# A Brief History of the Inflight Spectral and Radiometric Performance of EnMAP

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**13th EARSeL Workshop on Imaging Spectroscopy**
**València, 17.04.2024**

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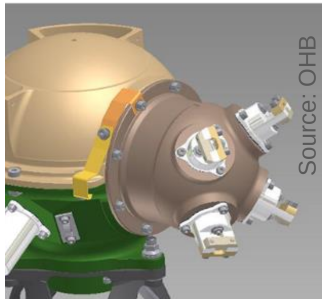
DLR

# EnMAP Onboard Calibration

1. **OBCA-Radiometric Stability** Lamp calibration with white spectralon sphere, frequency: weekly
2. **OBCA-Spectral** Spectral calibration with doped spectralon sphere, frequency: 2 weeks
3. **Absolute Radiometric** Sun calibration with sun diffuser, frequency: monthly. As of April 2024: every 2 months
4. **Linearity Calibration** with LEDs in front of focal plane, frequency: monthly
5. **A. Shutter Calibration Mechanism** Deep Space calibration, frequency: monthly
5. **B. Shutter Calibration Mechanism** dark measurement, frequency: before and after every image acquisition

1.


2.

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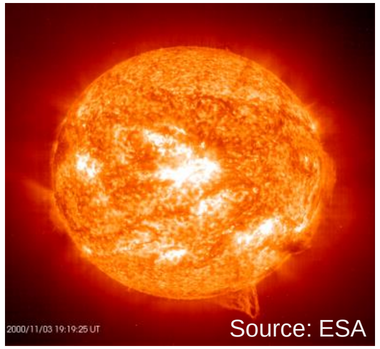


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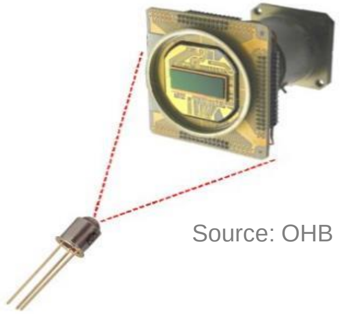



5A.

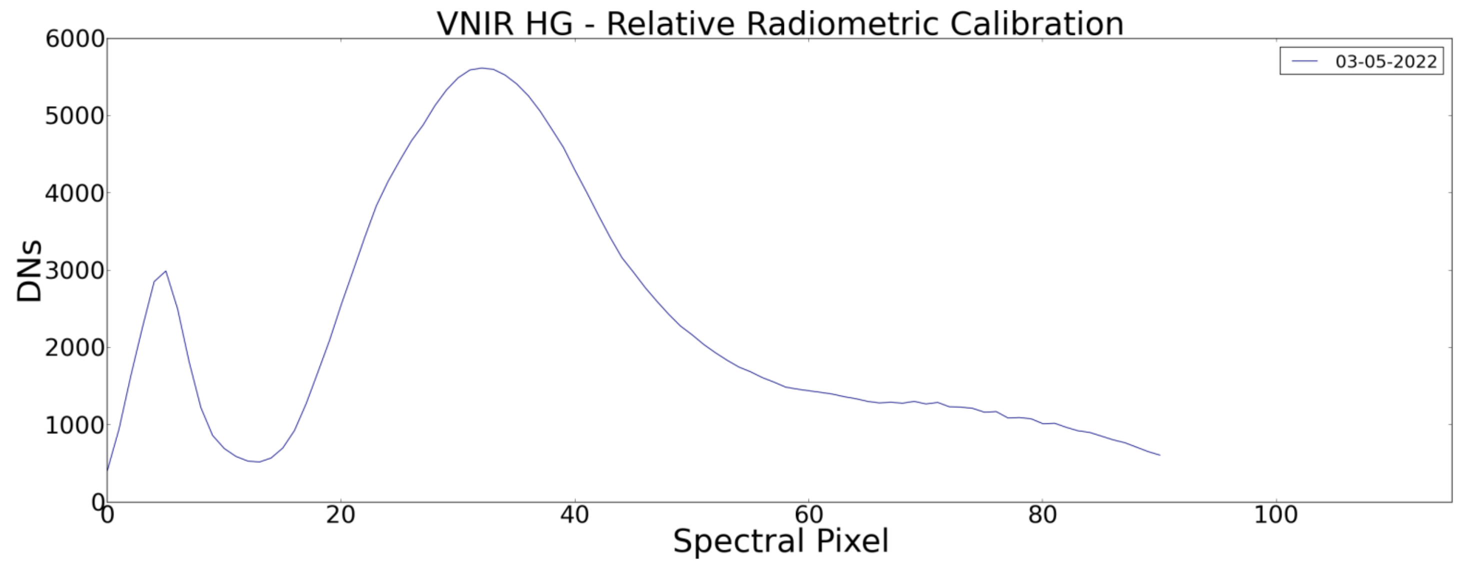

5B.

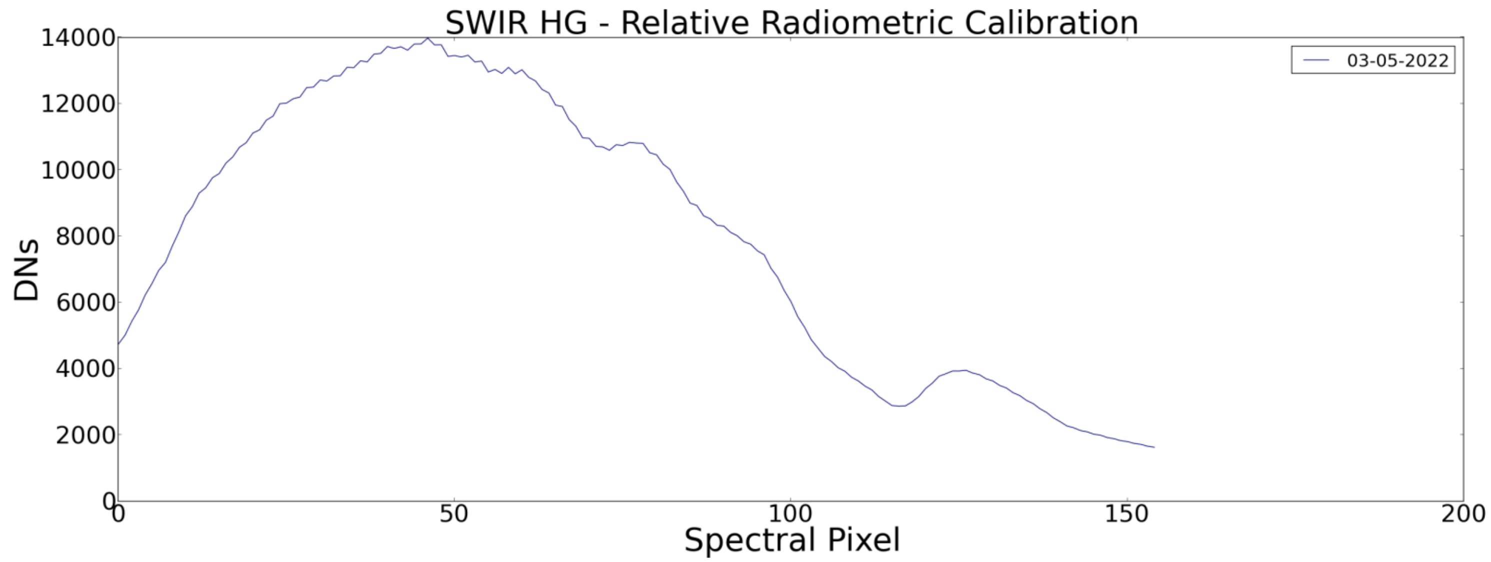

DLR

EnMAP

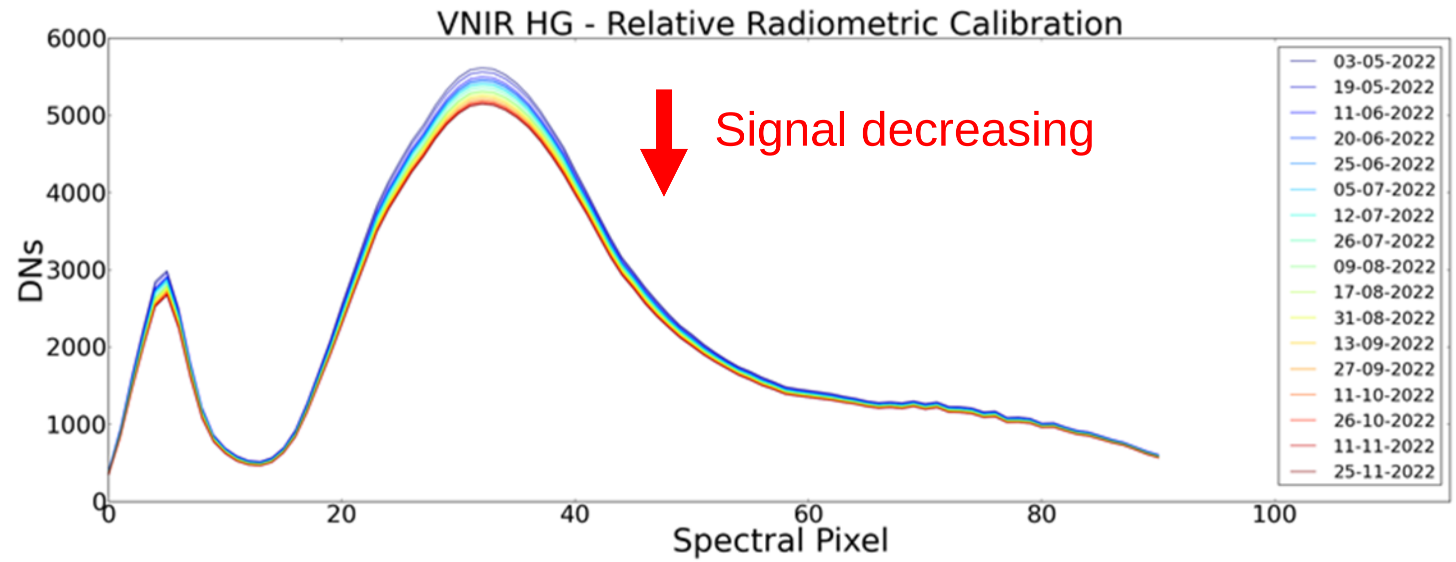
# Radiometric Calibration Measurements
# April – December 2022

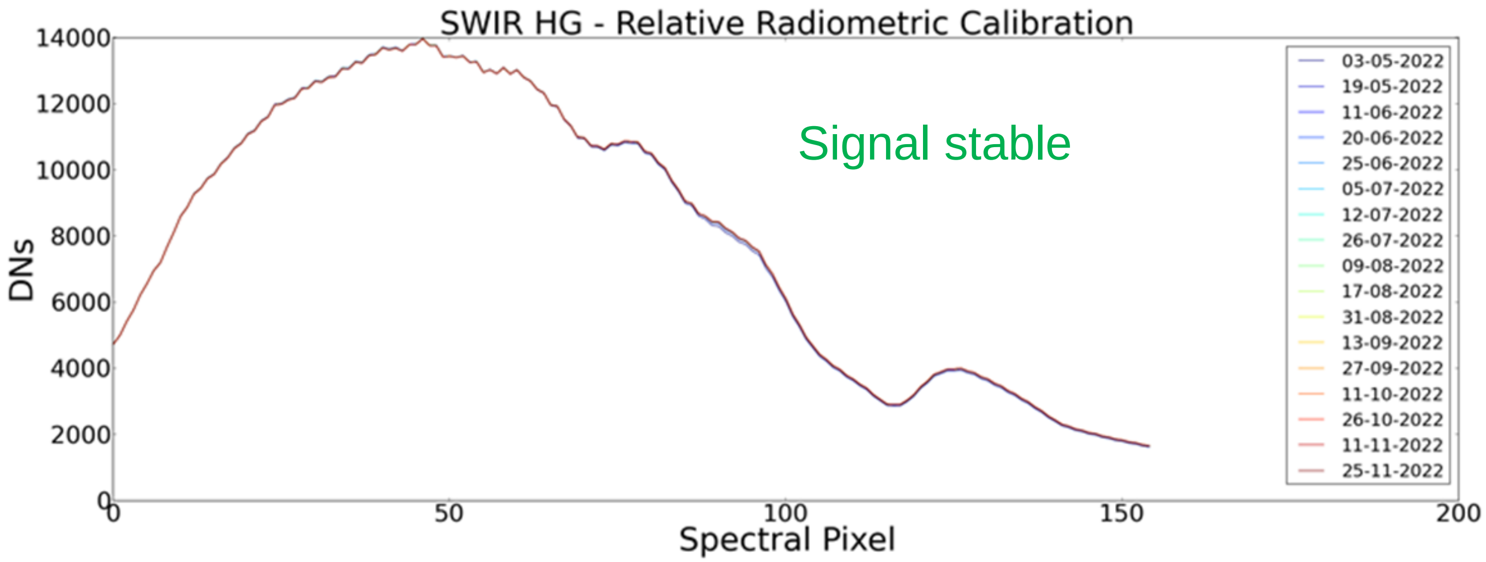
# First OBCA-Radiometric Lamp Measurements



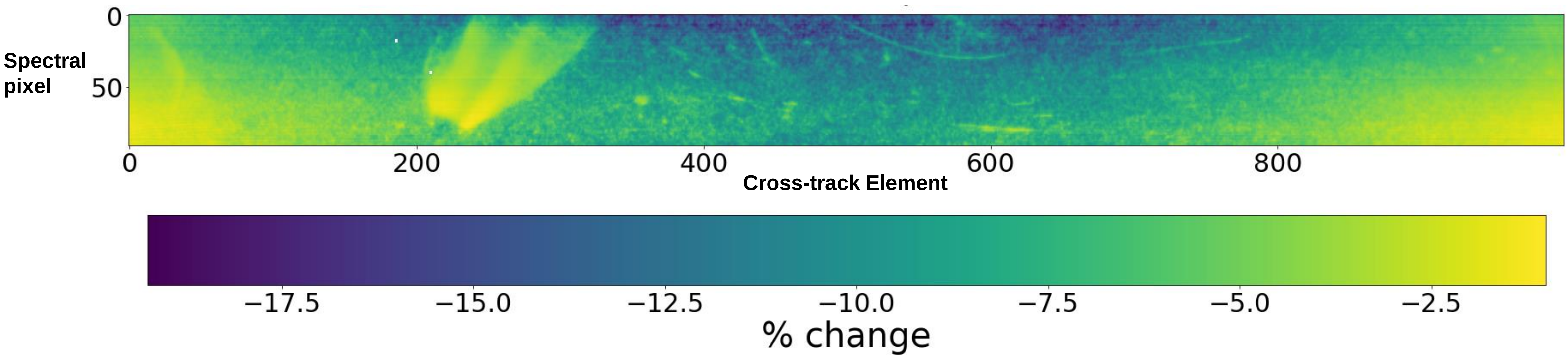
# Early OBCA-Radiometric Lamp Measurements



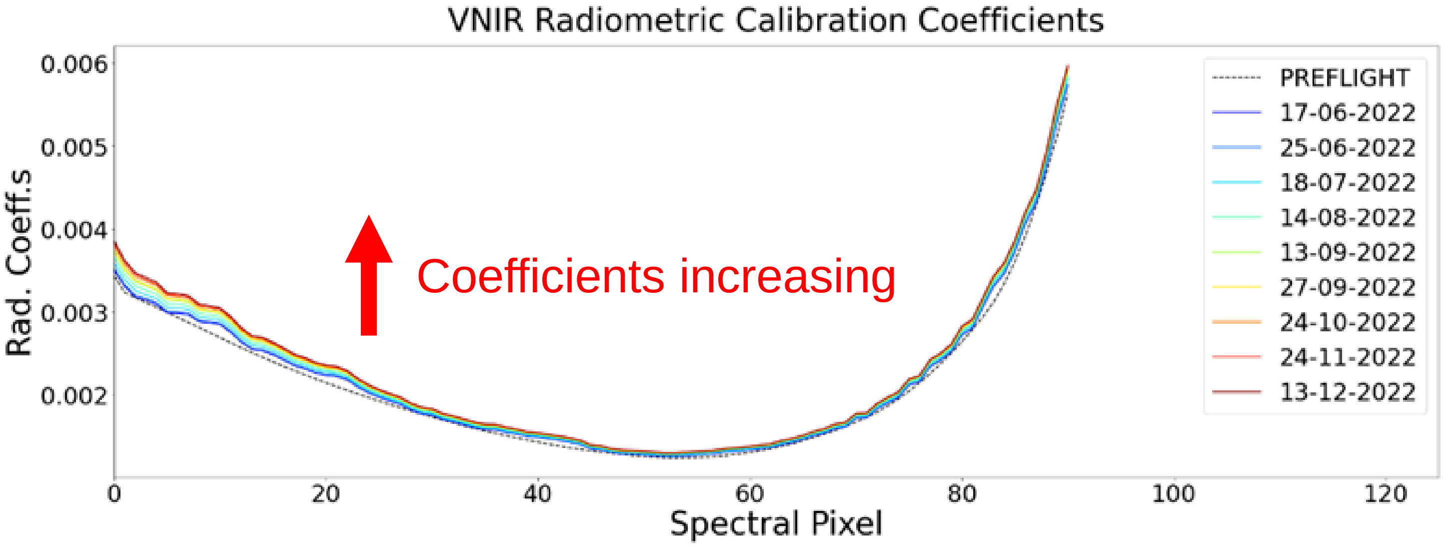
# Degradation Distribution Pattern

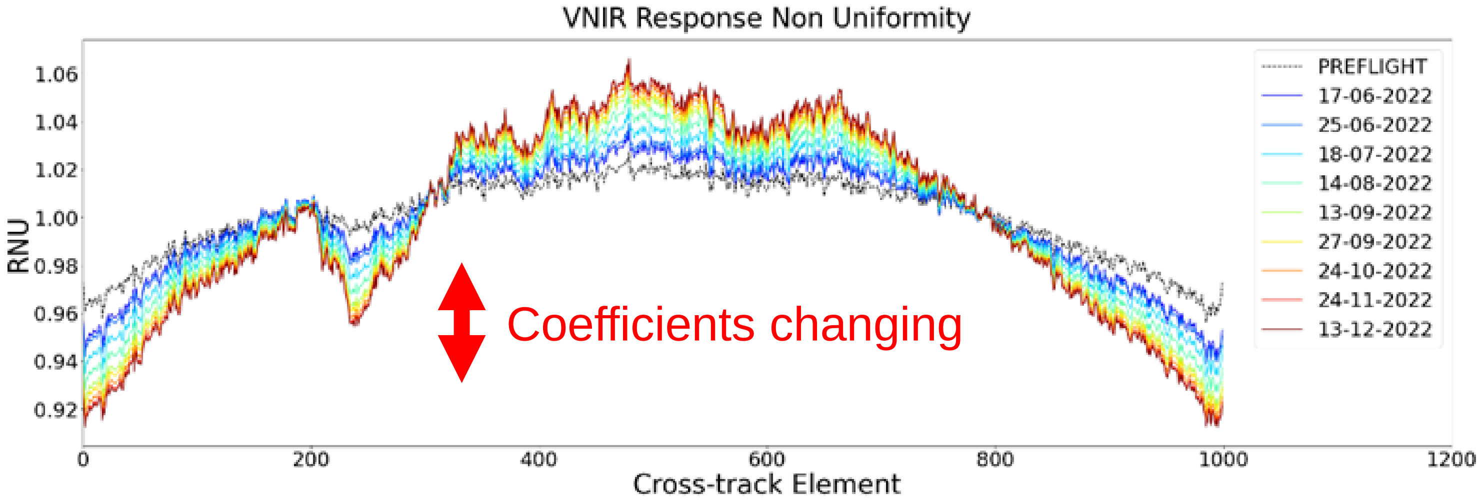
- Degradation map from OBCA-Radiometric Lamp in VNIR HG
- Percentage change from May – November 2022




- Degradation
  - affects VNIR only
  - affects high and low gains
  - is visible in other calibration systems **-> change in detector sensitivity**

# Early Mission Calibration Coefficients



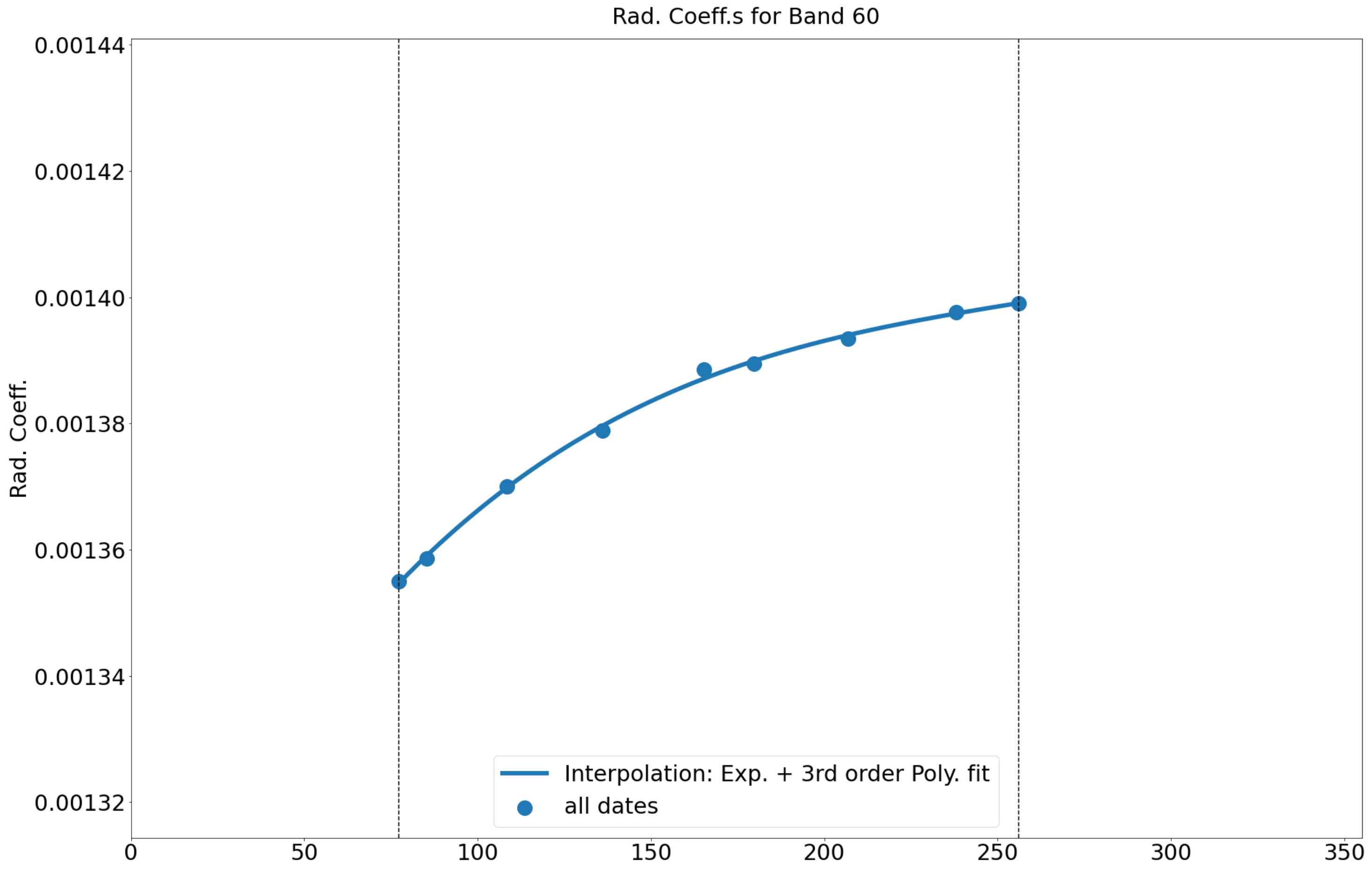



# Dynamic Coefficients

Due to fast degradation in VNIR sensor, calibration tables used in L1B processing could become outdated quickly

Solution: model VNIR RNU and radiometric behaviour with „Dynamic Coefficients“ from an exponential-polynomial function

Dynamic Coefficients are used between April – December 2022 rather than coefficients in calibration tables

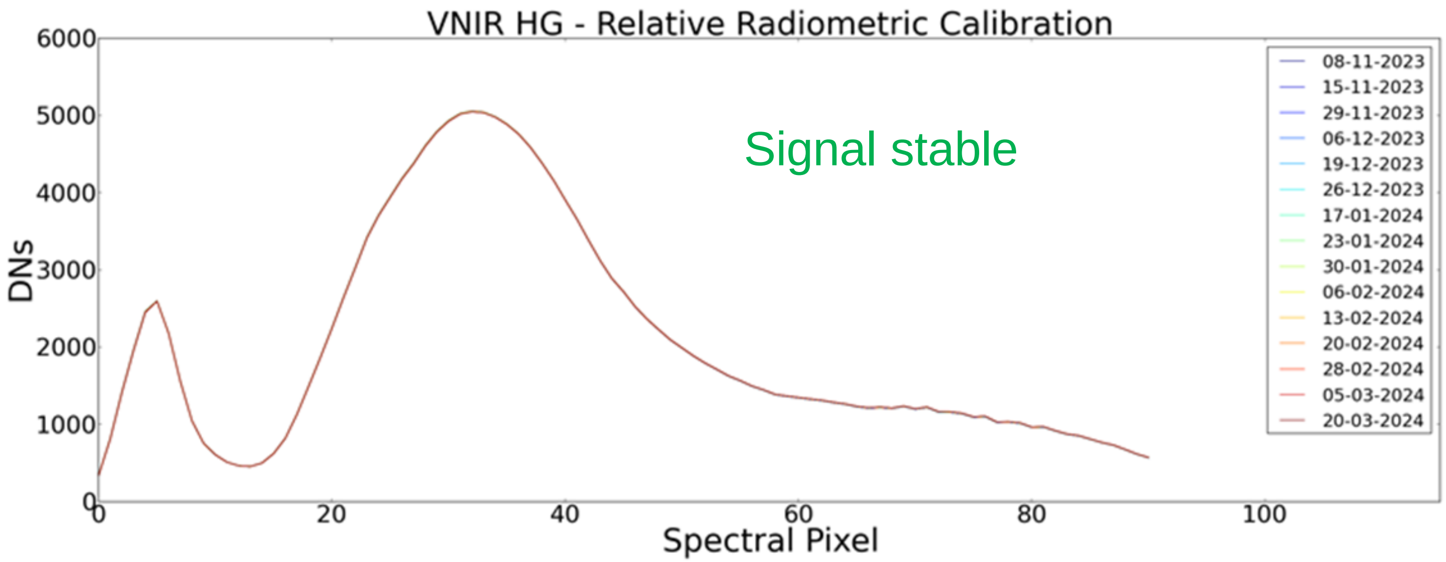


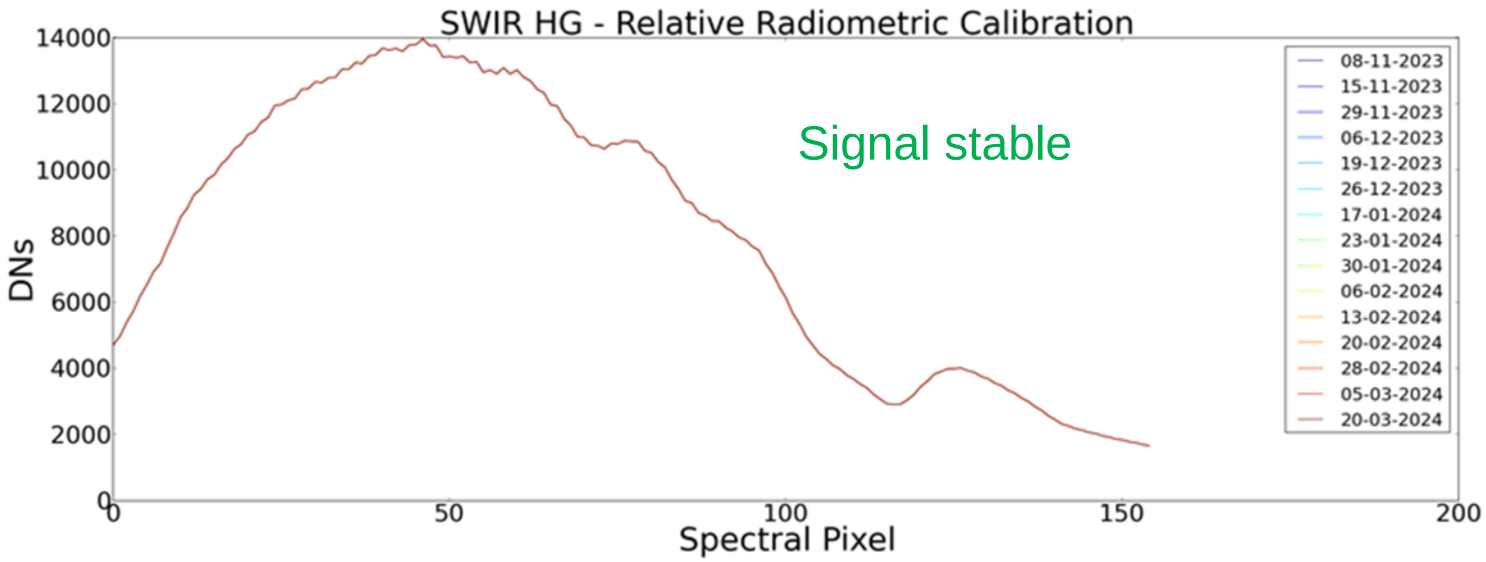

$$Coefficient^{RNU/CC} = Ae^{Bx} + Cx^3 + Dx^2 + Ex + F$$

X is days from 1st April 2022

# Radiometric Calibration Measurements January 2023 – April 2024

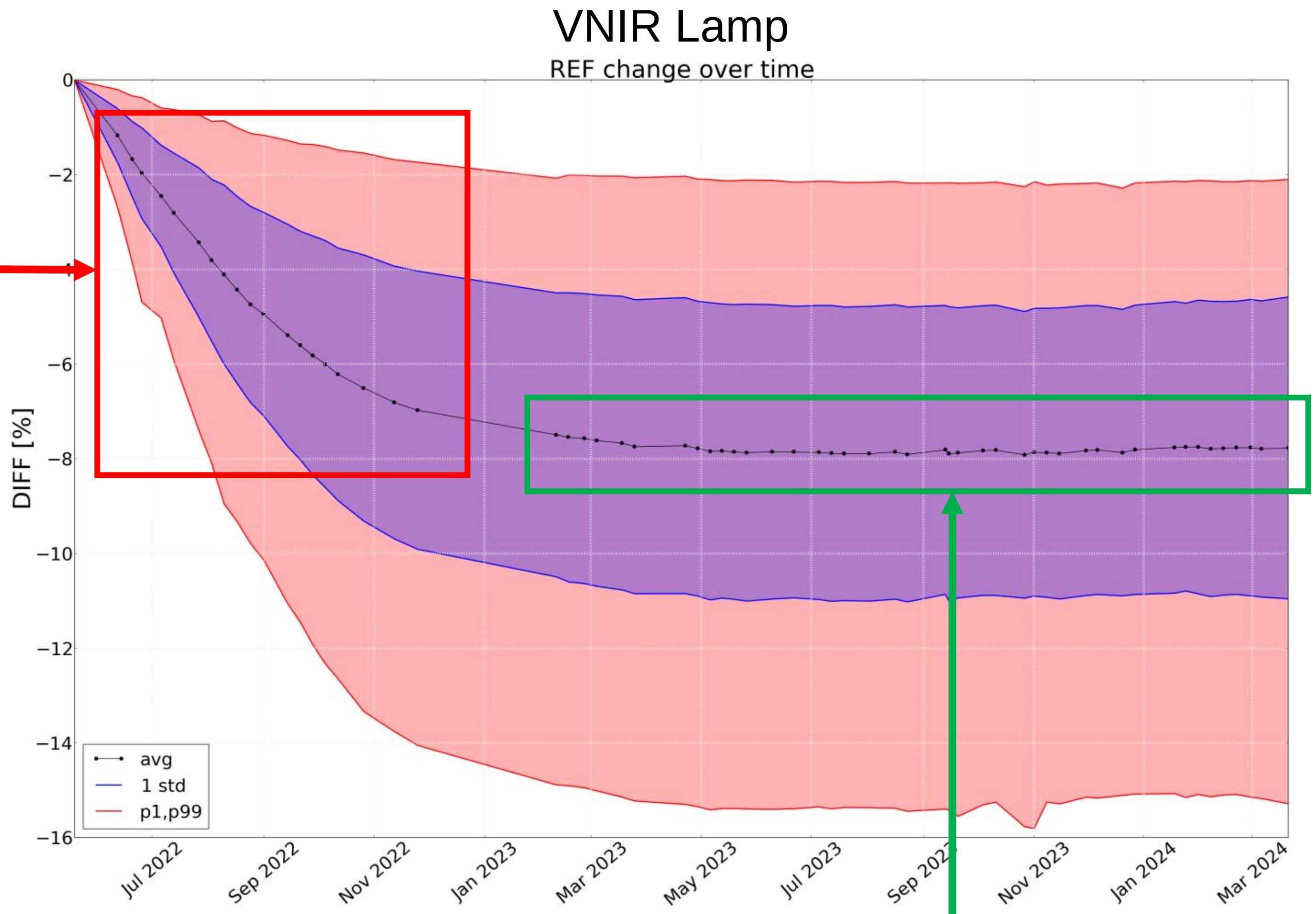
# Recent OBCA-Radiometric Lamp Measurements



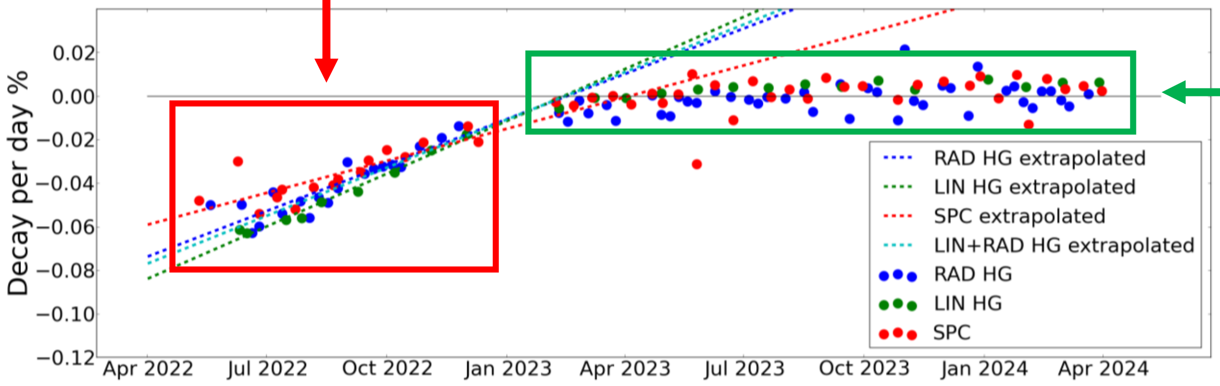



# Total Degradation

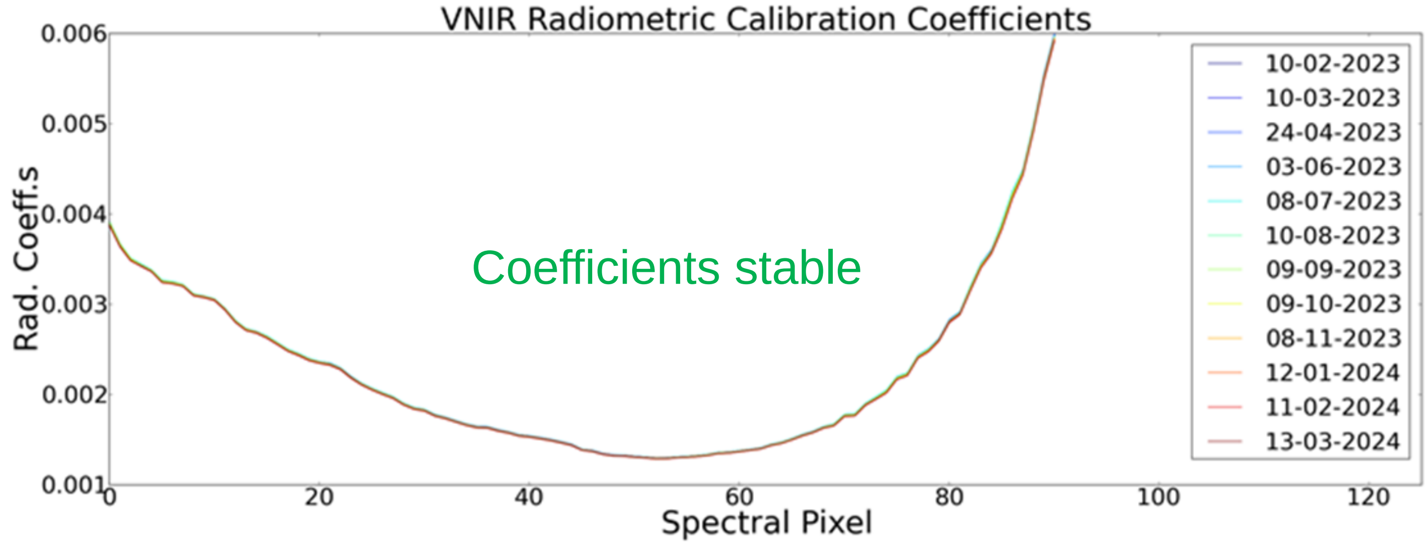
Degradation

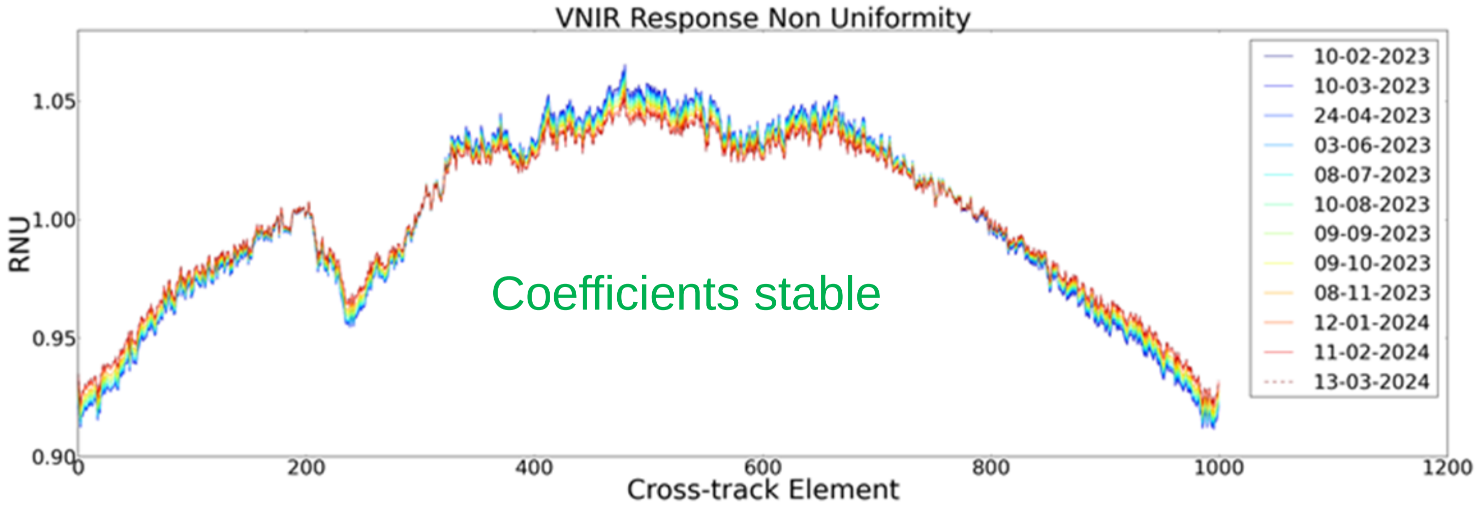



Stable



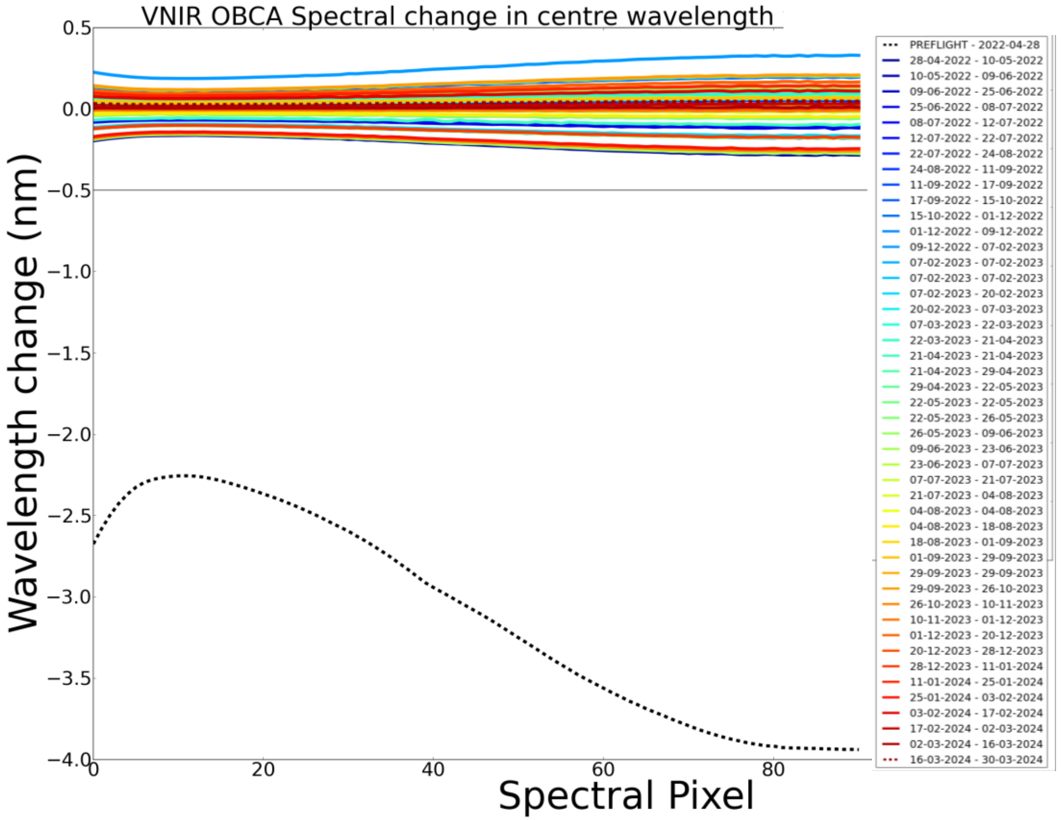
# Recent Calibration Coefficients

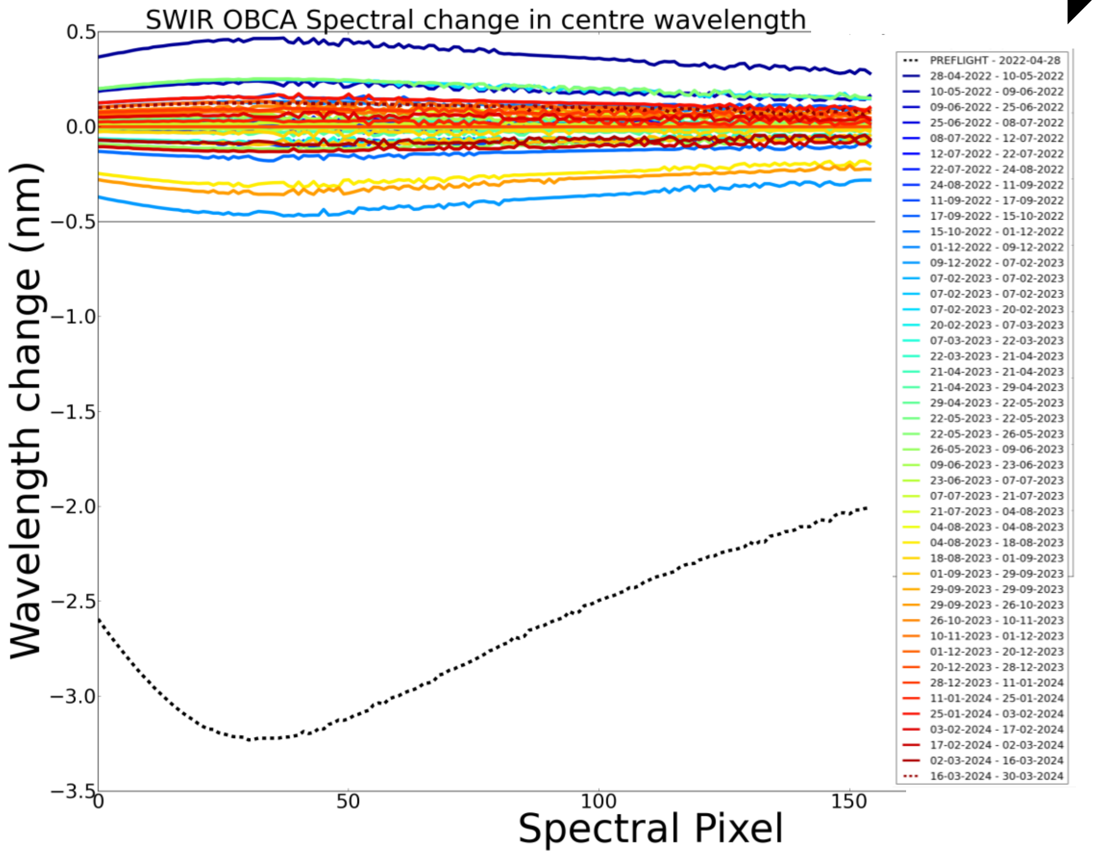


# Spectral and Dark Shutter Calibration Measurements April 2022 – April 2024

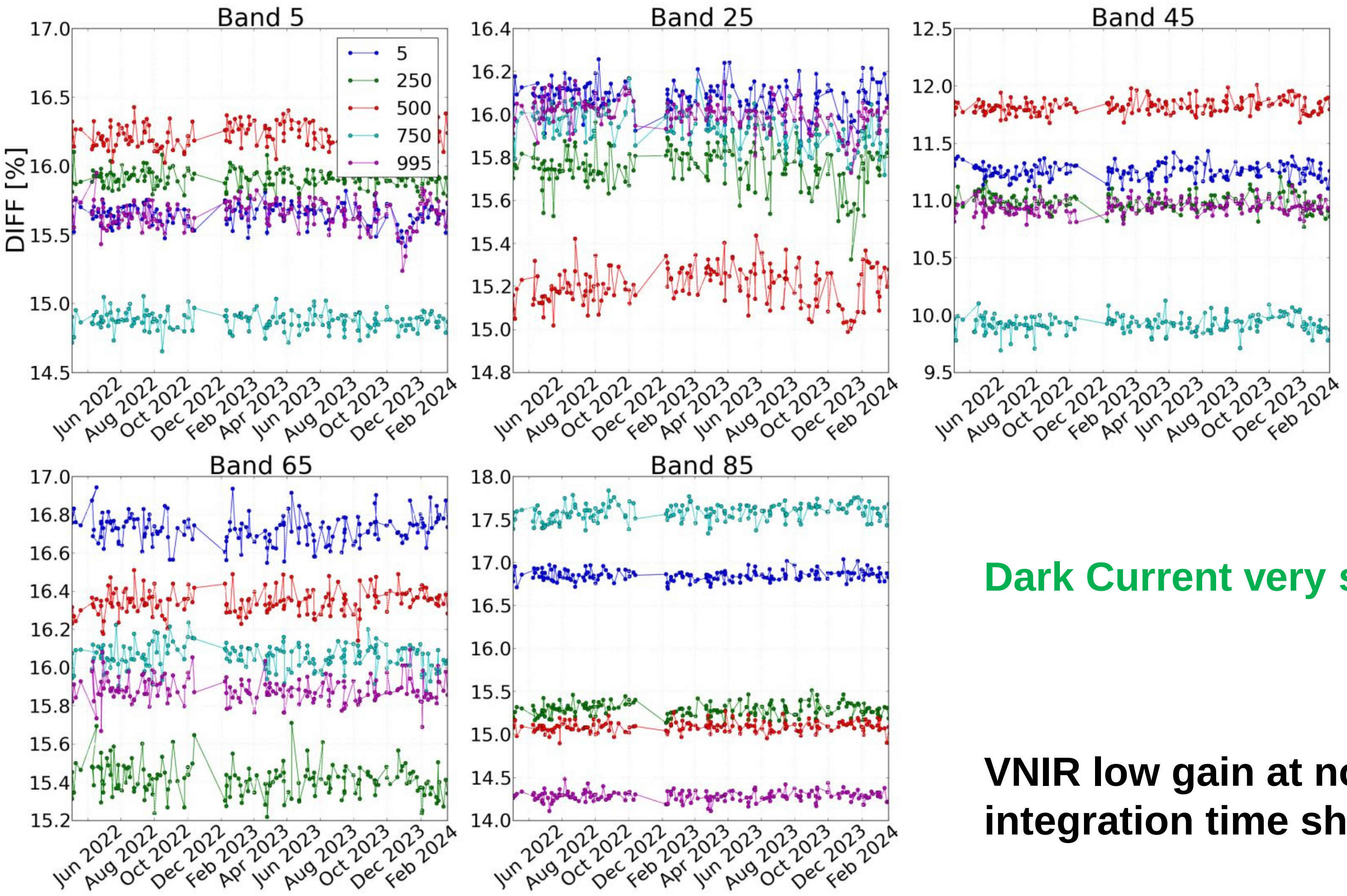
# Spectral Stability




- Good spectral stability: within requirements (0.5 nm VNIR, 1.0 nm  SWIR)
- 6 spectral updates during mission (4 during Commissioning, 1 after outage, 1 for SWIR band swap)

# Dark Shutter Stability




**Dark Current very stable in time**

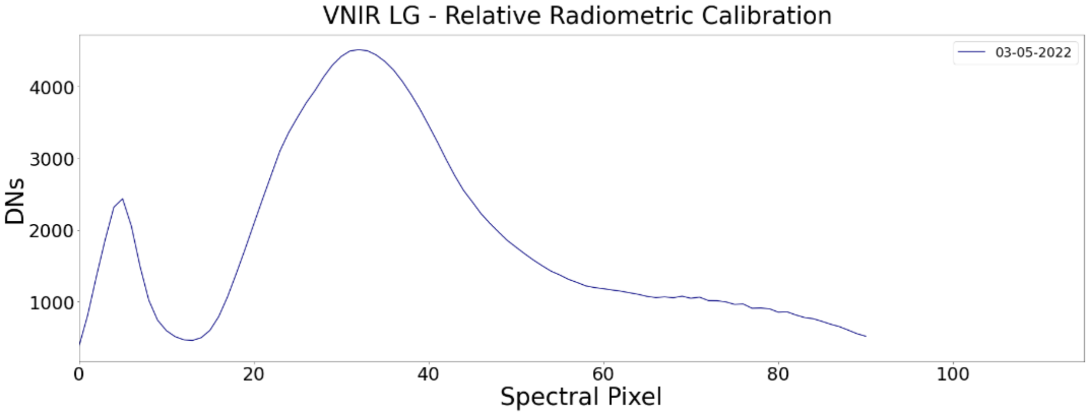
**VNIR low gain at nominal integration time shown here**

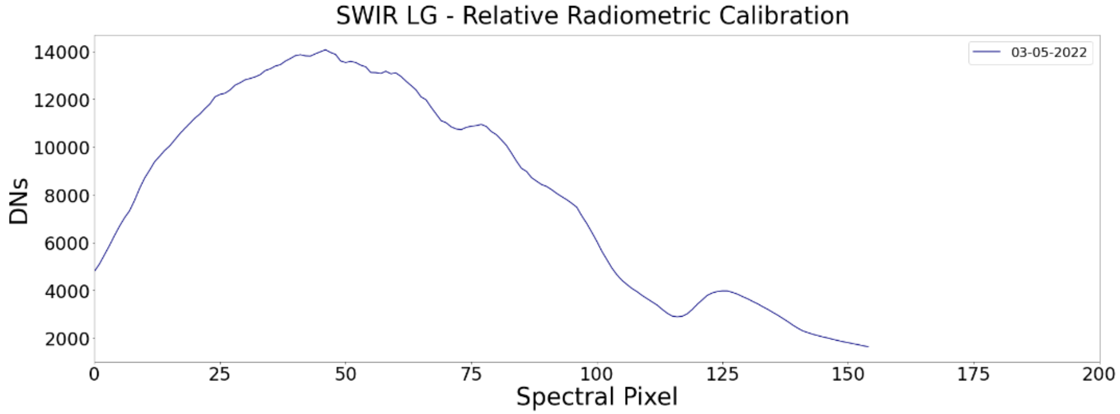
# EnMAP Calibration Summary

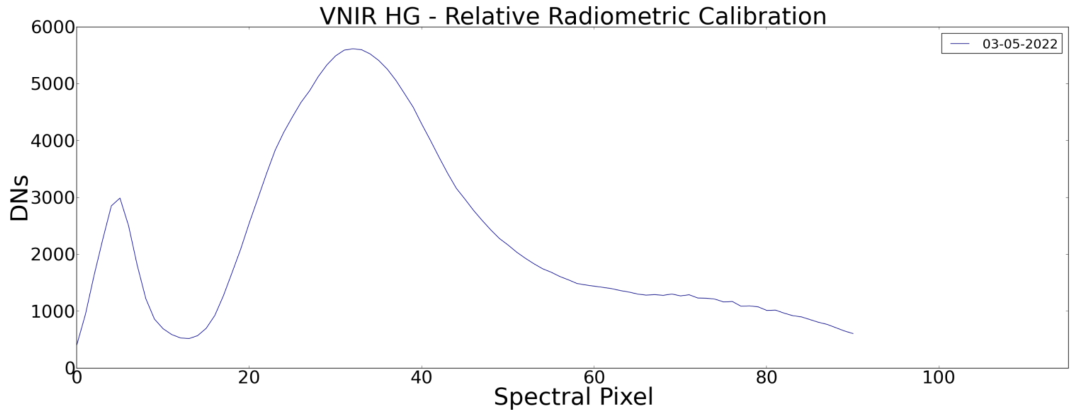
| | April – December 2022 | January 2023 – Present |
|---|---|---|
| VNIR sensor | Degradation (10%) | Stable |
| VNIR radiometric calibration coefficients | Changes due to degradation, dynamic coefficients used | Stable (meets 2.5% requirement between observations), calibration tables used |
| SWIR sensor | Stable after launch | Stable |
| SWIR radiometric calibration coefficients | Stable after launch (meets 2.5% requirement between observations) | Stable (meets 2.5% requirement between observations) |
| Dark Signal | Stable | Stable |
| VNIR spectral calibration | Stable after launch (meets 0.5 nm requirement) | Stable (meets 0.5 nm requirement) |
| SWIR spectral calibration | Stable after launch (meets 1.0 nm requirement) | Stable (meets 1.0 nm requirement) |
| VNIR-SWIR mismatch | Calibration improvement at low signals under investigation | |

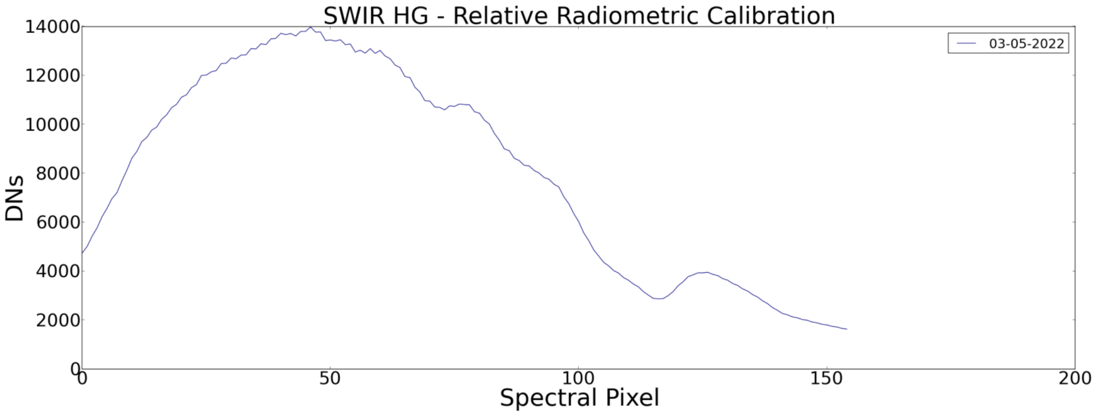
# BACKUP SLIDES

# First OBCA-Radiometric Lamp Measurements

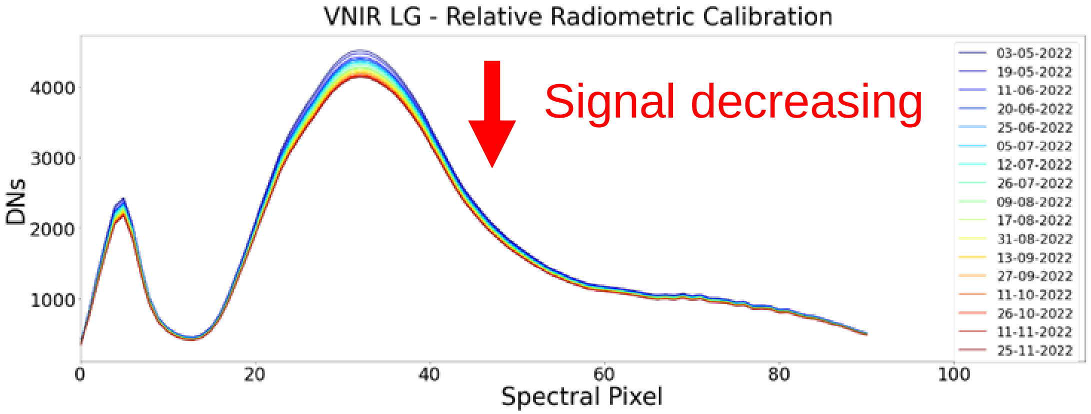


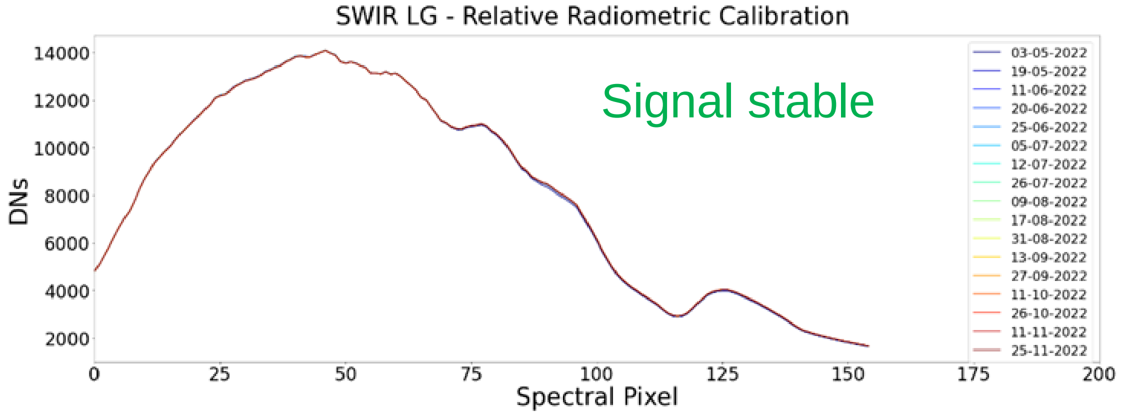



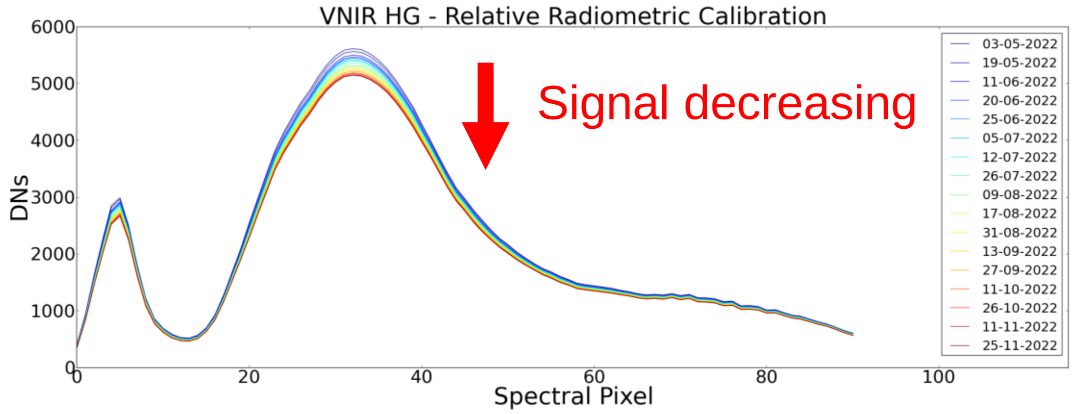



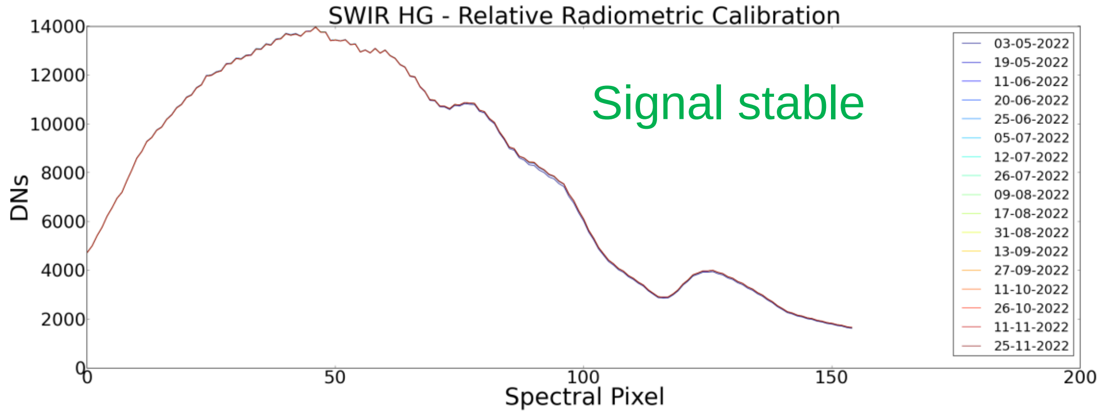



# Early OBCA-Radiometric Lamp Measurements

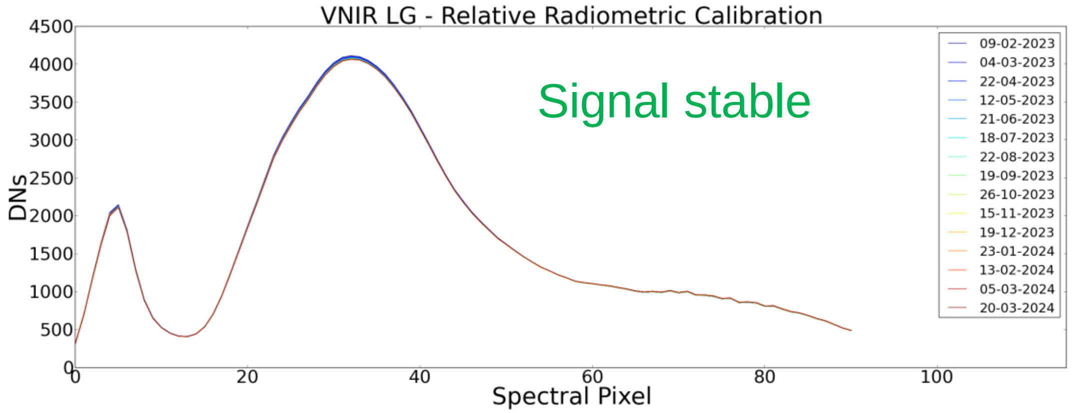


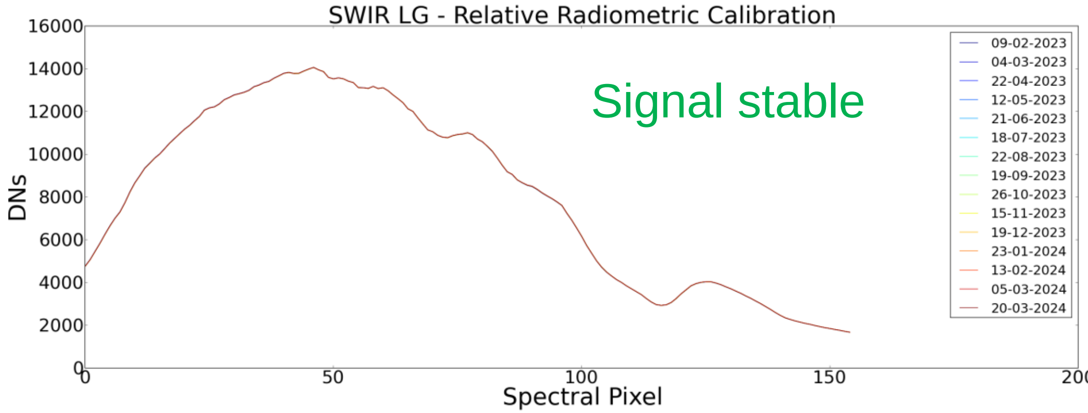



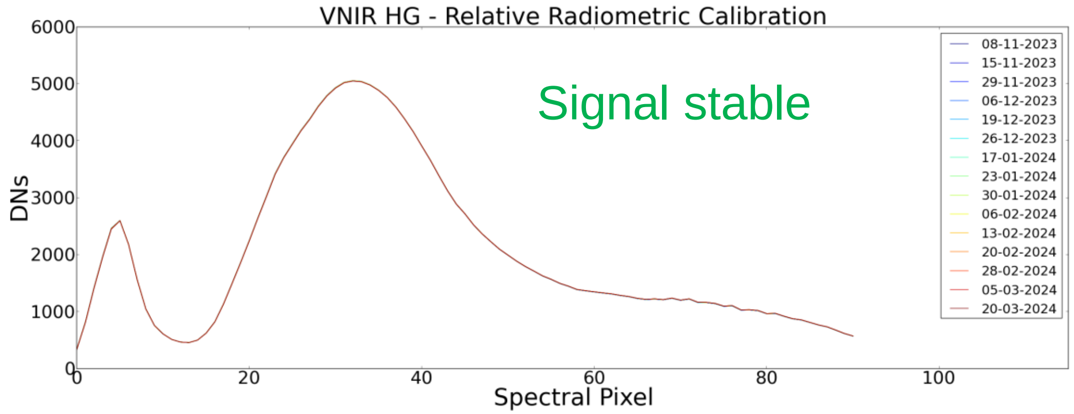



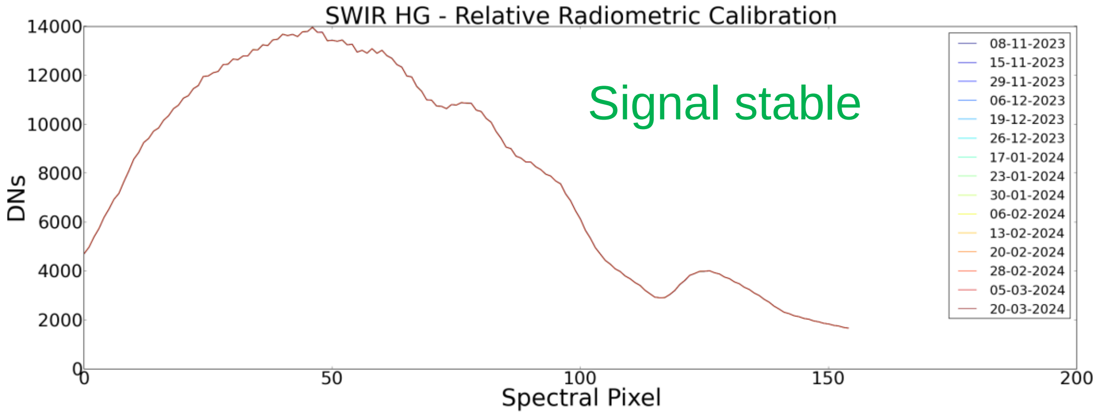



# Recent OBCA-Radiometric Lamp Measurements

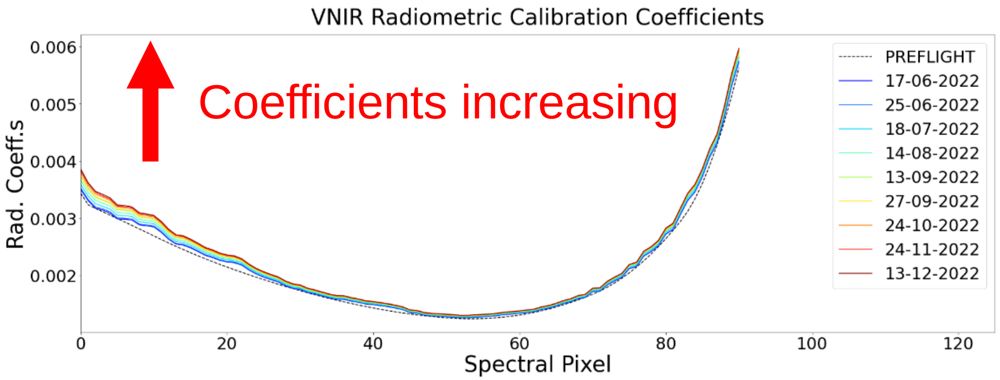


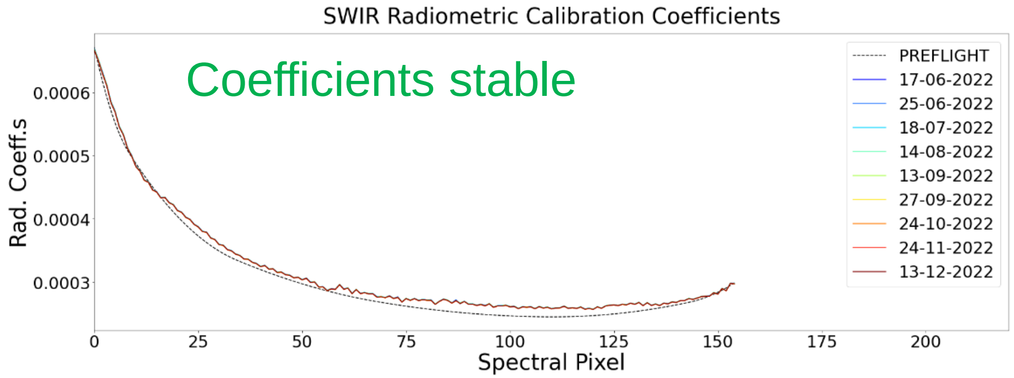



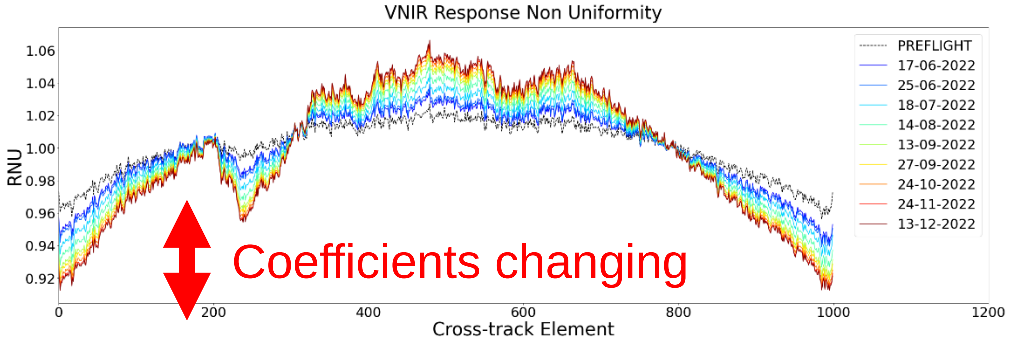



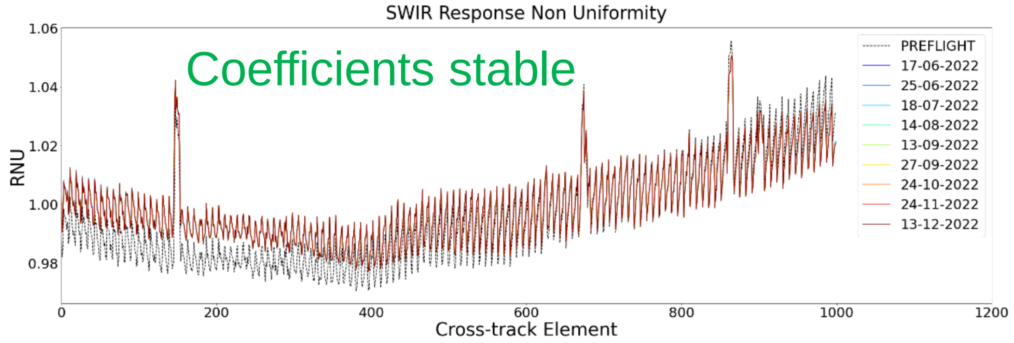



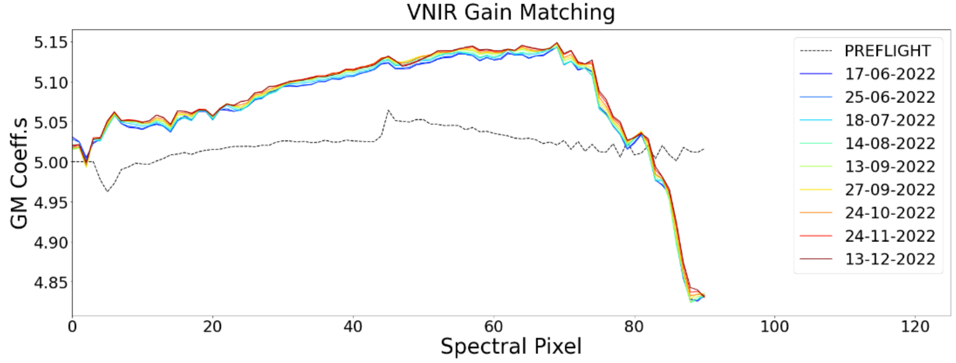
# Absolute Radiometric Calibration Coefficients

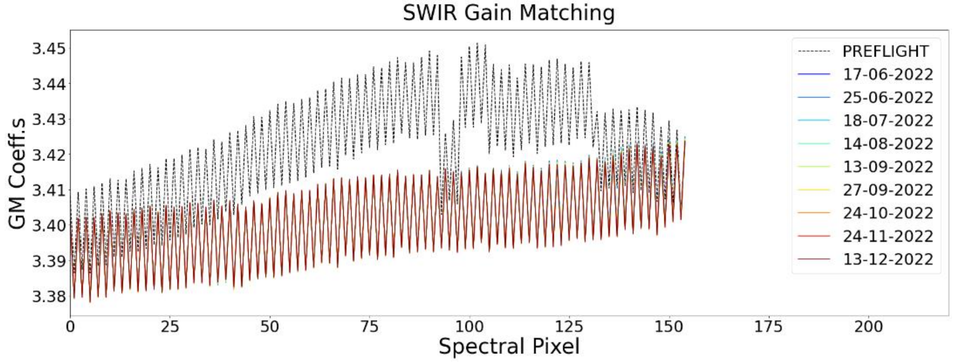


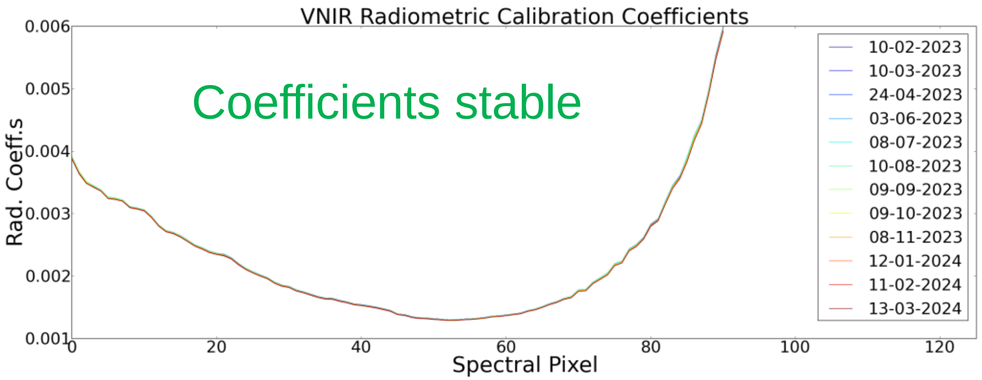



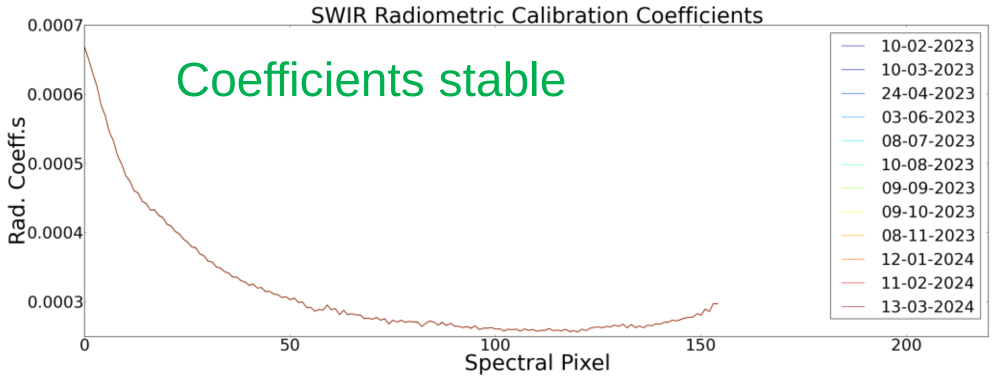



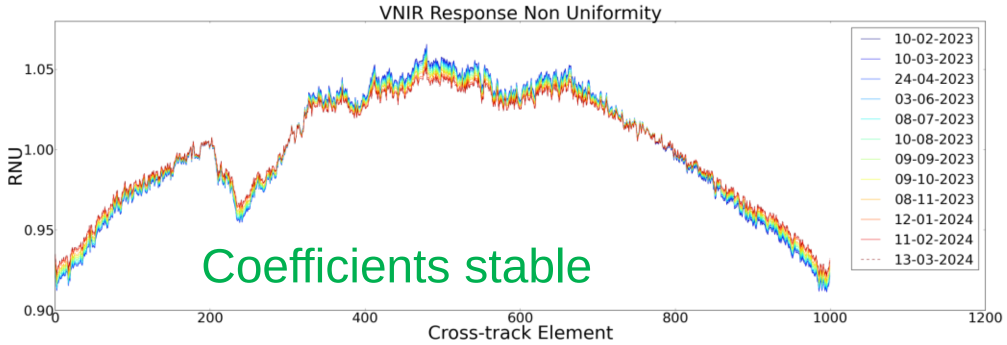



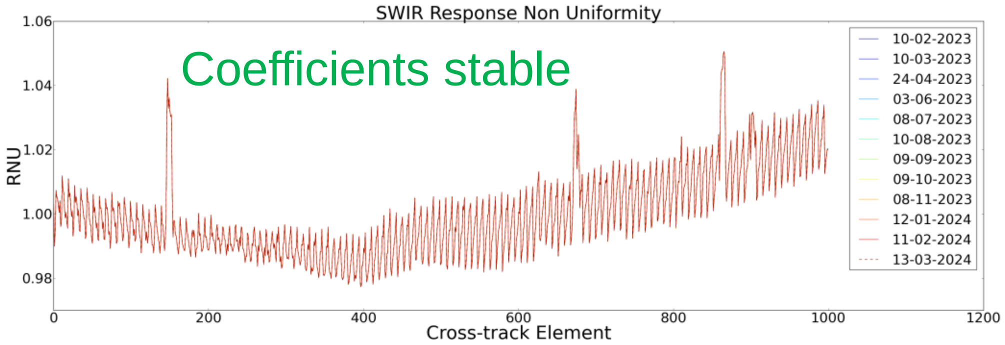



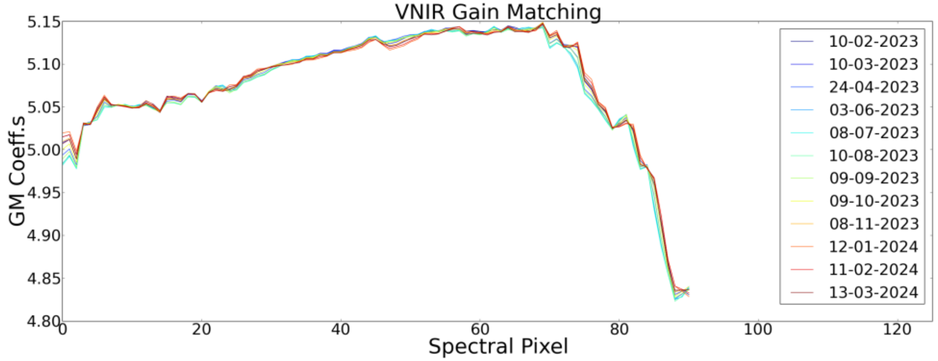
# Absolute Radiometric Calibration Coefficients

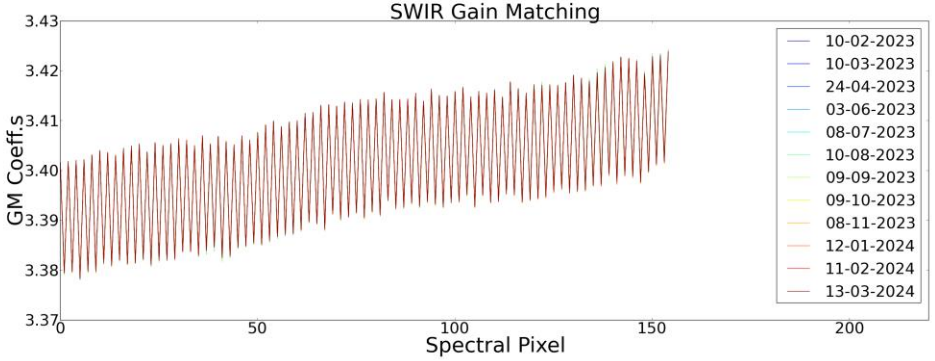


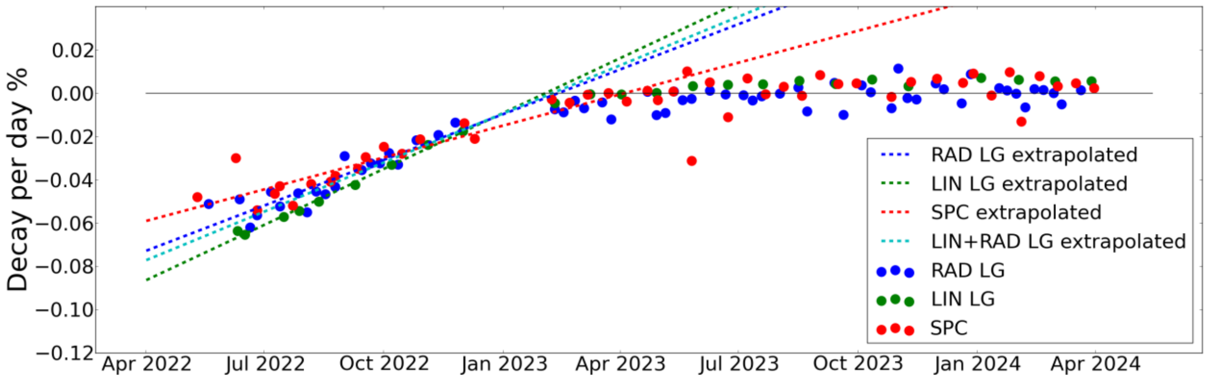



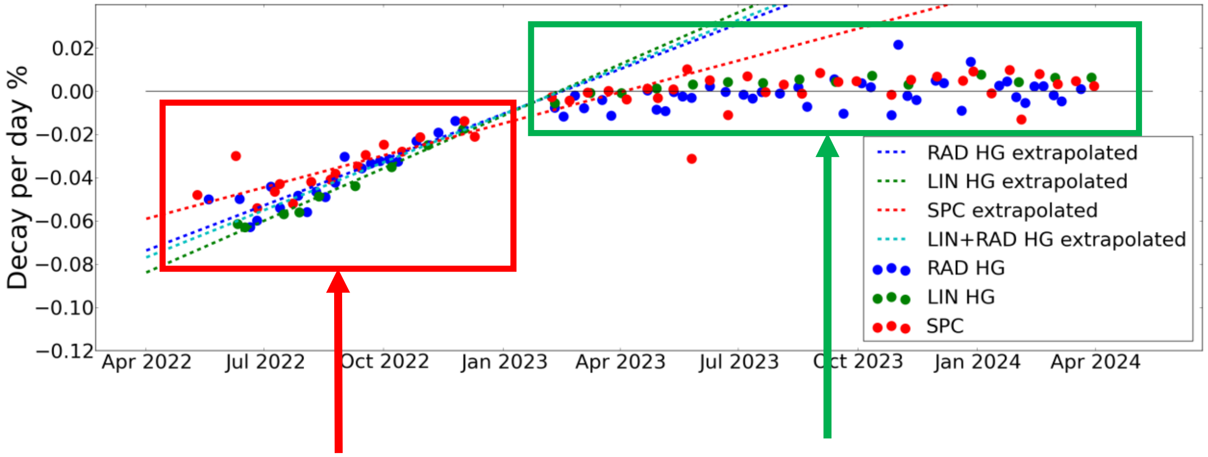



# Total Degradation

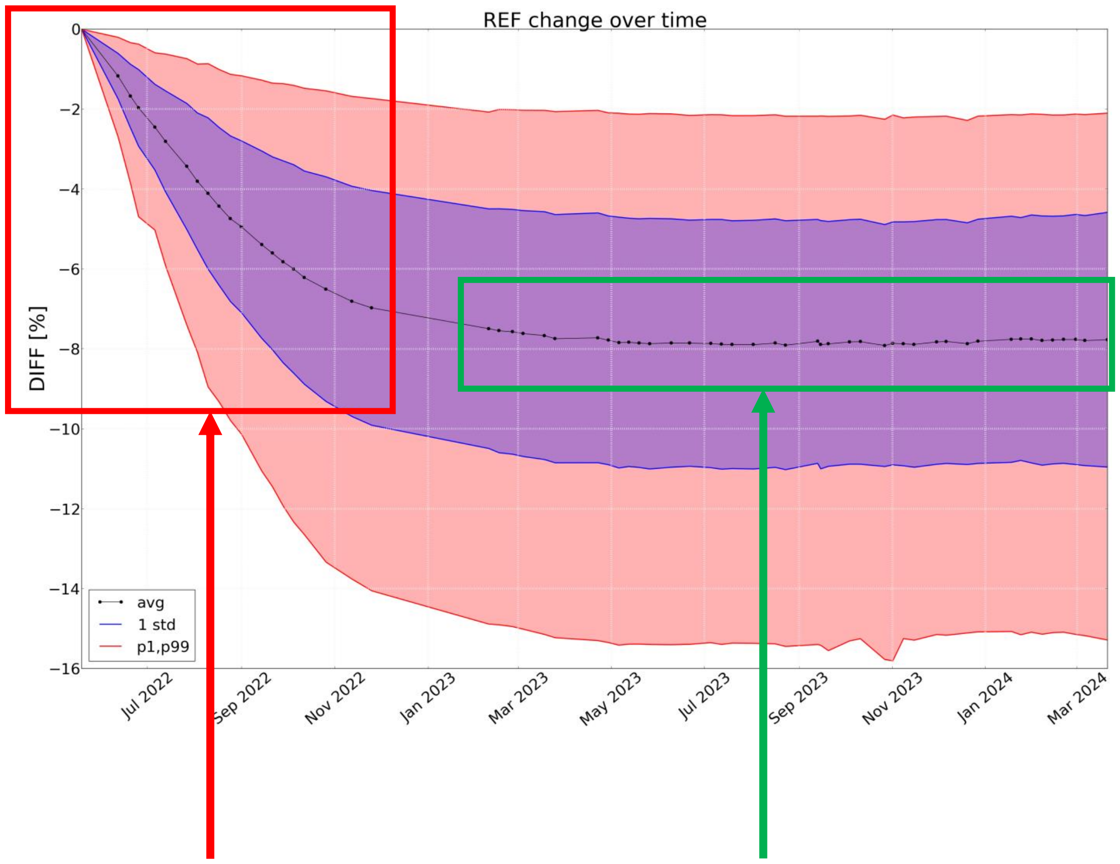



Degradation

Stable

VNIR Lamp




Degradation

Stable

# VNIR-SWIR mismatch

**Q: What is the reason for the apparent noise in some EnMAP L1C and L2A products in the spectral range between 900 and 1000 nm?**

A: The EnMAP instrument consists of two separate spectrometers, one covering the visible and near-infrared (VNIR) and the other covering the shortwave infrared (SWIR). The spectrometers overlap in the spectral range between 900 nm and 1000 nm with 12 VNIR and 10 SWIR bands. Since EnMAP L1C/L2A products contain a single spectral data cube with all bands ordered by wavelength (not separated by sensor), **the spectra have interleaved VNIR and SWIR bands between 900 nm and 1000 nm. Therefore, any slight signal mismatch between the sensors is seen as a zig-zag (spectral noise) pattern in the overlapping spectral range**. This is most obvious in low-radiance and/or inhomogeneous regions. There are two main reasons for the effect. First, the two spectrometers, which are independently calibrated in orbit, have **distinct sensor responses in the overlapping range**. The differences are especially important for low signals as they usually occur, for instance, in water bodies or forests. Second, the different lines of sight of VNIR and SWIR and any slight **errors in the co-registration** performed at L1C level will contribute to the mismatch between the sensors. Pixels in inhomogeneous regions or at the border between different surfaces are particularly affected.