Vicarious Calibration of the DESIS Imaging Spectrometer: Status and Plans

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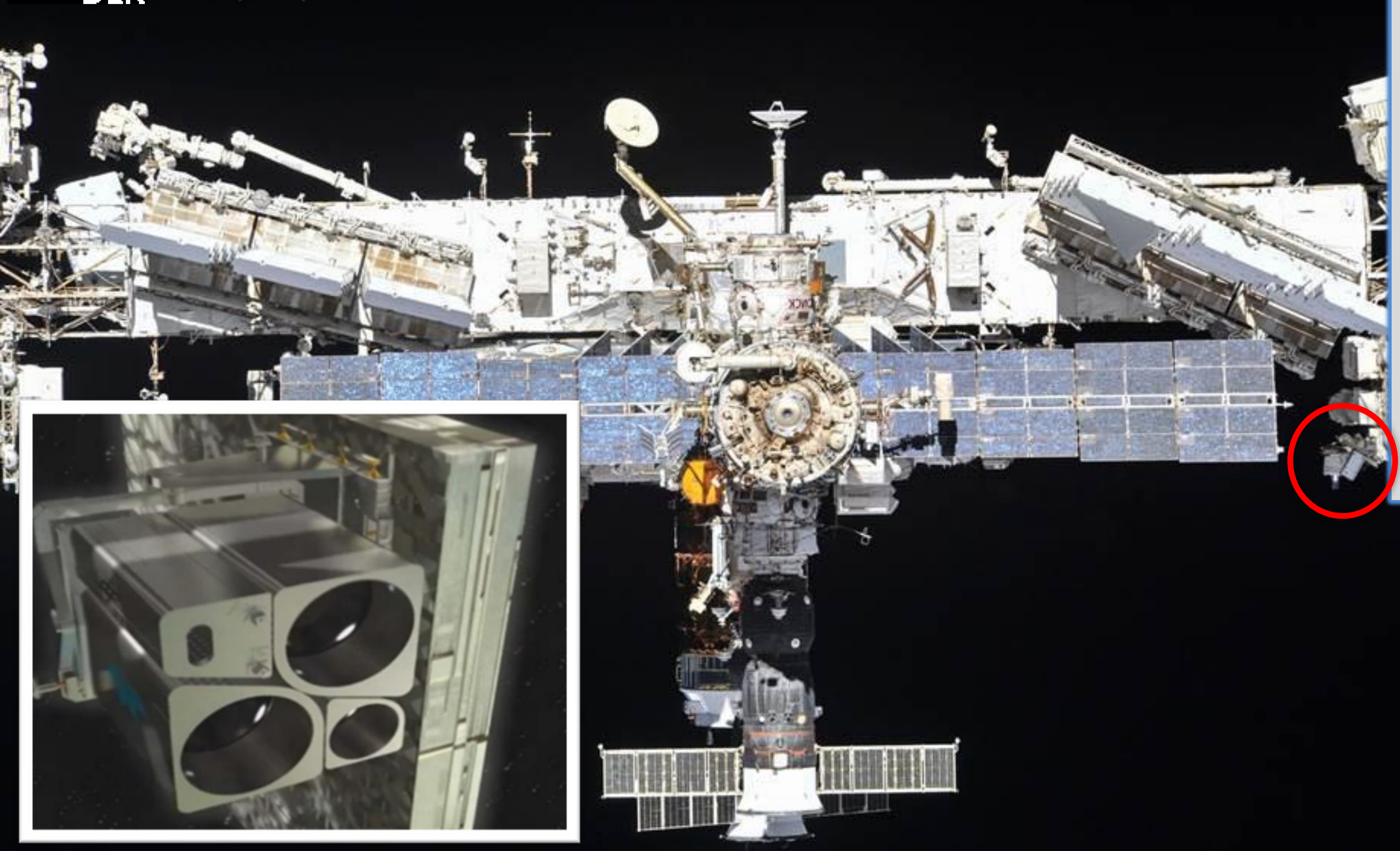
DESIS, MUSES and ISS



Teledyne Brown Engineering (USA) and **DLR** have partnered to build and operate the DLR Earth Sensing Imaging Spectrometer (**DESIS**) from the Teledyne-owned Multi-User System for Earth Sensing (**MUSES**) Platform on the ISS

MUSES provides accommodations for two large and two small hosted payloads and provides **core services** for the instruments

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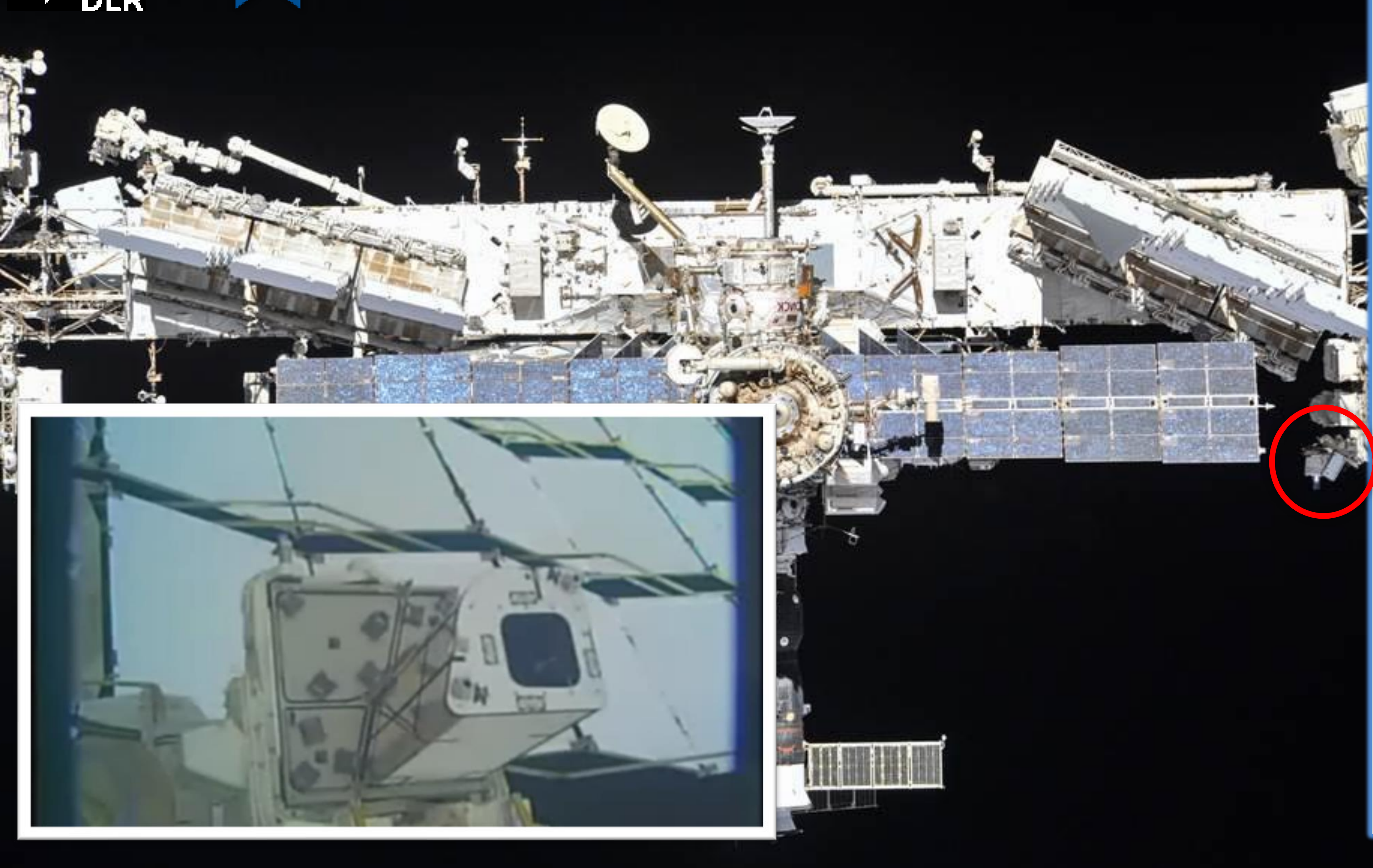

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DESIS, the hyperspectral sensor developed by DLR, is the first payload of MUSES.

DLR also established the Ground Segment and licensed the SW processors to Teledyne running in an Amazon Cloud

DESIS – Timeline and Results

2014 / 2015

MUSES / DESIS Start Mission

7. June 2017

MUSES installation on ISS

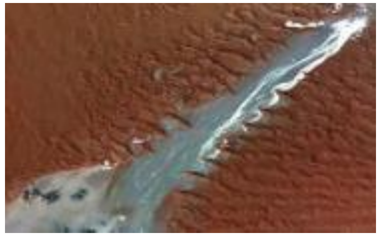
29. June 2018

DESIS launch from Cape Canaveral to ISS via SpaceX Dragon

27.-28.08 2018

Installation of DESIS in MUSES

23. October 2019



@ IAC Washington Start operational Phase

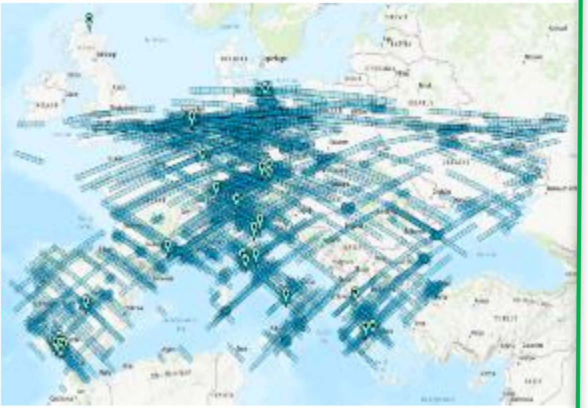
29.09.–01.10.2021

1st DESIS User Workshop (online)

Design, Implementation, Test | Commissioning | Operations

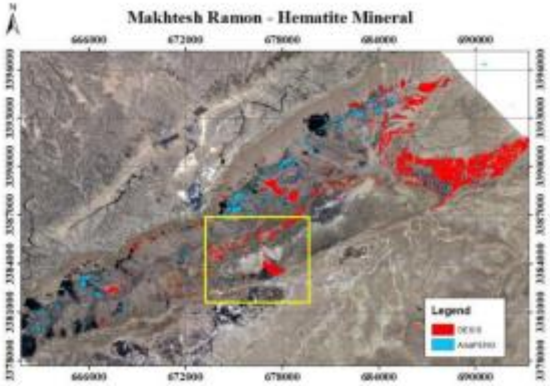
Since 2018 **~130.400** scenes processed and archived

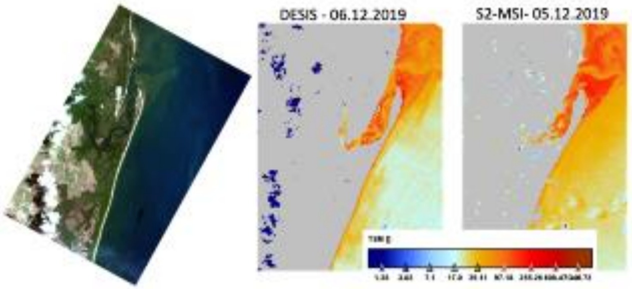
~23.000 scenes in USA



~8.600 scenes in Europe

First DESIS User workshop (September 2021)
Publication at The International Archives of the ISPRS





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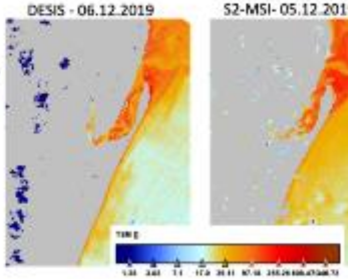


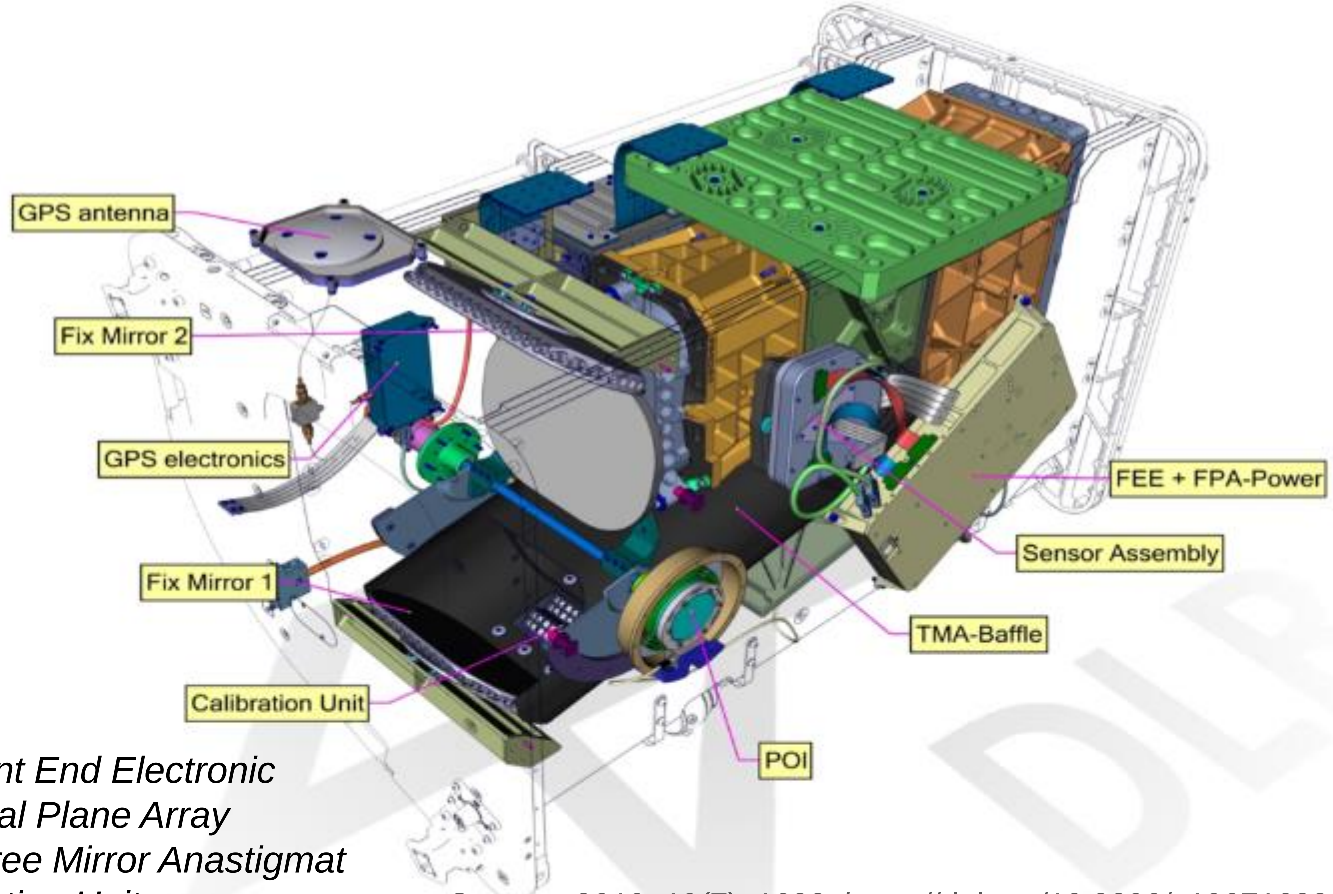
For information about DESIS data access and scientific applications check D. Cerra's contribution:

TH7.V19.3 - THE SPACEBORNE IMAGING SPECTROMETER DESIS: DATA ACCESS, OUTREACH ACTIVITIES, AND SCIENTIFIC APPLICATIONS

Thu, 21Jul, 15:45 - 16:00 UTC

DESIS Instrument

- Hyperspectral instrument consisting of a Three-Mirror-Anastigmat (TMA) telescope combined with an Offner-type spectrometer



Sensors 2019, 19(7), 1622; https://doi.org/10.3390/s19071622

Mission Instrument	MUSES/DESIS
Target lifetime	2018-2023
Off-nadir tilting (across-track, along-track)	-45° (backboard) to +5° (starboard), -40° to +40° (by MUSES and DESIS)
Spectral range	400 nm to 1000 nm
Spectral Sampling (res., acc.,bands)	2.55 nm, 0.5 nm, 235 bands. Binning: 118 , 79 , 60 bands
Spectral response	Gaussian shape, 3.5 nm FWHM
Software Binning (sampling distance, number bands)	Binning 2 (5.1 nm, 118 bands) Binning 3 (7.6 nm, 79 bands) Binning 4 (10.1 nm, 60 bands)
Radiometry (res., acc.)	13 bits, ~10%
Spatial (res., swath)	30 m, 30 km (@ 400 km)
SNR (signal-to-noise)	195 (w/o bin.) / 386 (4 bin.) @ 550 nm
Instrument (mass)	93 kg
Capacity (km, storage)	2360 km per day, 225 GBit

FEE: *Front End Electronic*
FPA: *Focal Plane Array*
TMA: *Three Mirror Anastigmat*
POI: *Pointing Unit*

DESIS Vicarious Calibration

Obtain consistent relative response in spatial and spectral directions:

- Flat response on homogenous input
- Smooth pixel to pixel transitions
- Consistent behavior across-track

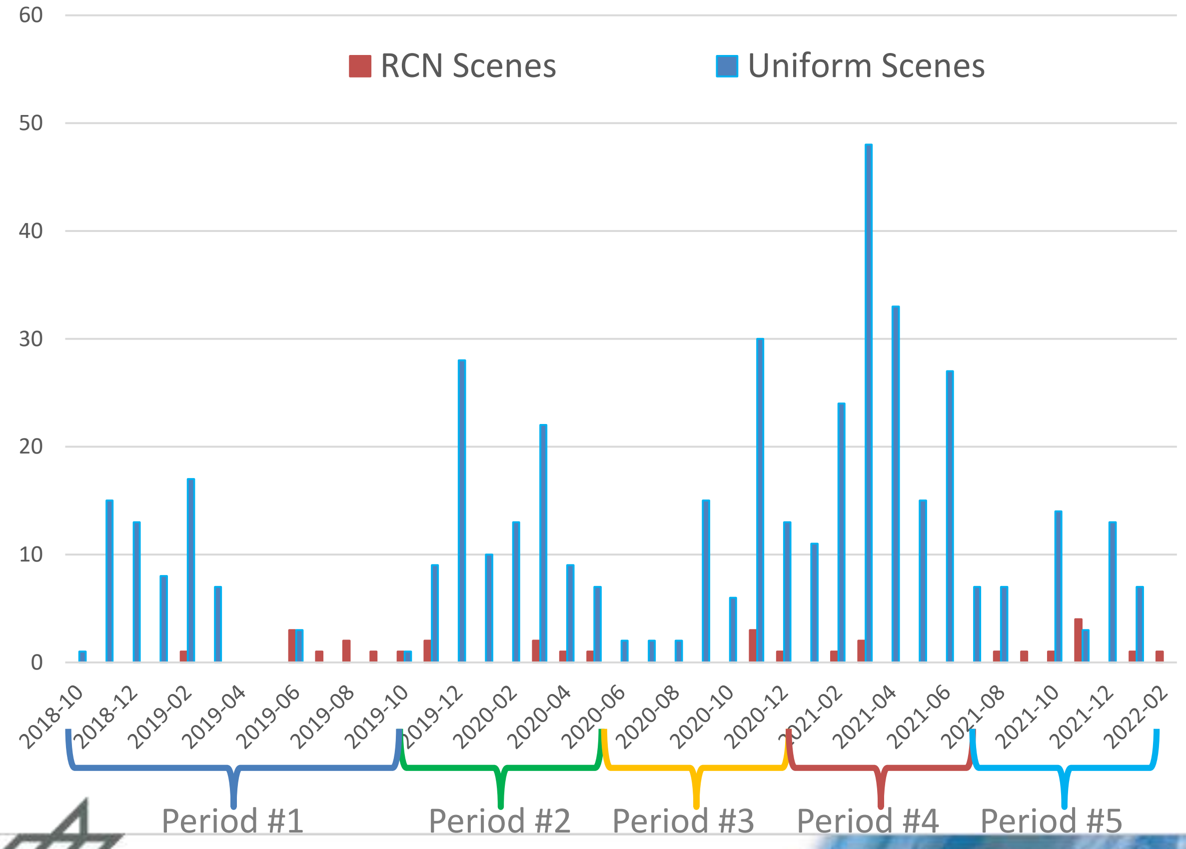
Obtain absolute radiance scale

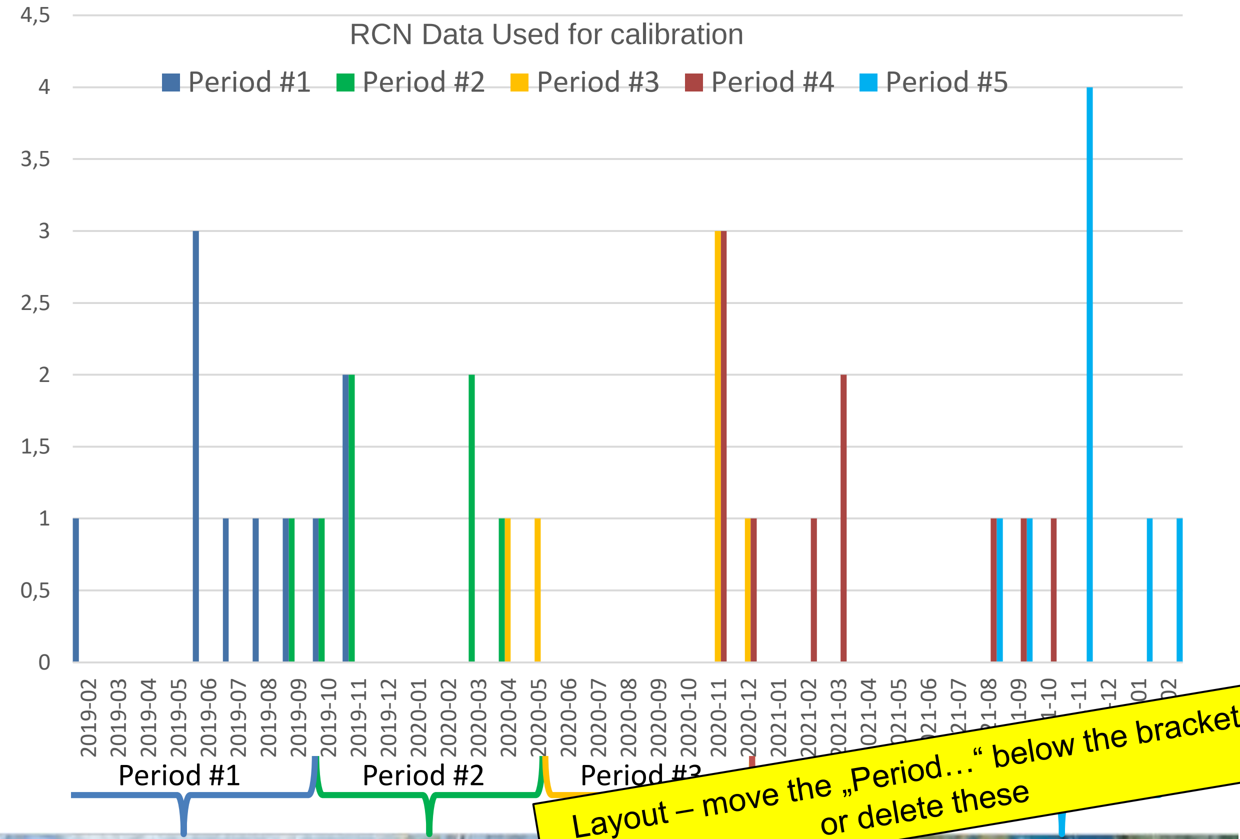
“Vicarious calibration of the DESIS imaging spectrometer“, E. Carmona et al., IGARSS2021

DLR

Vicarious calibration data

- Input scenes not evenly distributed in time
- Particularly challenging to have abundant good quality RCN scenes
- Calibration updates arrive several months after data acquisition





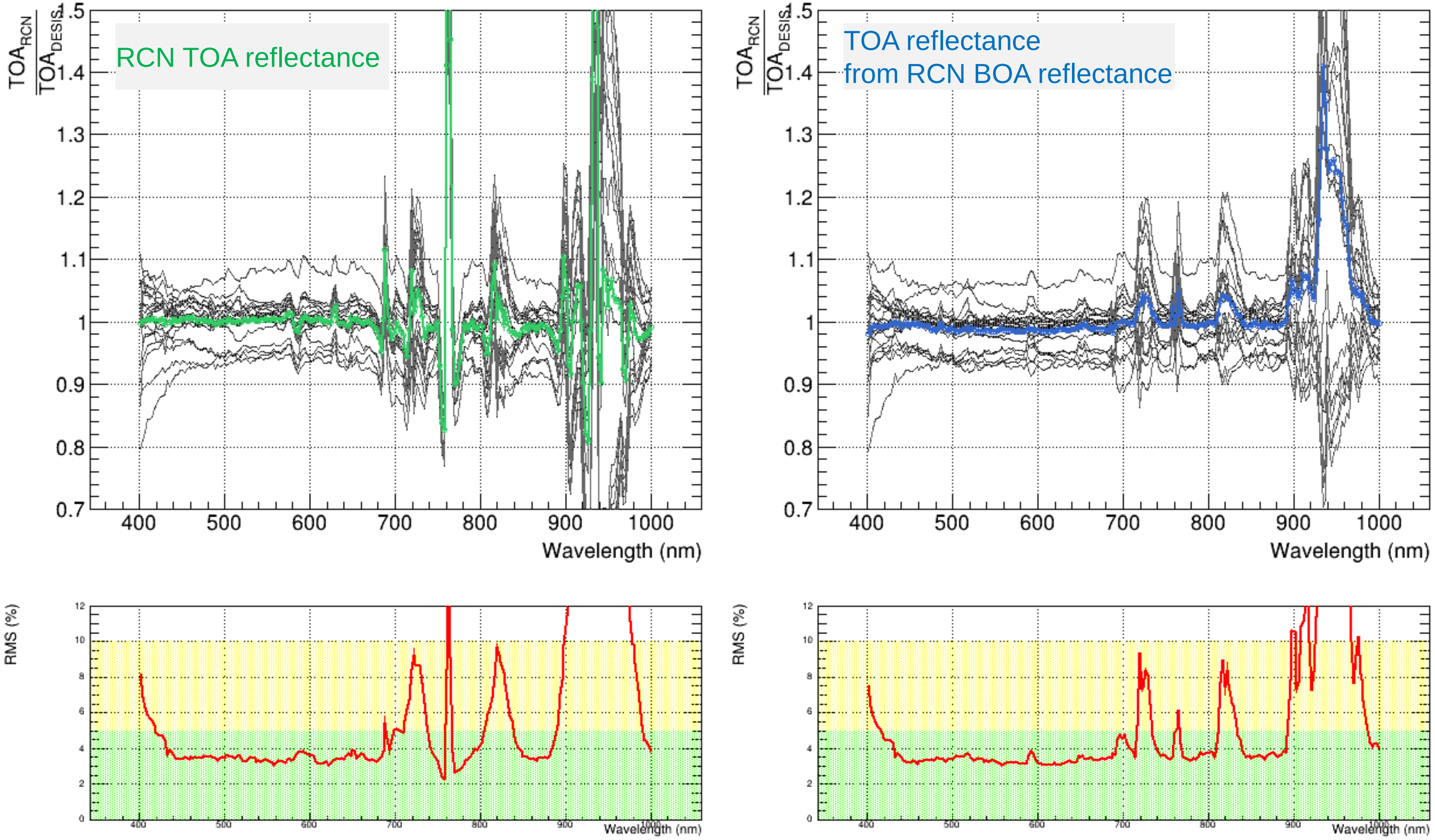
Layout – move the „Period…“ below the bracket or delete these

Results from 3 calibration periods: All RCN Data Results

- Absolute calibration adjusted with RCN data for 3 different periods

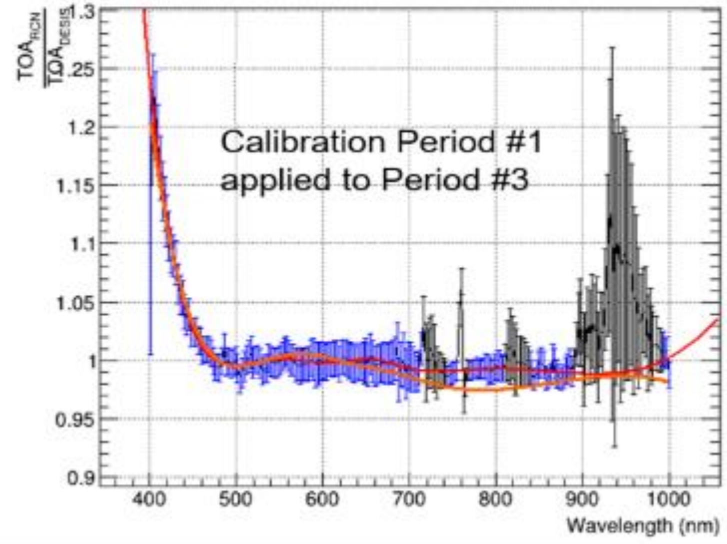
- Absolute calibration uses only part of RCN scenes (19)
  - good atmospheric conditions
  - below 50 degrees Sun Zenith Angle

- These summary plots show **19** RCN scenes used for calibration

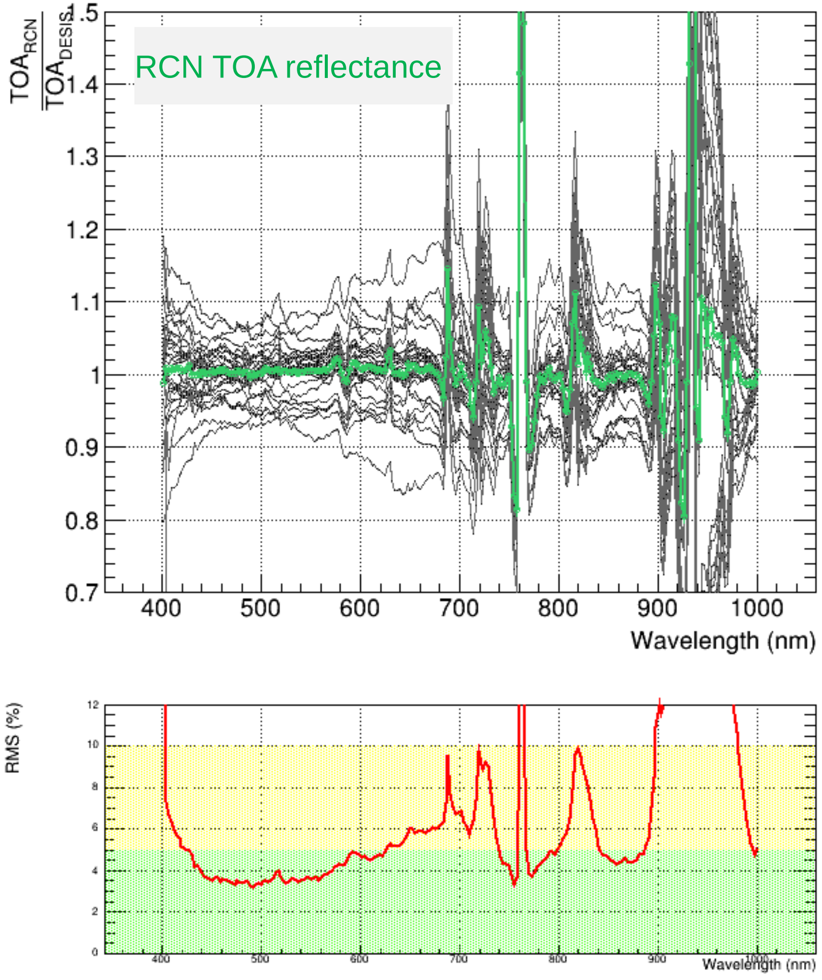


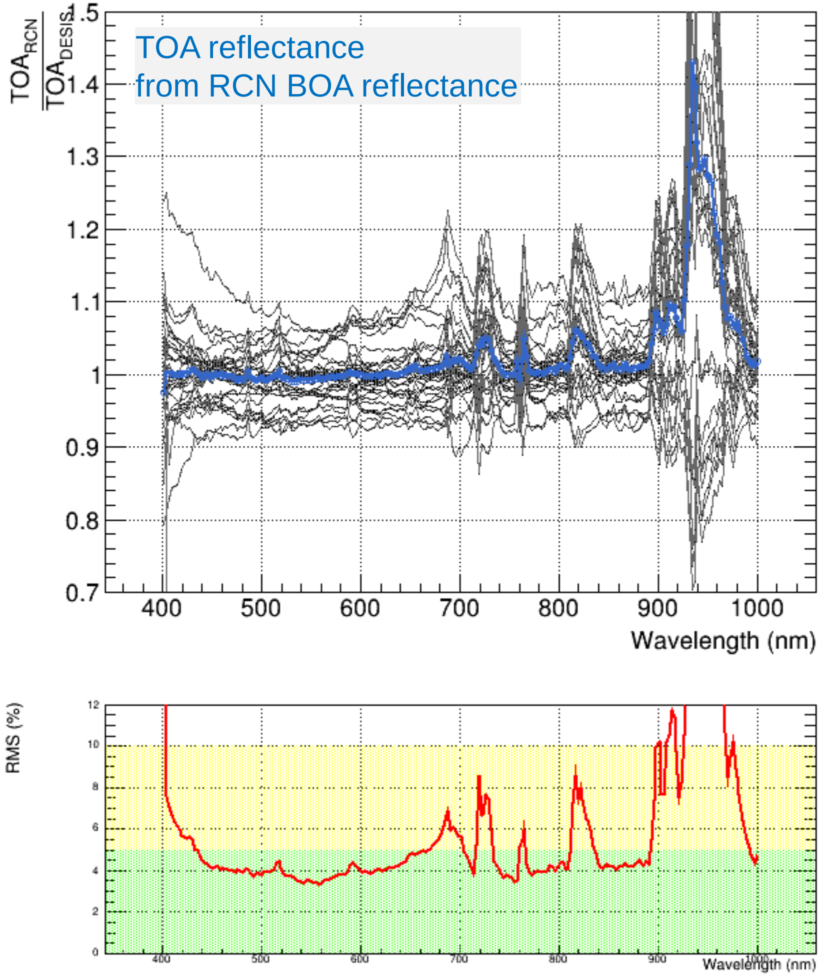
Results from 3 calibration periods: All RCN Data Results

- Same result with **all** RCN scenes (**30** scenes)
- Main difference between calibration periods is found below 500 nm:



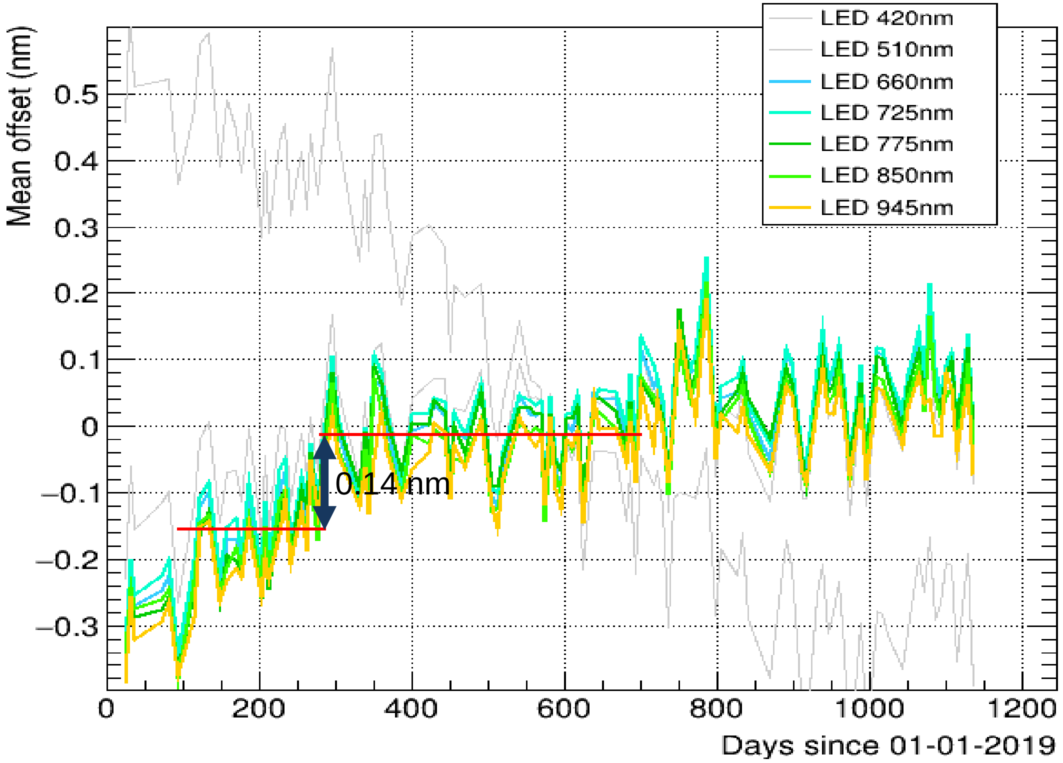
- Change below 500 nm is too fast for updates every 7-8 months

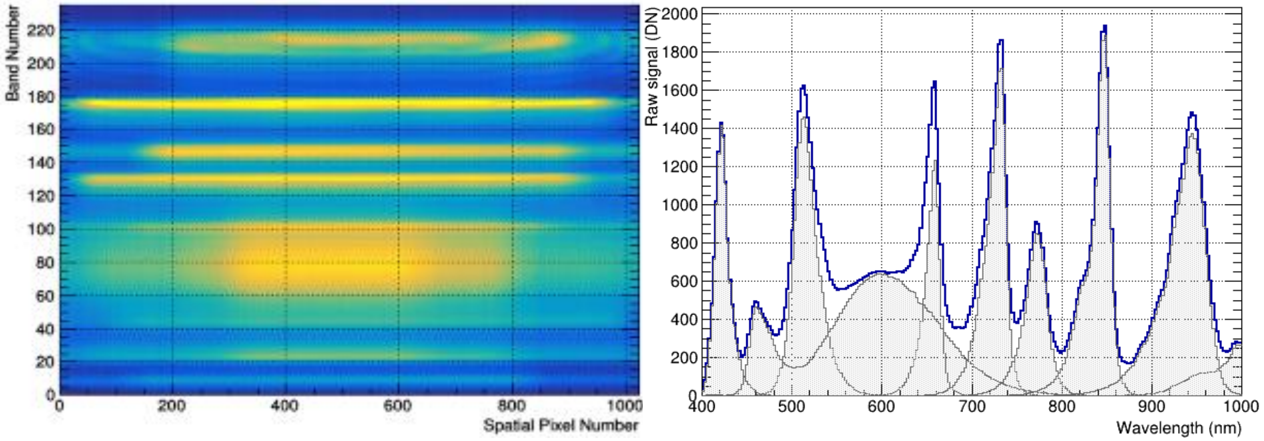




Calibration unit

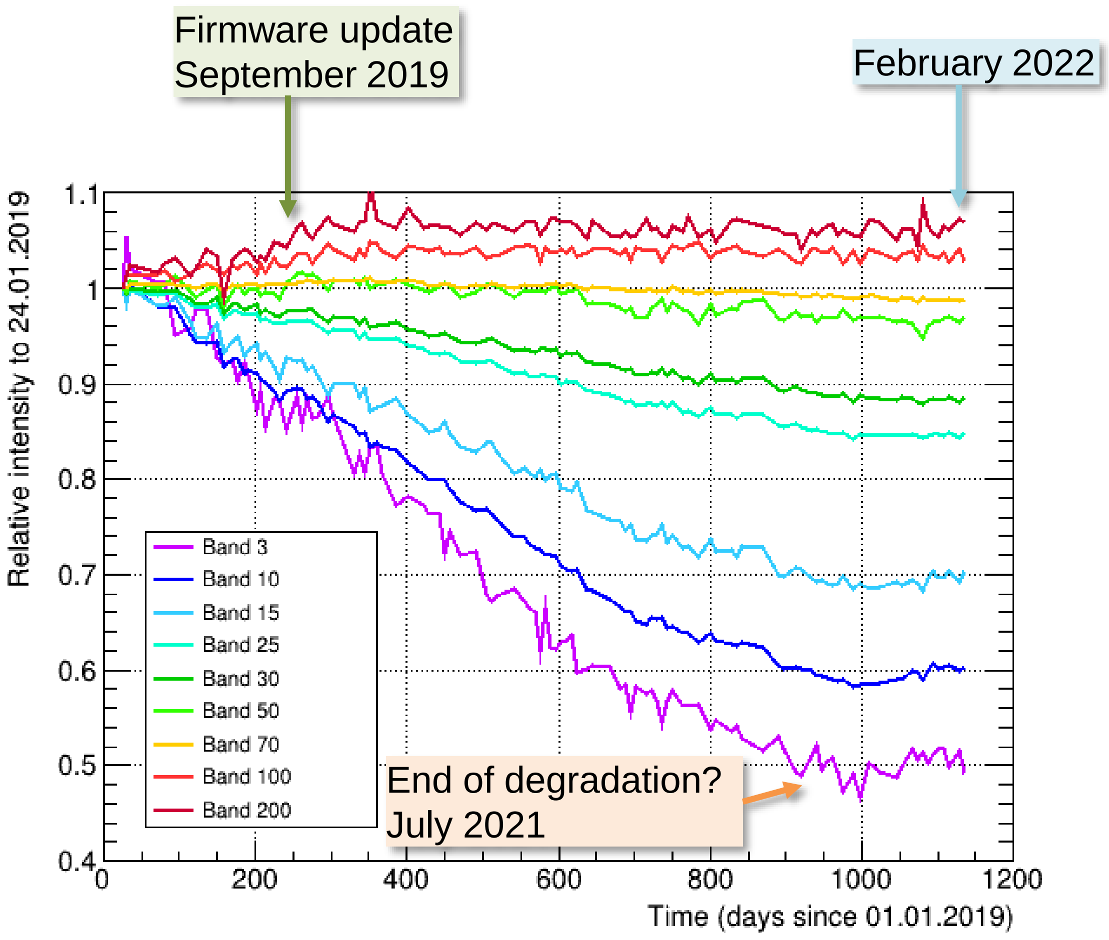
- Equipped with 9 different types of LEDs. It allows to measure signal with different LED types
- 1 Calibration measurement every 1 or 2 weeks for 3 years
- It allows for precise spectral stability measurements:





- The idea is now to use this calibration data to build a model for the detector changes over time

Calibration Data



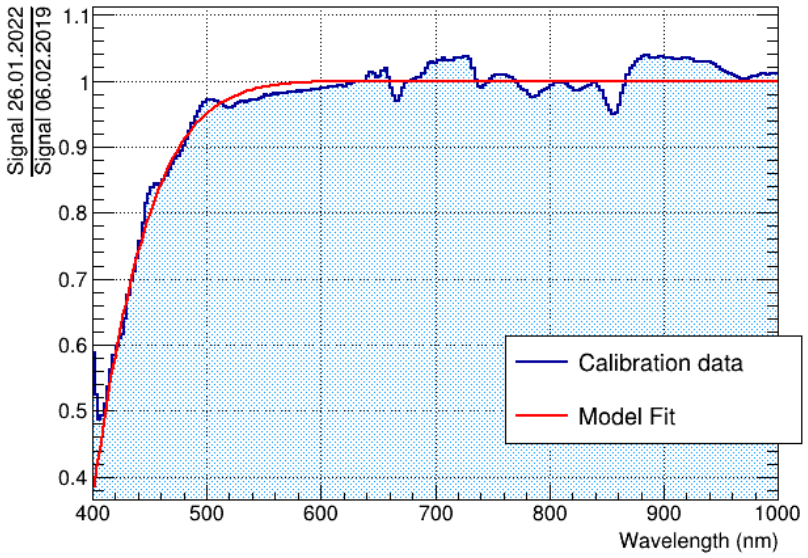
- First bands show a fast degradation reaching 50% of initial performance 1000 days after reference point. The decrease is very close to linear.

- Good approximation for this decrease with a gaussian fit:

$$Decrease\ 1000\ days = \frac{A}{\sigma} * \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$$

- Where x is wavelength and A, μ, σ are 3 parameters fitted from the calibration data

- Small discrepancies in first 2 bands and across-track

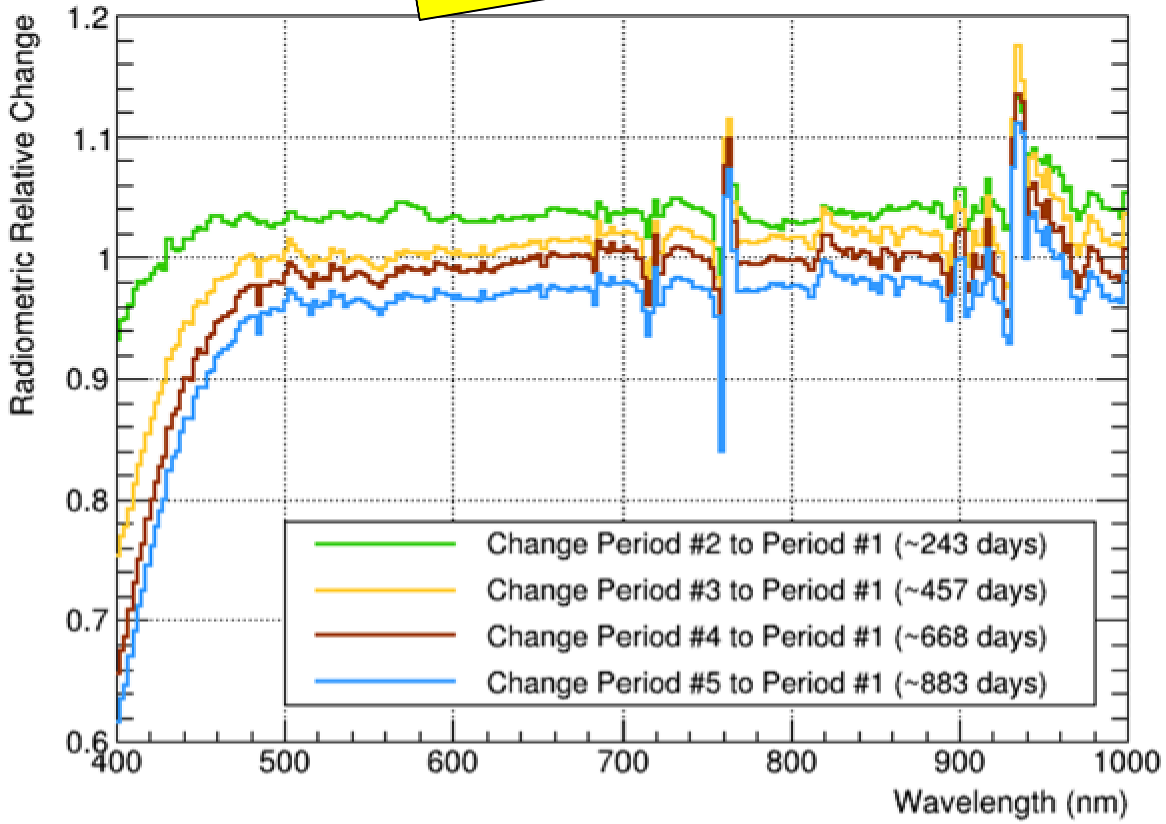


Comparison with Radiometric update from Vicarious Calibration

- Unfortunately model does not seem to match the data
- Based on existing vicarious calibration data, one can obtain similar grap
- Main similarity:
  - CAL data reproduces the fast decrease in performance below 500 nm

- Main differences are:
  - CAL data shows a maximum decrease down to 40% from the initial values, while the Vicarious data shows a maximum decrease down to 60%

„Based on existing vic. Cal. data …" => don't understand this. Isn't the plot already generated using Vic. Cal. Data ?



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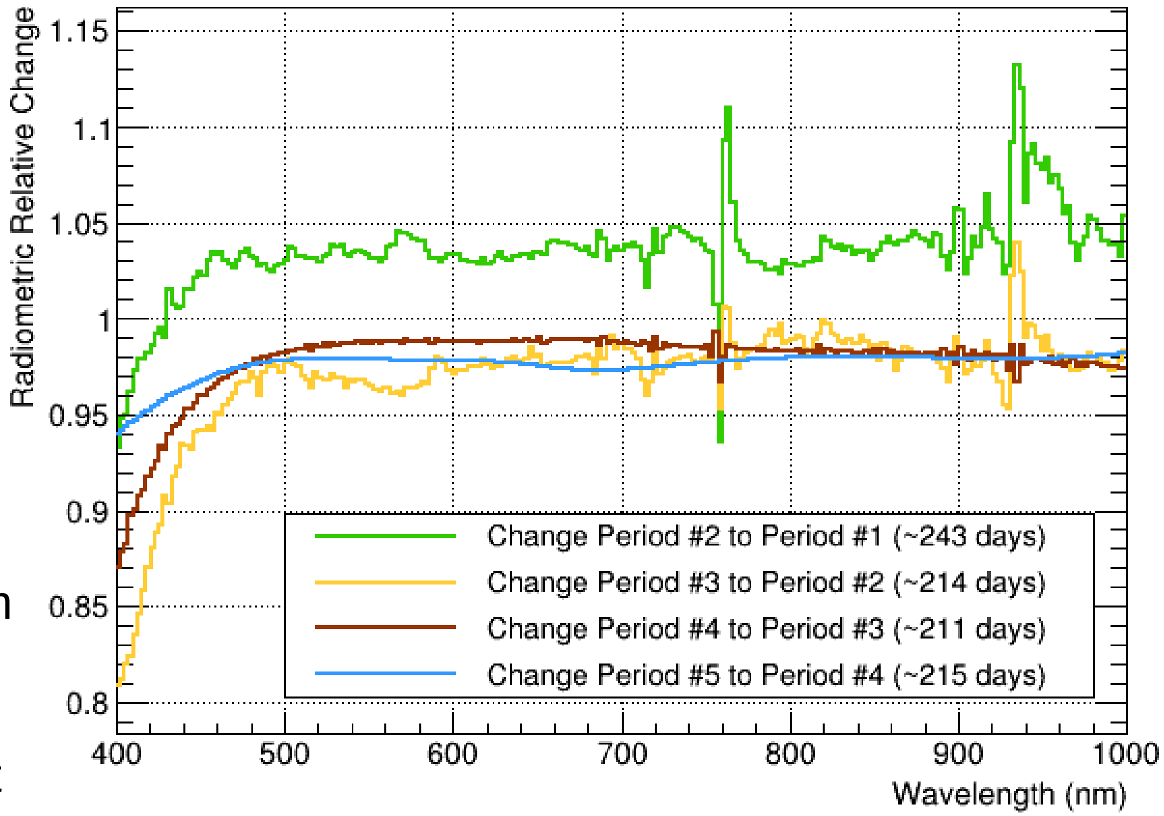
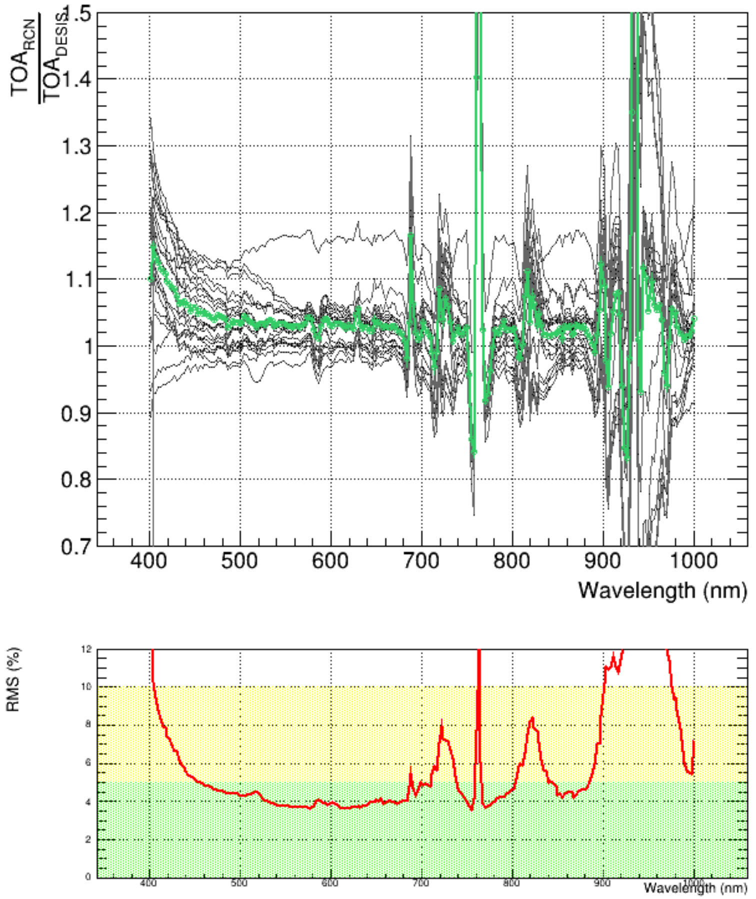
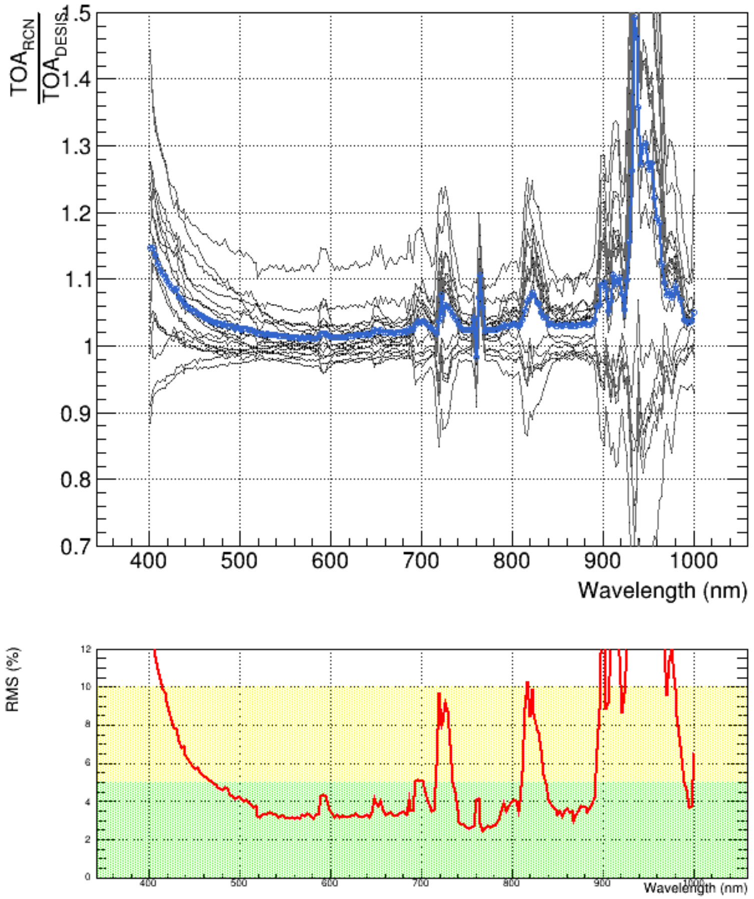
- Unfortunately model does not seem to match the data
- Based on existing vicarious calibration data, one can obtain similar graphs
- Main similarity:
    - CAL data reproduces the fast decrease in performance below 500 nm
- Main differences are:
    - CAL data shows a maximum decrease down to 40% from the initial values, while the Vicarious data shows a maximum decrease down to 60%
    - CAL data does not reproduce decrease of ~2% between periods (3.4%/year) above 500 nm
    - CAL decrease below 500 nm is constant until August 2021, but vicarious results show different intensities for different periods



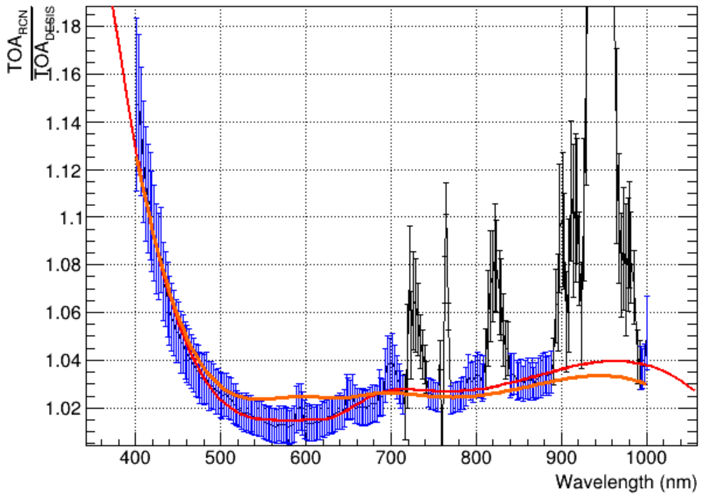
Latest Vicarious calibration data

- New calibration periods continue using baseline vicarious calibration
- Data in **periods #4** and **#5** with calibration for period #3:



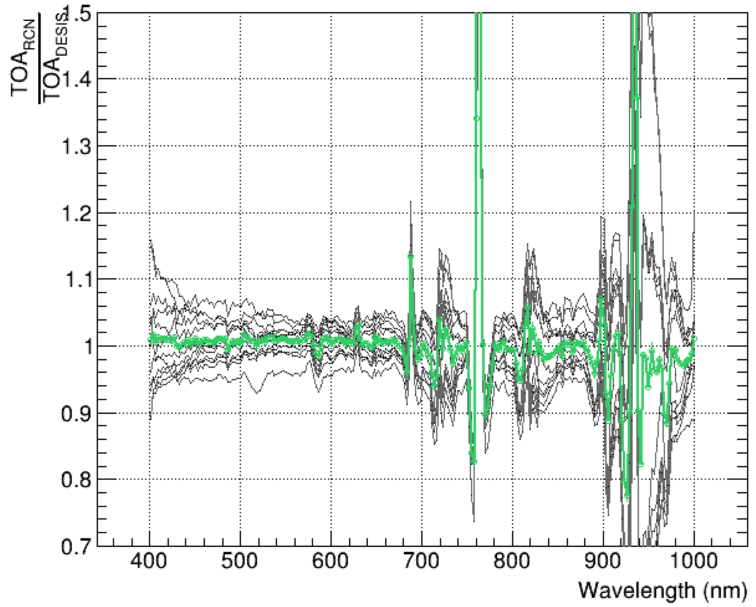


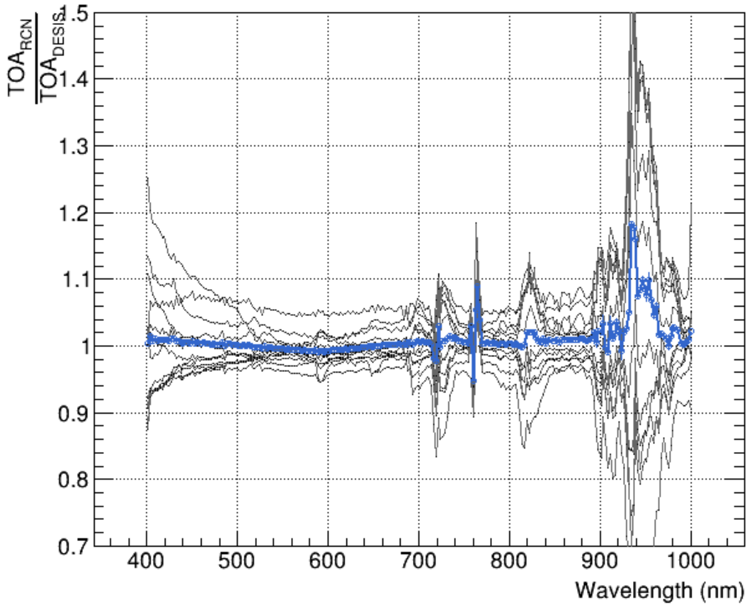
- Large variation of calibration below 500 nm as seem in other periods
- Magnitude is smaller

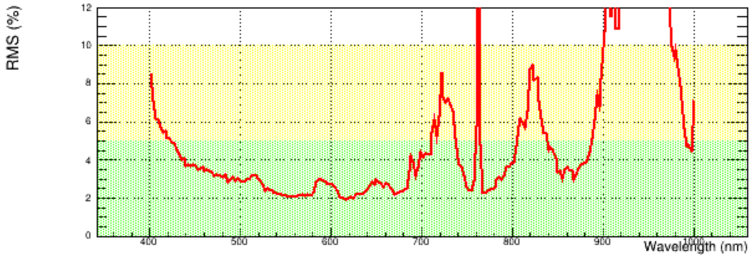


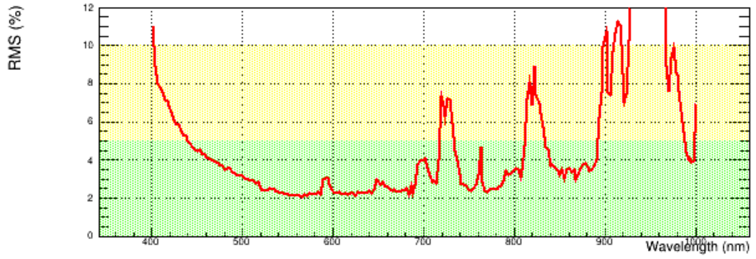
Latest Vicarious calibration data

- New calibration periods continue using baseline vicarious calibration used in DESIS
- Data in **period #4** calibrated with calibration in period #4 (preliminary):





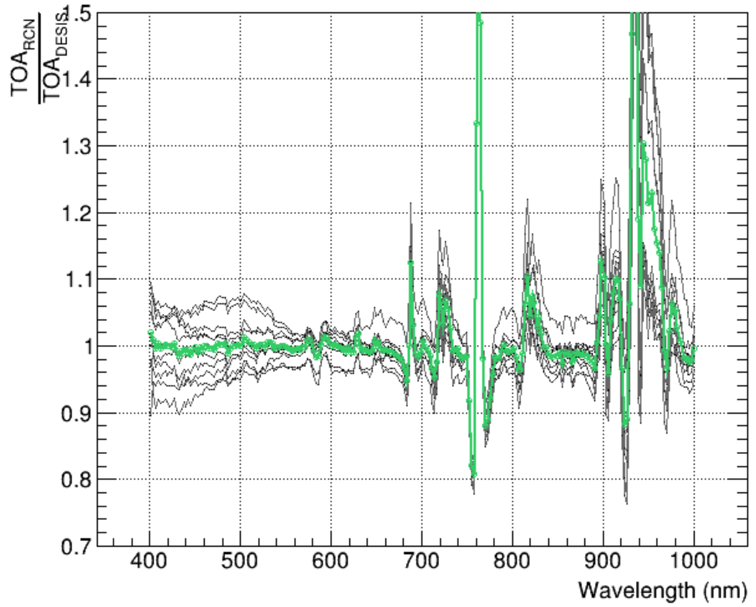


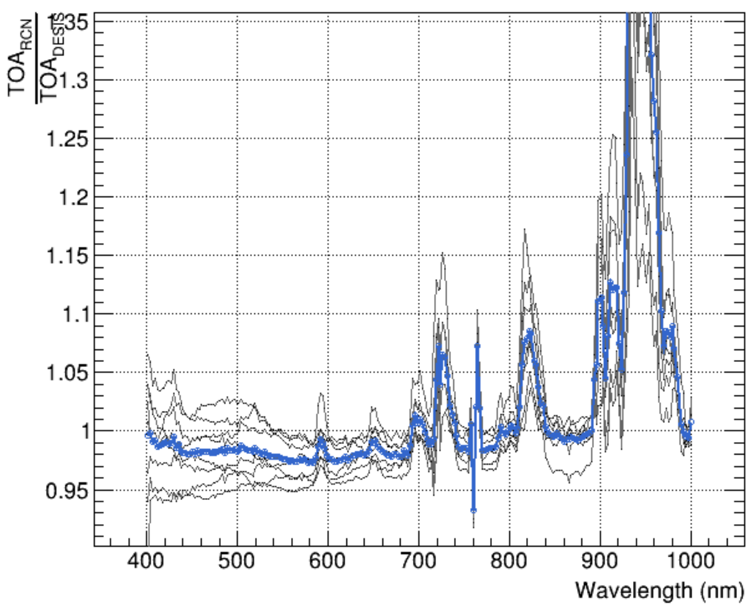


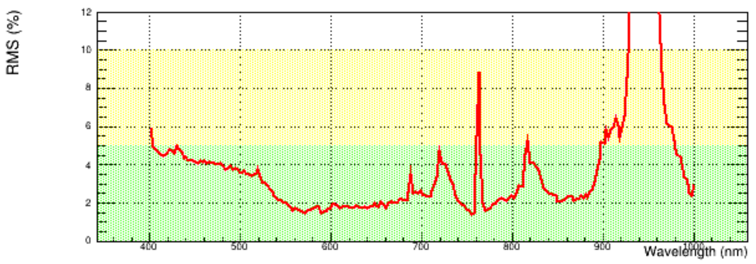
- Similar results as seen in other periods
- After calibration bias is corrected, but RMS below 500 nm is significant larger than above 500 nm

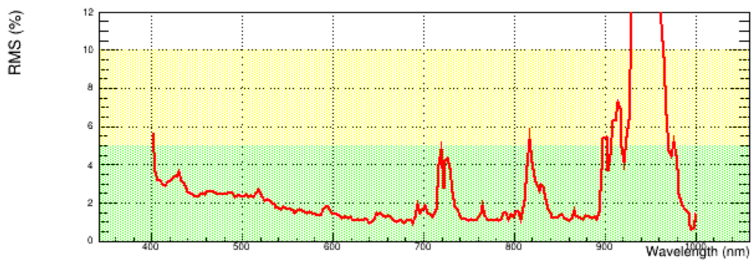
Latest Vicarious calibration data

- New calibration periods continue using baseline vicarious calibration used in DESIS
- Data in **period #5** calibrated with calibration in period #5 (preliminary):









- As indicated by LED calibration data, no sign of degradation below 500 nm on Period 5 (starts 01.07.2022)
- LED calibration data seem to reproduce well the trends, but not the actual intensity of the effect
- Not accurate enough for model, but probably accurate about change of behavior in July 2021

Summary & Outlook

- Vicarious calibration is the baseline calibration method of the DESIS imaging spectrometer

- Fast change of radiometric performance below 500 nm in DESIS is chall[illegible] calibration method (~20% degradation / year)

Maybe reword „periods“ with „procedure“ / „approach“ ?

- Above 500 nm the current calibration periods guarantee that difference between periods is ≤2% (~3.4% / year)

- In order to improve the calibration under 500 nm, we developed a model to characterize the sensor behavior using the on-board spectral calibration data
  - Model reproduces well trends, but does not reproduce accurately the values in the vicarious data

- Evidence of no further degradation below 500 nm after August 2021 from LED data, confirmed with vicarious data

- Next steps:
  - use vicarious data to develop model of sensor performance between 01.01.2019 and 01.07.2021
  - cross-calibration with other hyperspectral instruments (e.g. EnMAP)

Thank you for your attention !

DLR