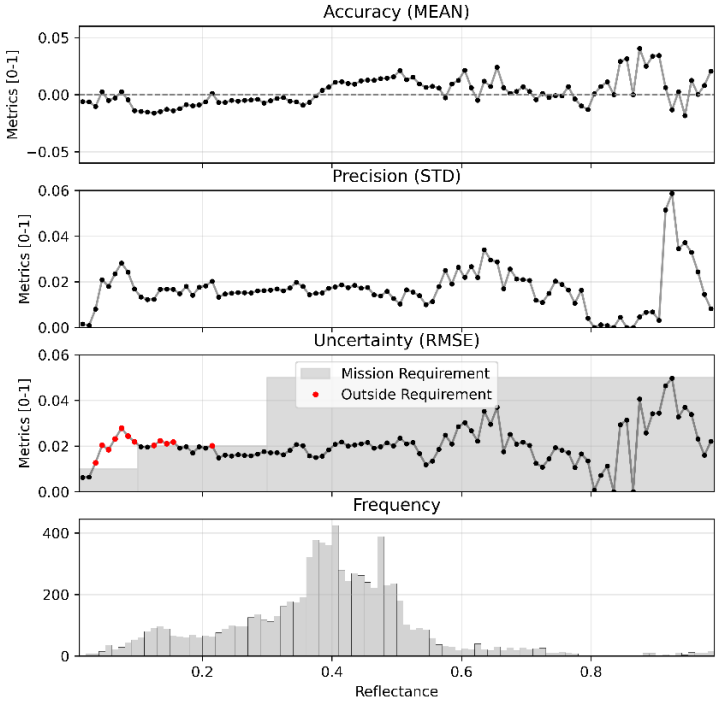
EnVAL: validation of EnMAP products - results

Top-of-atmosphere radiance validation



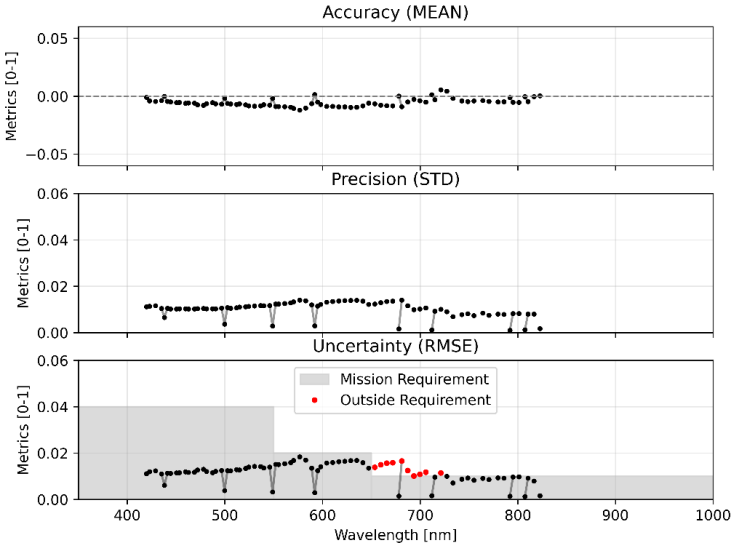
Errors between EnMAP TOA radiance and propagated TOA radiance from in situ measurements against wavelength for all arid validation sites based on **44 matchups**.

Bottom-of-atmosphere reflectance validation



Errors between EnMAP and in situ BOA reflectance against reflectance level for all validation sites based on **62 matchups**.

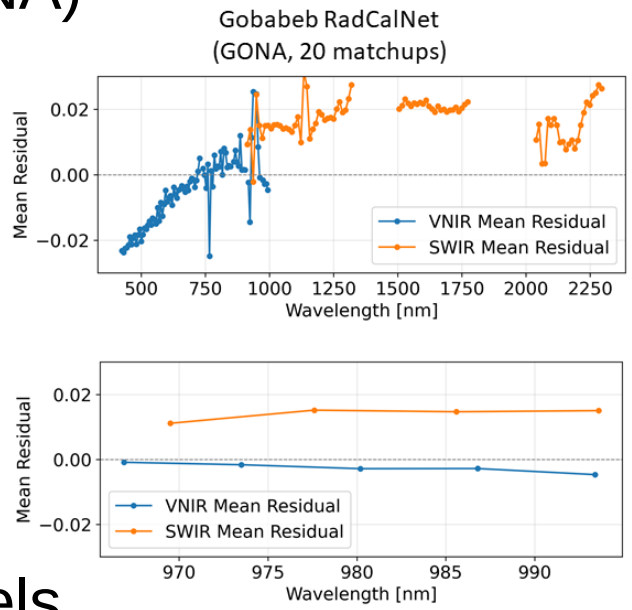
Normalized Water-Leaving Reflectance validation

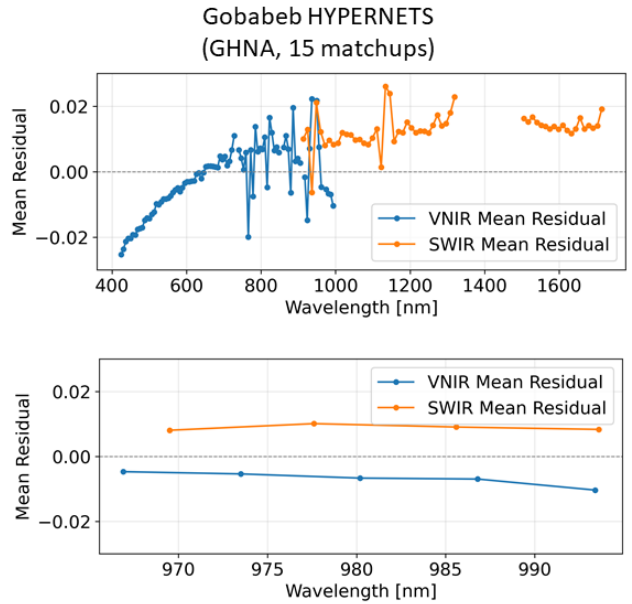


Errors between EnMAP and in situ Normalized Water-Leaving Reflectance against wavelength based on **90 matchups**

BOA reflectance validation – Comparison of GONA and GHNA

- 10 new matchups for the Gobabeb HYPERNETS (GHNA) site
- Enable direct comparison between two independent measurement stations
- Results show overall good consistency
- A stronger positive bias is observed in the SWIR channels for RadCalNet compared to HYPERNETS

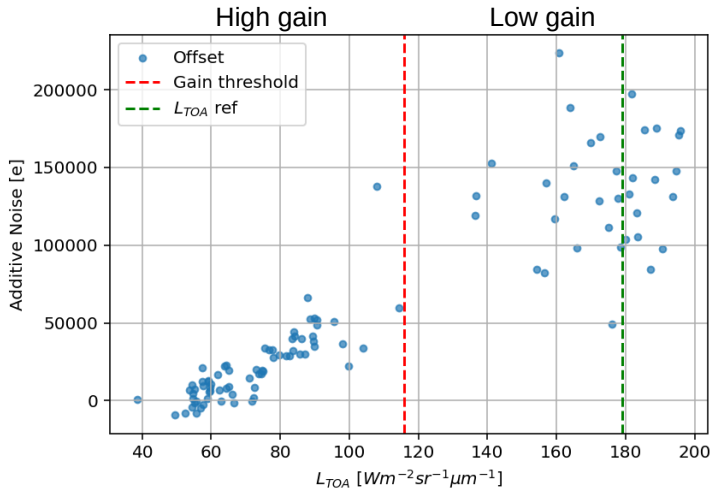




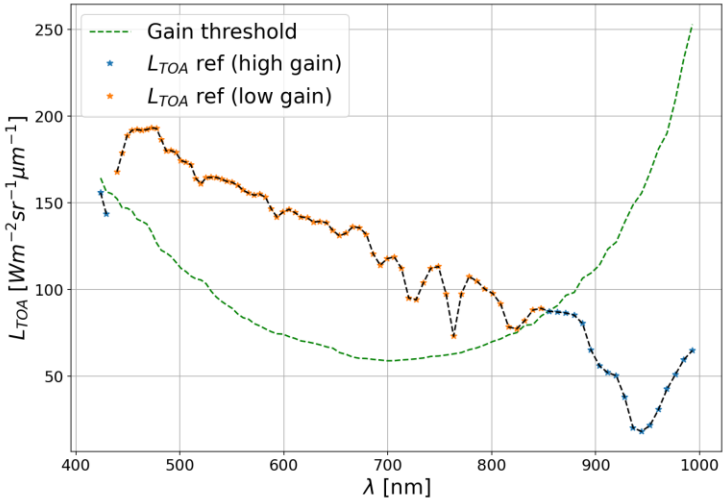
Signal-to-Noise Ratio (SNR): New noise model

- The **observed SNR** can be described as a combination of:
  - photon noise (signal-dependent)
  - additive noise (signal-independent)
- The **additive noise** component can be derived from the **observed SNR** and corresponding $\mathbf{L_{TOA}}$
- This enables scaling of the **SNR** to a **reference radiance** and **fwhm**

Additive noise vs. LTOA at 496 nm

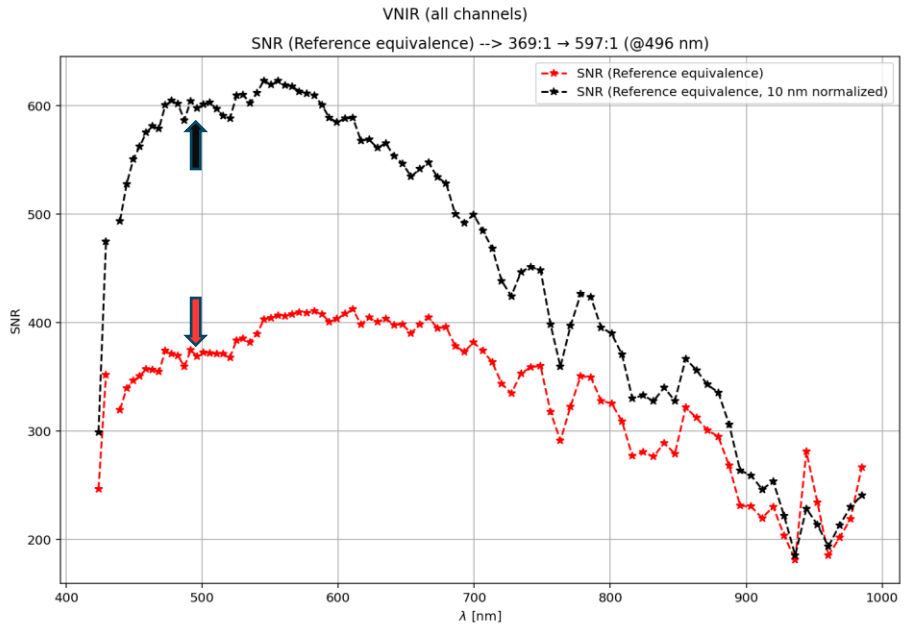


Gain threshold and reference LTOA for all VNIR channels



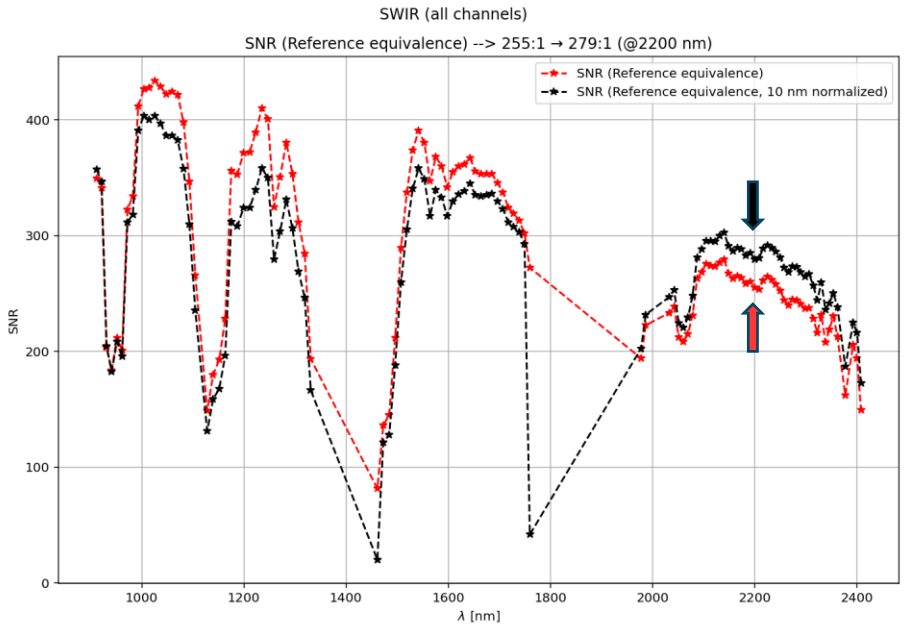
Signal-to-Noise Ratio (SNR): Results

VNIR (Mean of 106 Tiles, Version>= 01.05.06)



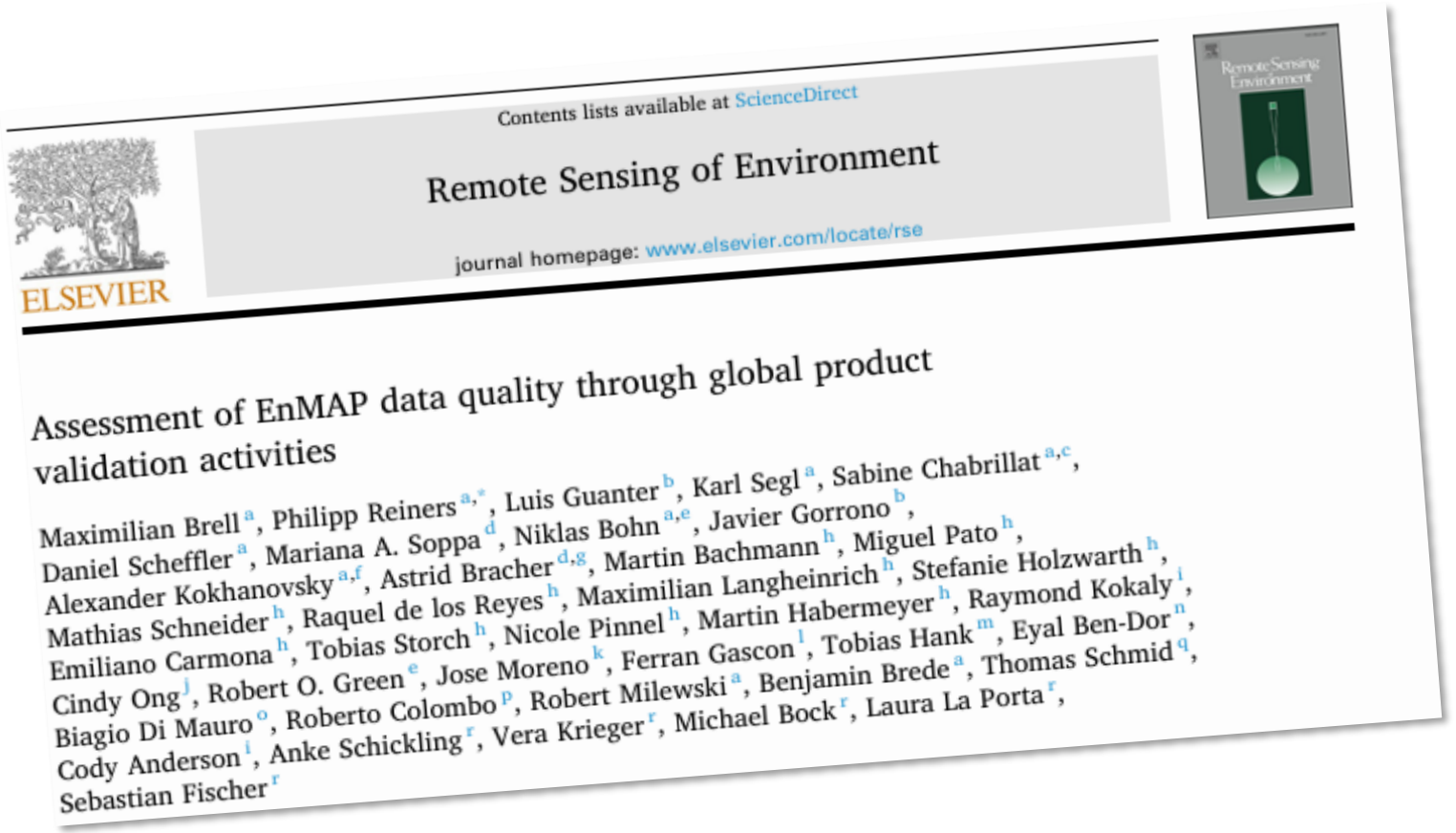
SNR_{Ref} @496nm: **369:1** (Mission requirement > 343:1)
SNR_{Ref} 10 nm @496nm : **597:1** (Mission requirement > 500:1)

SWIR (Mean of 98 Tiles) , Version>= 01.05.06)



SNR_{Ref} @2200nm: **255:1** (Mission requirement > 137:1)
SNR_{Ref} 10 nm @2200nm : **279:1** (Mission requirement > 150:1)

Publication of external EnMAP validation in RSE



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Assessment of EnMAP data quality through global product validation activities

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Scan me!

New contact for the support of EnMAP validation campaigns

From 01.07.2026 for the support of EnMAP validation campaigns please contact **Dr. Stéphane Guillaso**:

stephane.guillaso@gfz.de

SUMMARY

Enmap.org, Laguna Marano, Italy

Summary

- Calibration
  - The VNIR and SWIR Absolute Radiometric calibration is stable and meets the 2.5% requirement between observations
  - Early mission degradation of the VNIR sensor has been mitigated by frequent updates to the radiometric calibration
  - The VNIR and SWIR Spectral calibration is stable and meets 0.5 nm requirement
  - The SNR is greater than **590 at 495 nm** for a radiance value of 36 mW/sr/cm^2/µm (better than requirement of 500:1) and **248 at 2200 nm** for a radiance value of 0.5 mW/sr/cm^2/µm (better than requirement of 150:1)
  - A VNIR-SWIR mismatch between 900-1000 nm linked to a linearity issue is under investigation using Earth, Moon and calibration measurements
- Validation
  - Validation of top-of-atmosphere radiance, bottom-of-atmosphere reflectance, and normalized water-leaving reflectance shows that results are largely within mission requirements
  - New HYPERNETS stations JAES, JSIT, LOBE, and WWUK are currently integrated into the external EnMAP validation
  - Comparison of results from the independent RadCalNet and HYPERNETS stations at Gobabeb shows consistent results
  - A new SNR noise model was implemented, deriving both the additive and photon noise component
  - The SNR for radiance of a 30% reflective target, normalized to an SSI of 10 nm, is **597 at 495 nm** (better than requirement of 500:1) and **297:1 at 2200 nm** (better than requirement of 150:1)
  - Great thanks to the field validation teams and the external EnMAP validation at GFZ especially **Prof. Sabine Chabrillat** and **Dr. Karl Segl**

Imprint

Topic: **Radiometric and Spectral Calibration Activities for EnMAP**
14th EARSeL Workshop

Date: 2026-06-02

Author: David Marshall Ingram

Institute: DLR, Remote Sensing Technology Institute

Federal Ministry of Research, Technology and Space

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Absolute Radiometric Calibration – focal plane

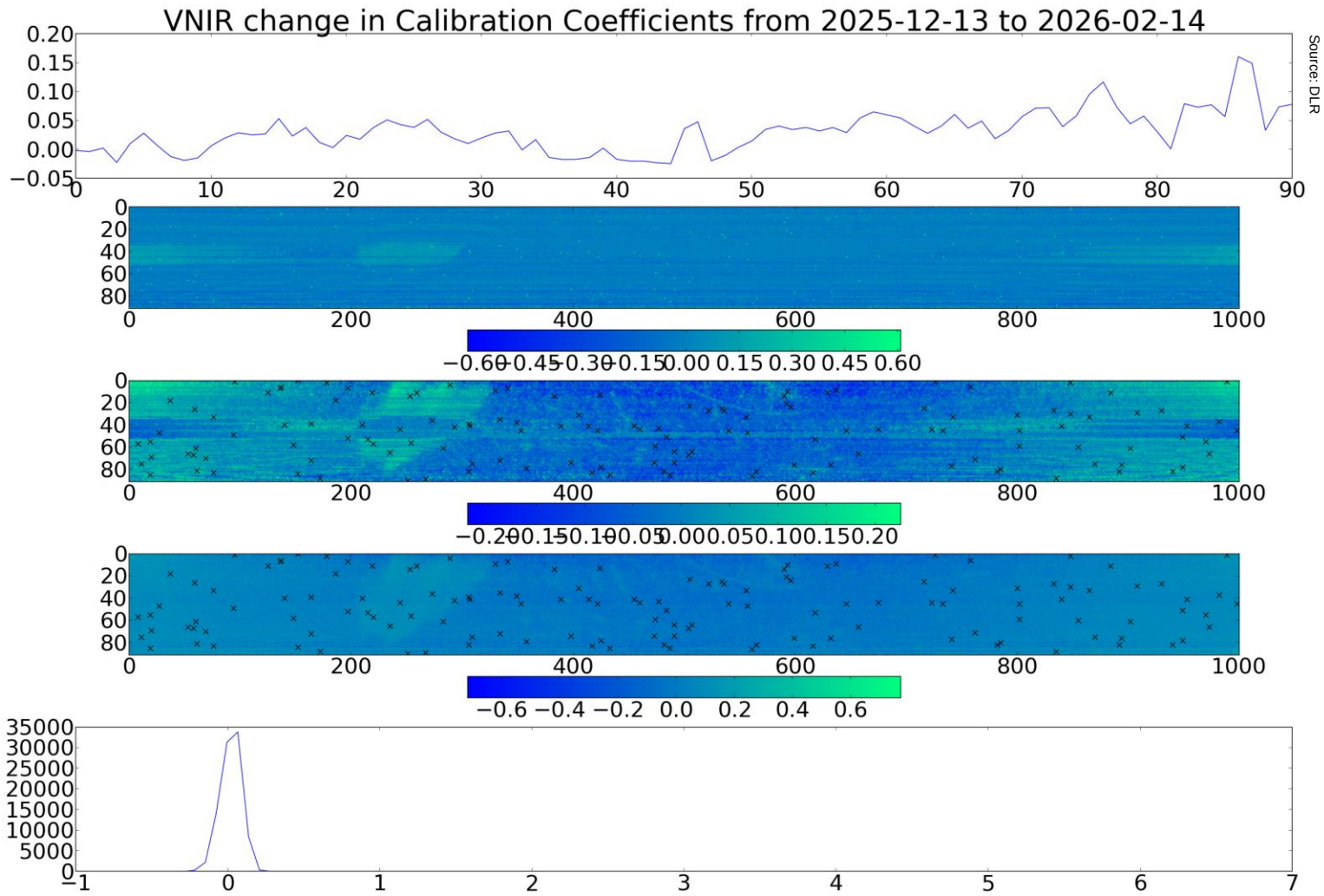
Radiometric
% change

Gain Matching
% change

RNU
% change

All Radiometry
% change

Rad.xGMxRNU
Distribution of % changes



All color maps scaled to 3x standard deviation