Verification of EarthCARE MSI Level-1 and cloud data from the first year using MTG/FCI measurements

Sebastian Bley[1], *Anja Hünerbein*[1], *Nicole Docter*[1], *Rene Preusker*[2], *Nils Madenach*[1], *Annika Burzik*[1], *Mino Odendahl*[1], *Gregor Walter*[1], *Nikolaus Metzner*[1]

1 TROPOS, 2 FU-Berlin

Gefördert durch:
Bundesministerium für Wirtschaft und Klimaschutz
aufgrund eines Beschlusses des Deutschen Bundestages

TROPOS

Freie Universität Berlin

GIVE EVID-03
Validation Project

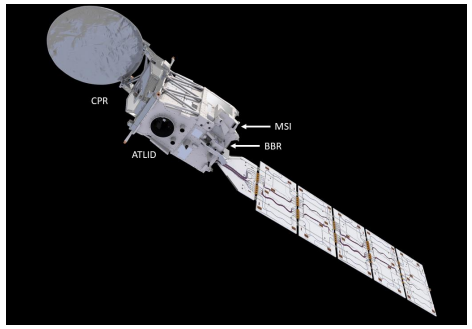
earth care
disc

JAXA esa

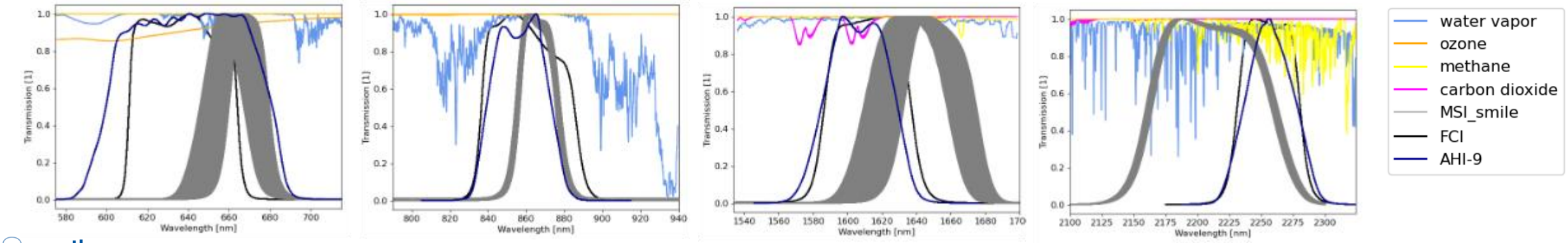
EarthCARE Science and Validation Workshop 2025
1-5 December 2025 | The University of Tokyo | Tokyo, Japan

Ad-hoc vicarious calibration - Methodology

Step 1: Spectrally align MSI VNS radiances with corresponding FCI radiances through Spectral Band Adjustment Factors (SBAFs).



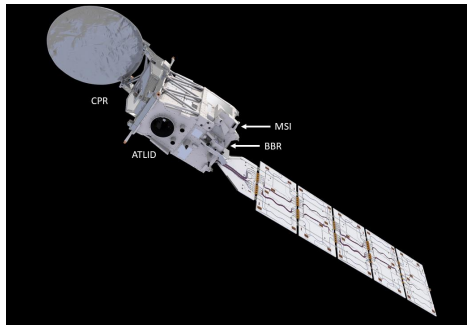
VIS NIR SWIR-1 SWIR-2



Ad-hoc vicarious calibration - Methodology

Step 1: Spectrally align MSI VNS radiances with corresponding FCI radiances through Spectral Band Adjustment Factors (SBAFs).

Step 2: Compare FCI-like MSI radiances with collocated FCI radiances and apply QC filters.



- **Restrict viewing geometry deviations.**
- **Focus on cloud scenes only (**MSI cloud fraction within one FCI pixel = 1)
- **Apply pixel homogeneity filter (**STD of MSI reflectance within one FCI pixel < 0.1 following Doelling et al. 2002)

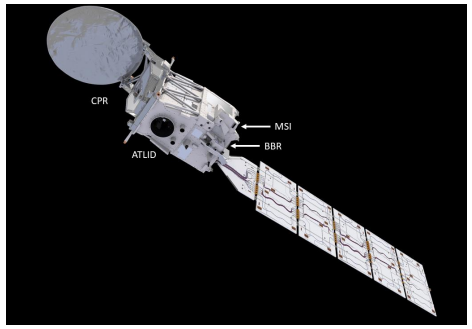
Ad-hoc vicarious calibration - Methodology

Step 1: Spectrally align MSI VNS radiances with corresponding FCI radiances through Spectral Band Adjustment Factors (SBAFs).

Step 2: Compare FCI-like MSI radiances with collocated FCI radiances and apply QC filters.

Step 3: Calculate correction factors for the MSI VNS maintenance gains from linear regression between MSI and FCI radiances for cloud scenes.

Step 4: Apply band specific corrections factors to each of the VNS bands.

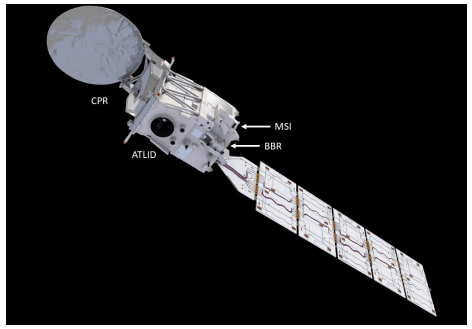


BAND	MSI-VIS	MSI-NIR	MSI-SWIR1	MSI-SWIR2
Correction factors (c)	0.9596	0.9920	0.8827	0.8970

$$L(msi)_{cor} = c\, L(msi)$$

Ad-hoc vicarious calibration - Methodology

- Ad-hoc vicarious calibration of radiance at nadir.
- No SMILE considered.
- Objective to have a stable and homogeneous calibration and solar irradiance for BA – ready for comprehensive calibration



More details →

First Year of In-Orbit EarthCARE MSI Level-1 Data

Sebastian Bley[1], Anja Hünerbein[1], Nils Madenach[1], Nicole Docter[1], Annika Burzik[1], Gregor Walter[1], Rene Preusker[2], Michael Eisinger[3], Fabien Marnas[4], Edward Baudrez[5], Antje Ludewig[6], Manuel Ruiz[7], Cameron Bean[7], Shweta Agarwal[7], Lennart Zimmermann[8], and Timon Hummel[9]

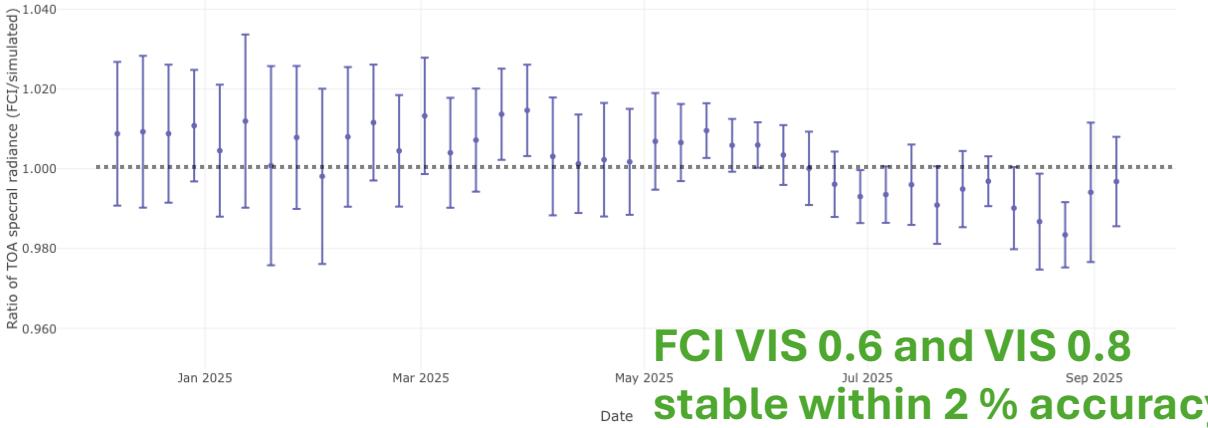
[1]Leibniz Institute for Tropospheric Research, Leipzig, Germany
[2]Freie Universität Berlin (FUB), Berlin, Germany
[3]European Space Agency (ESA), ECSAT, Harwell, United Kingdom
[4]European Space Agency (ESA), ESTEC, Noordwijk, The Netherlands
[5]Royal Meteorological Institute of Belgium, Brussels, Belgium
[6]Royal Netherlands Meteorological Institute (KNMI), de Bilt, the Netherlands
[7]GMV, Sir Colin Campbell Building Innovation Park Triumph Road. Nottingham, UK
[8]Airbus Defence and Space GmbH, Germany
[9]European Space Agency (ESA), ESRIN, Frascati, Italy

Correspondence: bley@tropos.de

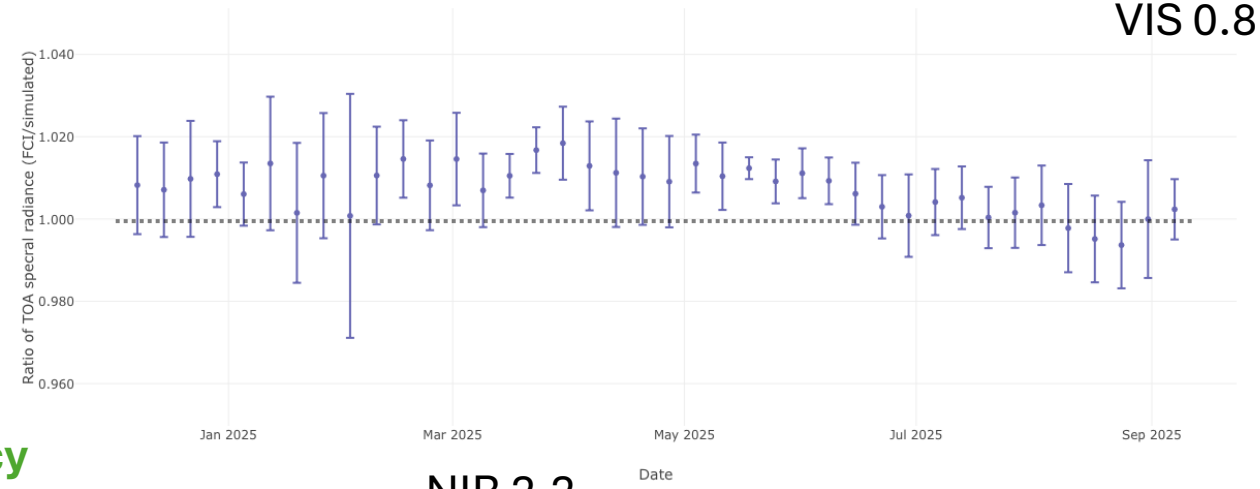
MSI versus FCI – FCI radiometric performance

FCI absolute desert vicarious calibration: Ratio of TOA spectral radiance (FCI/simulator)

VIS 0.6

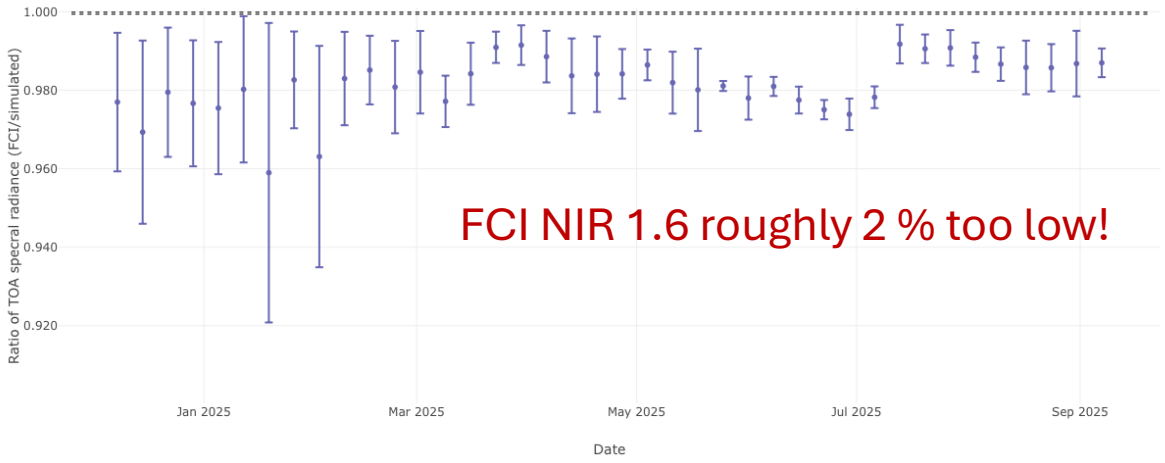


VIS 0.8



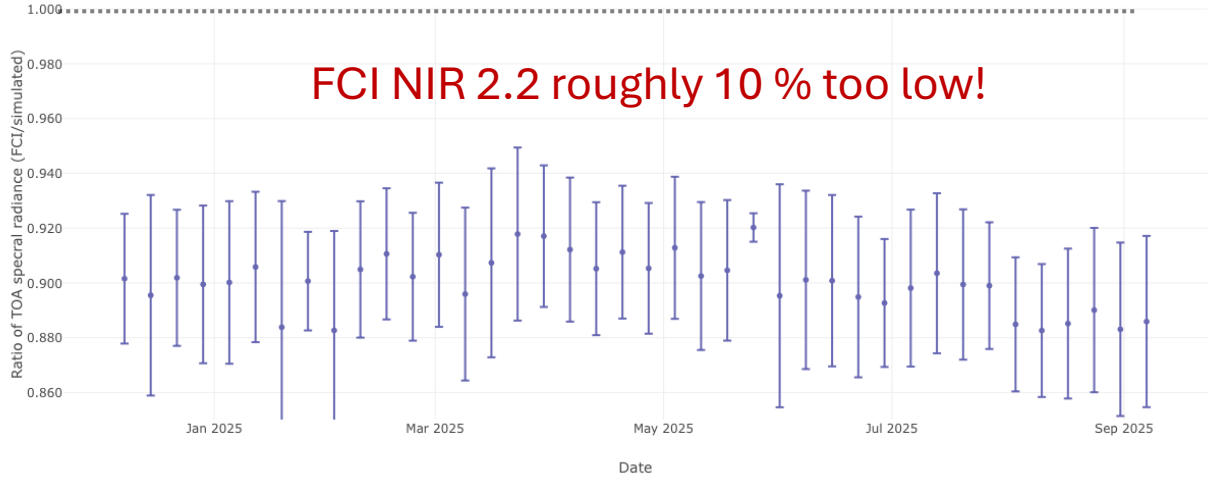
FCI VIS 0.6 and VIS 0.8 stable within 2 % accuracy

NIR 1.6



FCI NIR 1.6 roughly 2 % too low!

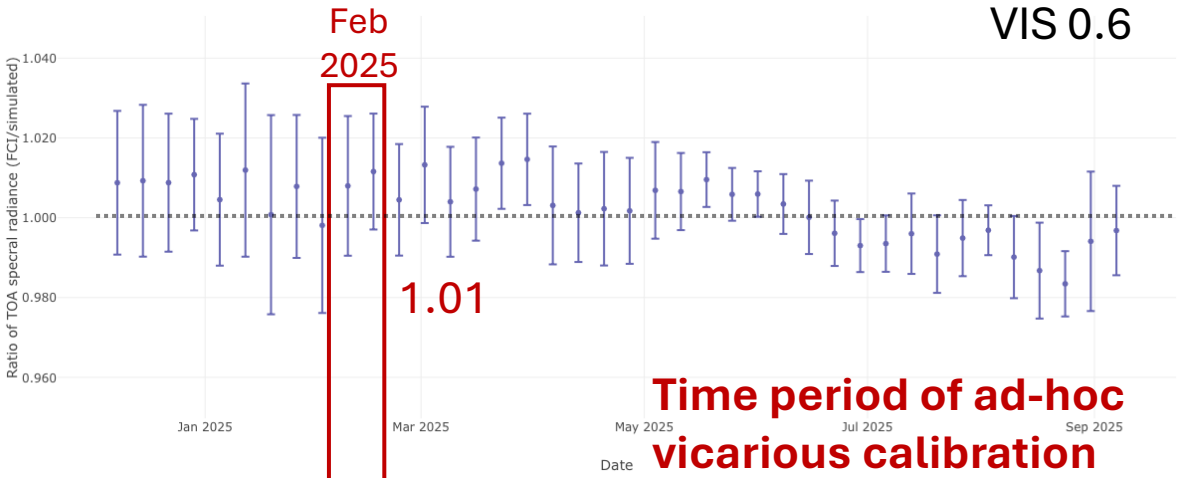
NIR 2.2

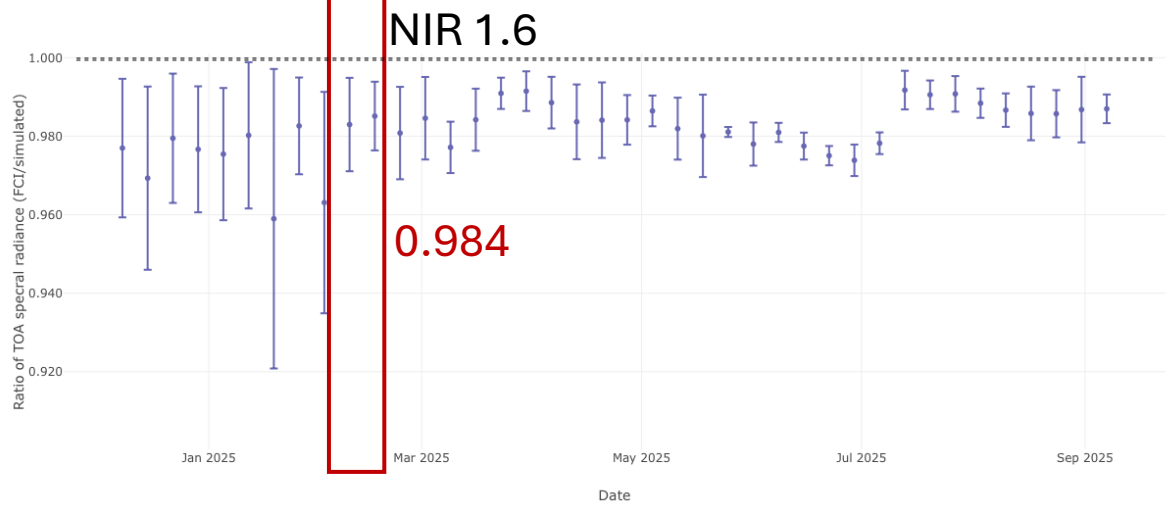


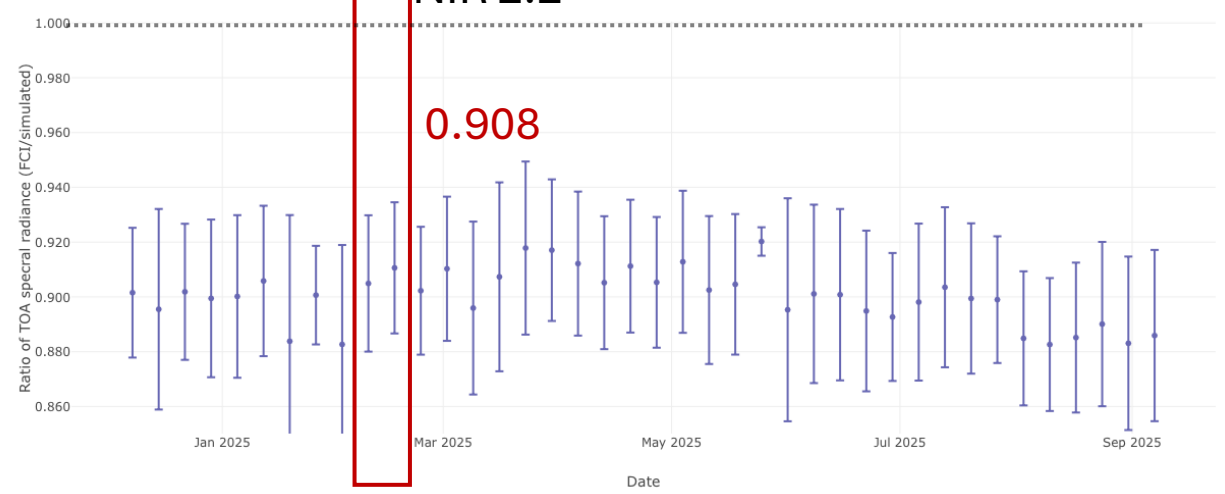
FCI NIR 2.2 roughly 10 % too low!

MSI versus FCI – FCI radiometric performance

FCI absolute desert vicarious calibration: Ratio of TOA spectral radiance (FCI/simulator)

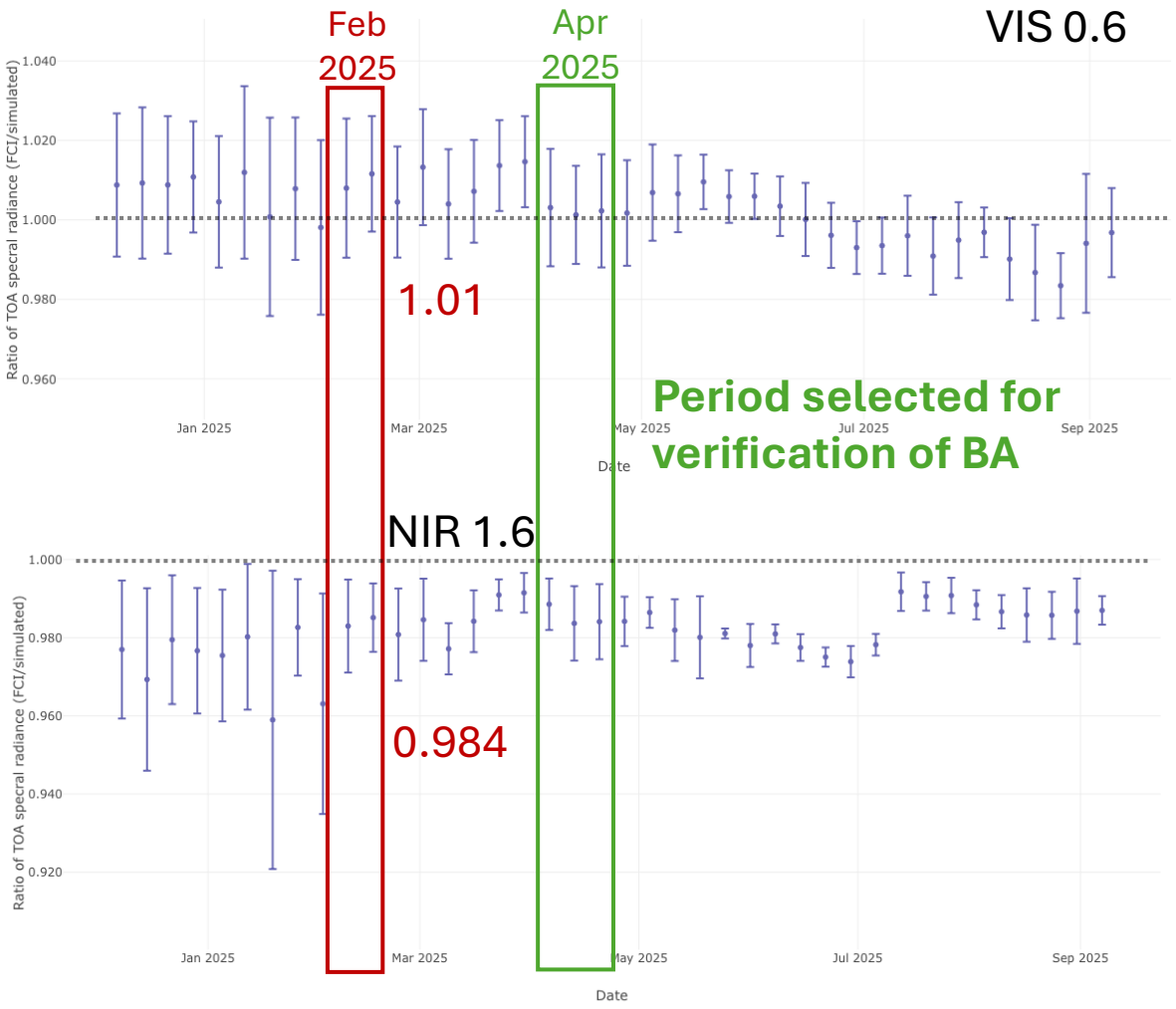


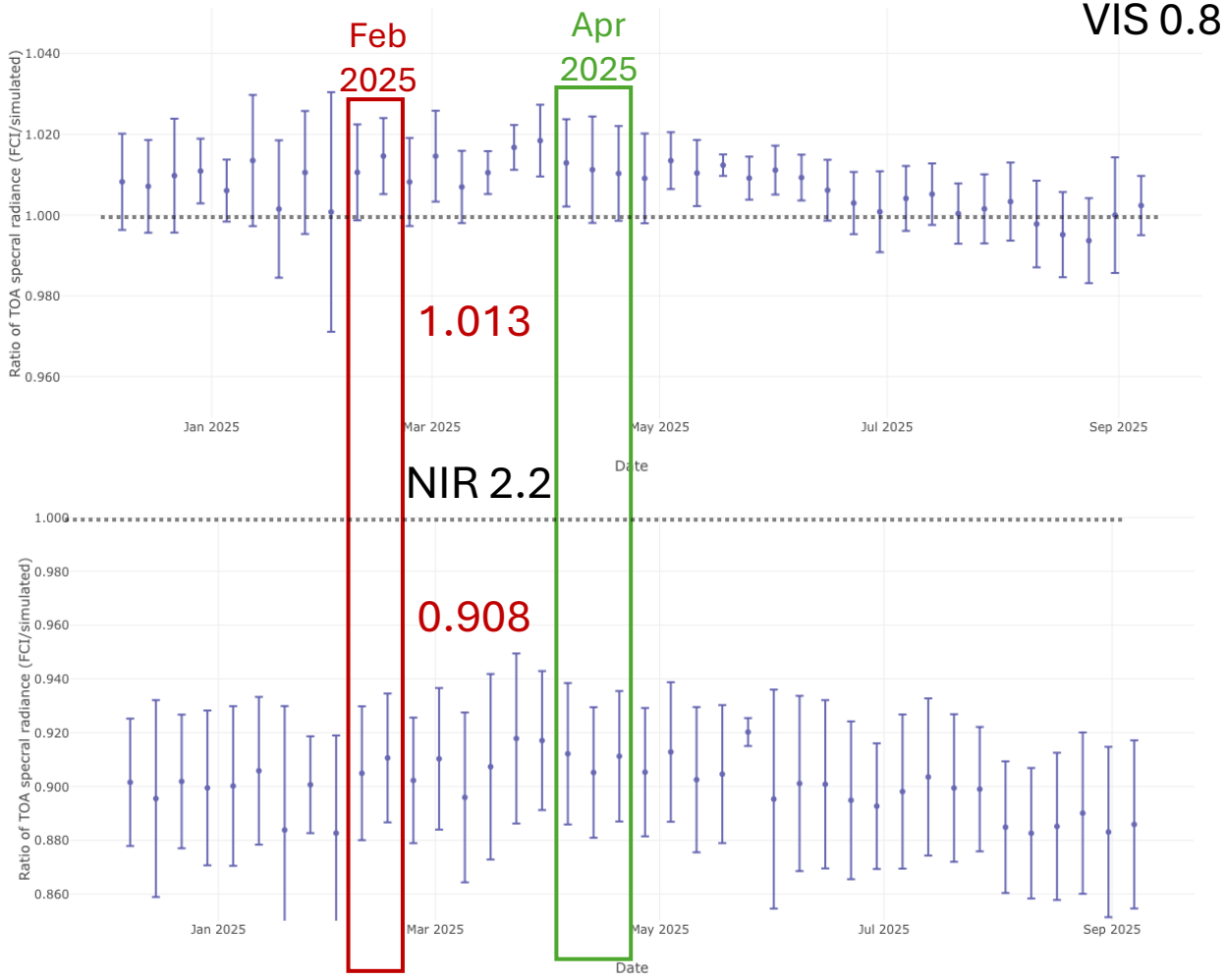




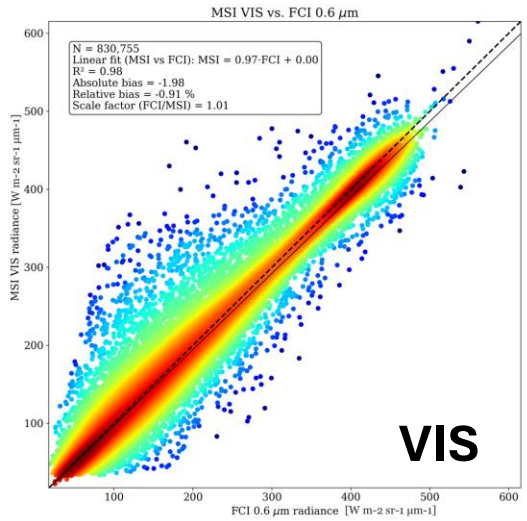
MSI versus FCI – FCI radiometric performance

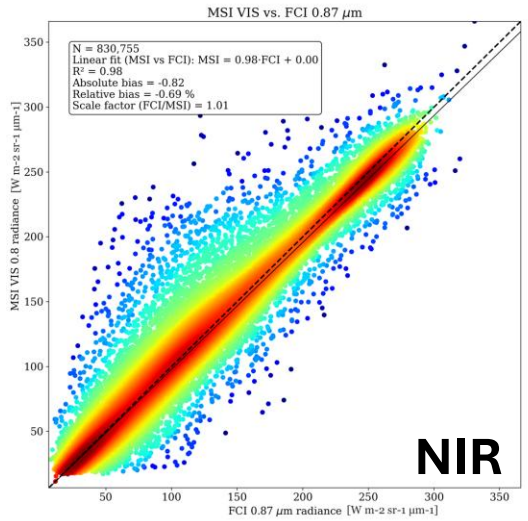
FCI absolute desert vicarious calibration: Ratio of TOA spectral radiance (FCI/simulator)

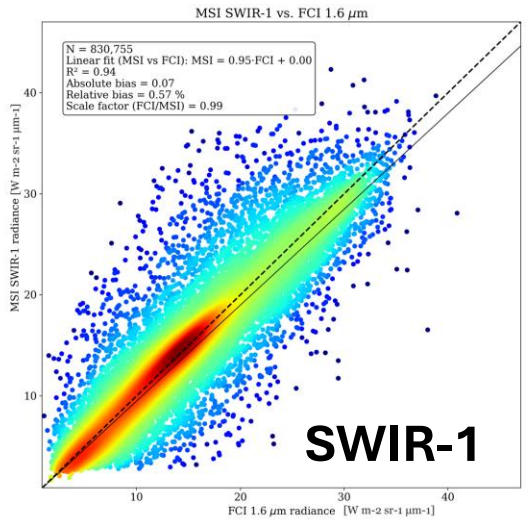


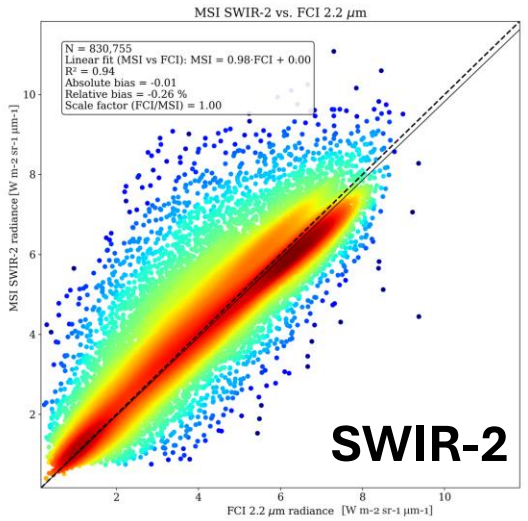


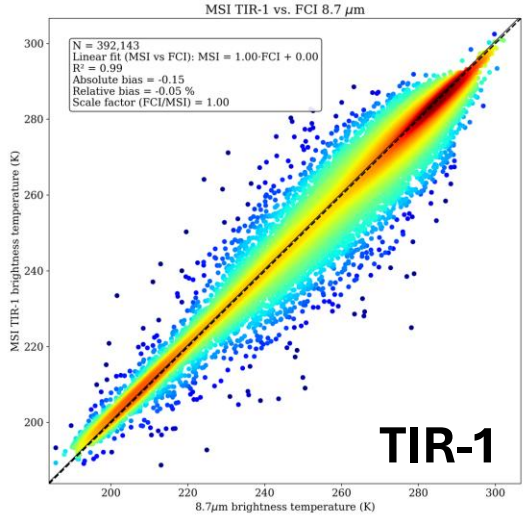
Verification of MSI L1 BA against FCI

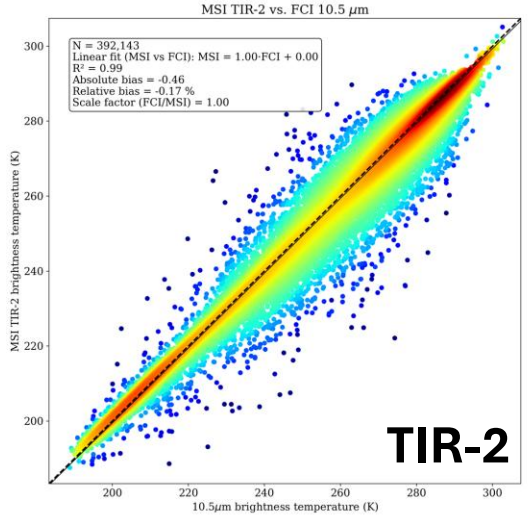


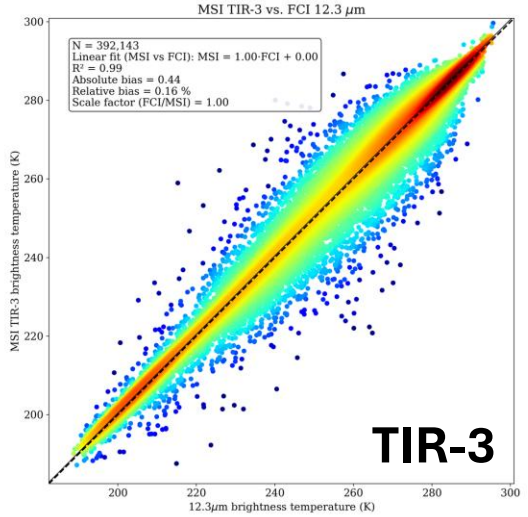










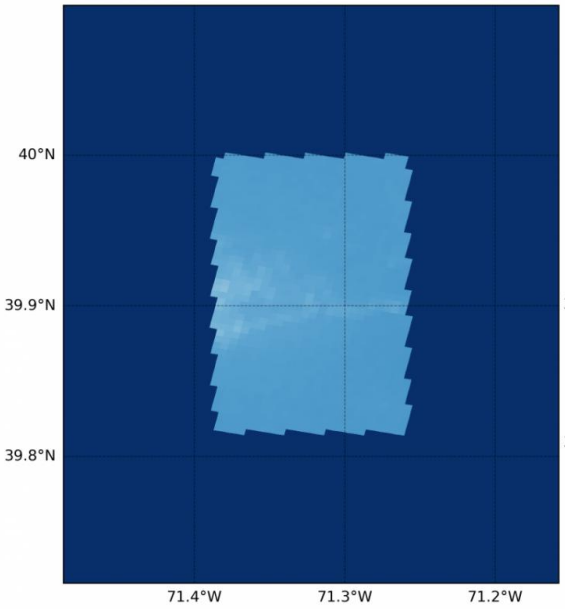


- Relative difference below 1% across all bands
- SWIR-1 and SWIR-2 very sensitive to cloud microphysics
- 10 % offset in SWIR-2 translated from FCI to MSI (please consider when comparing to other instruments).

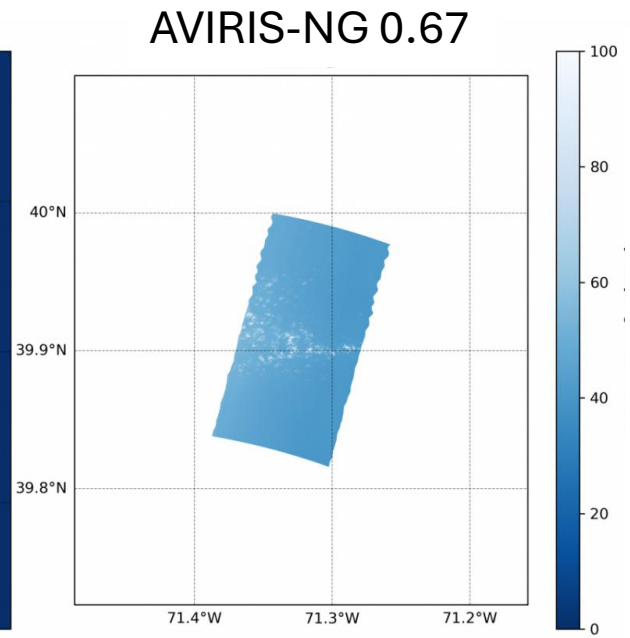
Verification of MSI L1 BA against airborne imagers

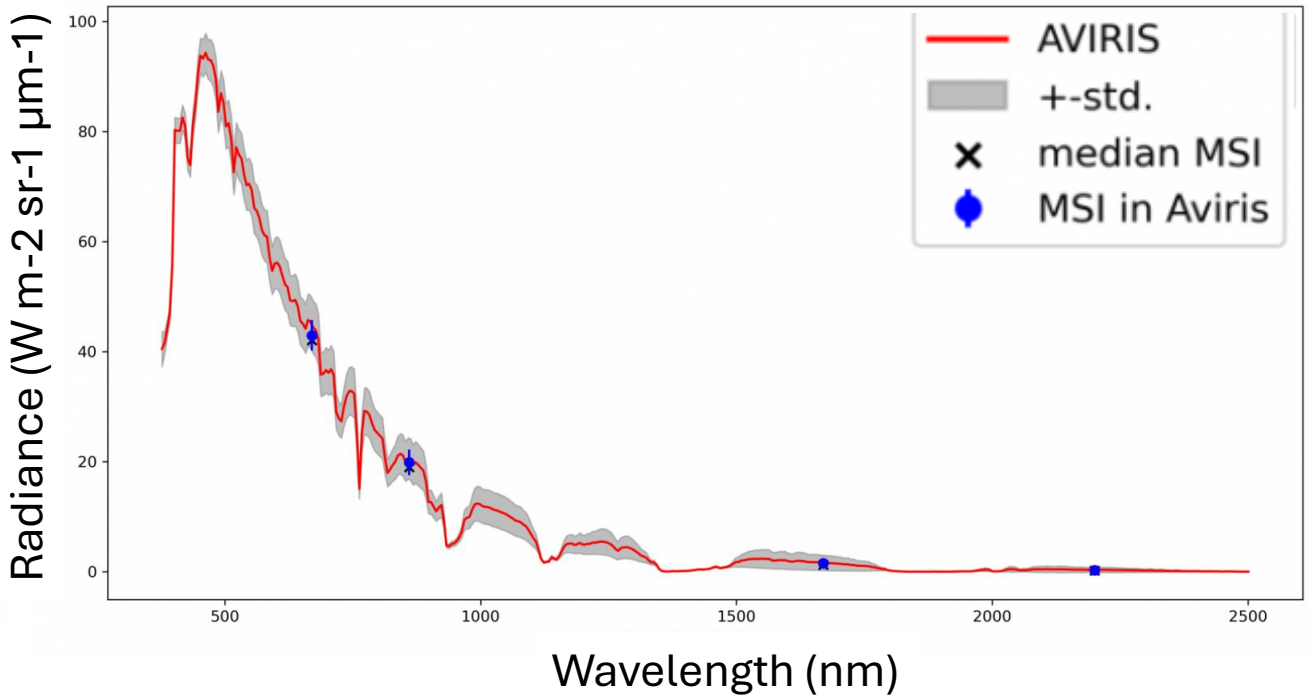
AVIRIS-NG imager onboard Gulfstream III during ARCSIX

MSI VIS 0.67



AVIRIS-NG 0.67





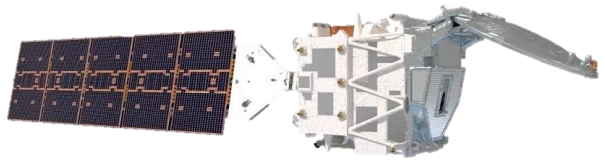
16 August 2024
Frame 01242D
MSI-RGR L1: BA

→ Comparison against airborne imager L1 data indicates good agreement for clear sky over ocean

Credits: N. Metzner, TROPOS

Case study: L2 cloud product validation

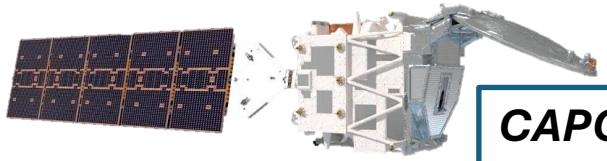
M-CLD used for MSI: **Baum et al.** general habit mixture



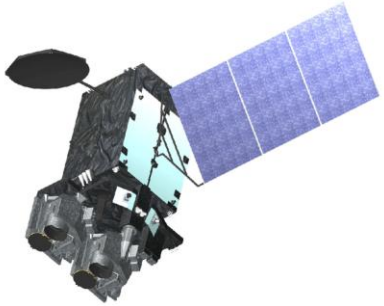
KNMI-CPP for SEVIRI: **Baum et al.** general habit mixture

Level-2 validation challenge: How to disentangle cloud-property differences due to Level-1 measurement differences from those caused by retrieval assumptions (e.g., Ice-Cloud Microphysical Assumptions)?

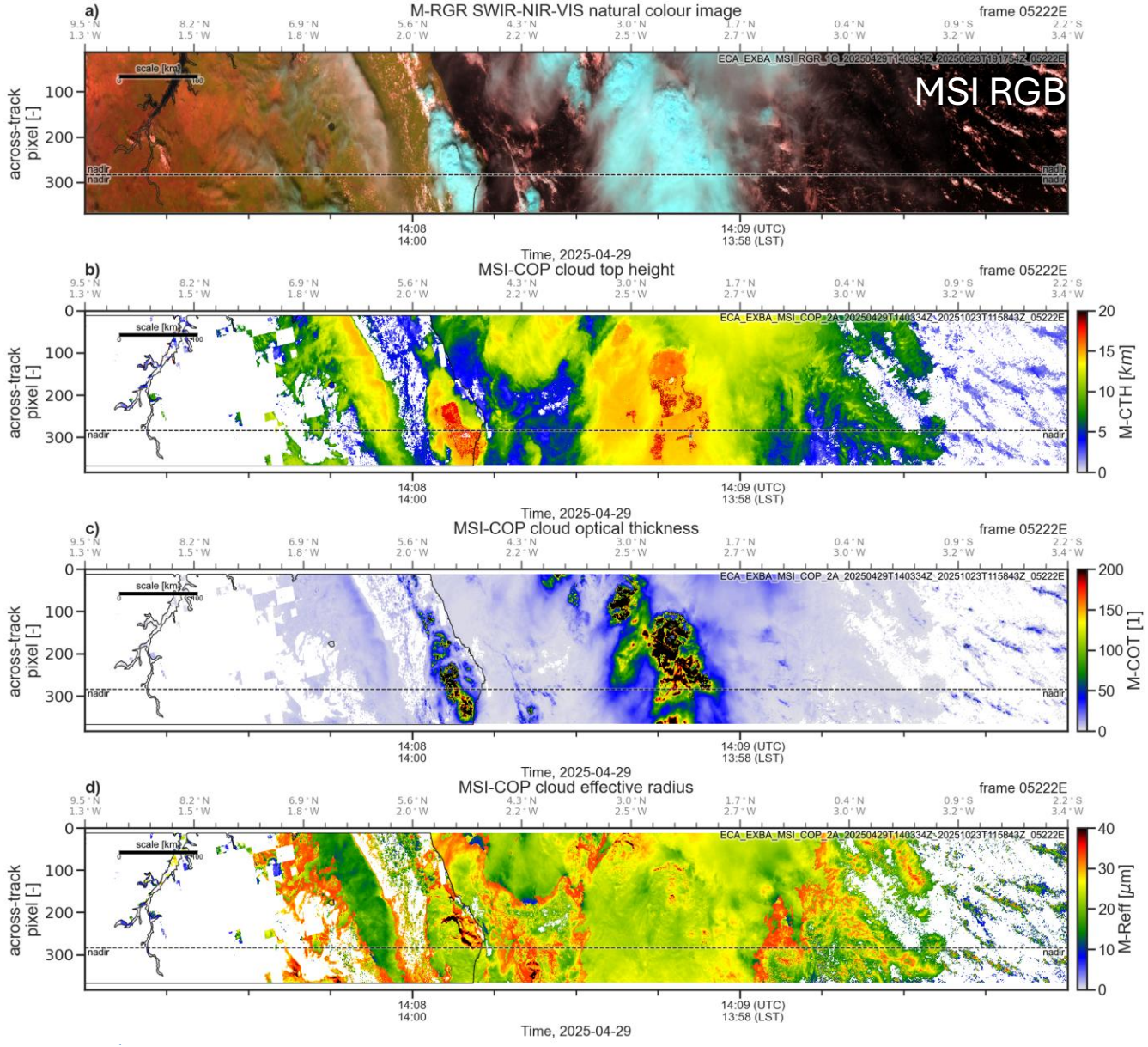
Optimal Cloud Analysis (OCA) used for FCI: **Baran et al.** universal habit mixture – a physically constrained mixture based on observed particle geometries.



CAPCOM for AHI on Himawari & for JAXA ice cloud retrieval for MSI (MSI_CLP): **Voronoi model** of highly irregular ice particles



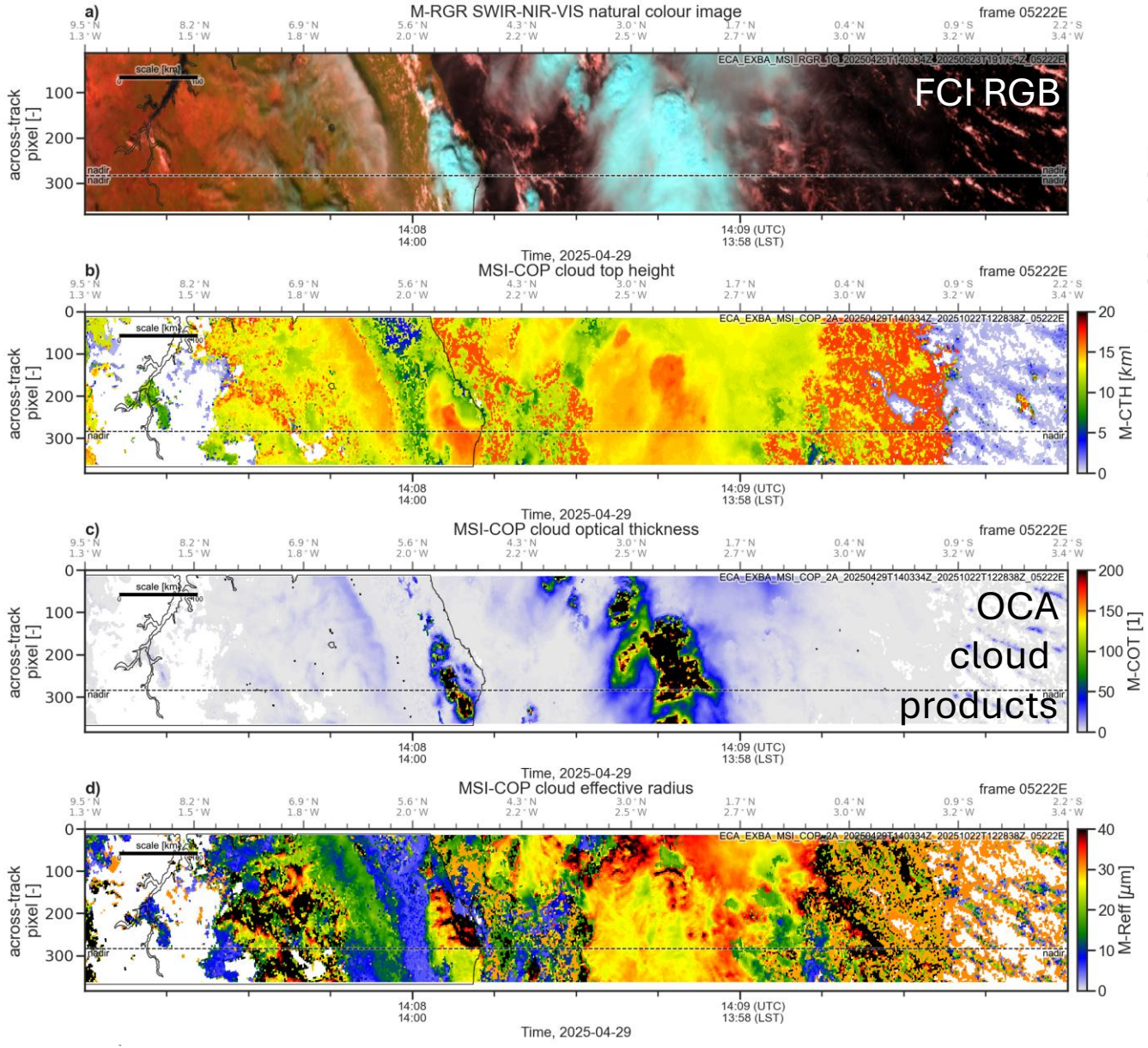
Case study: L2 cloud product validation

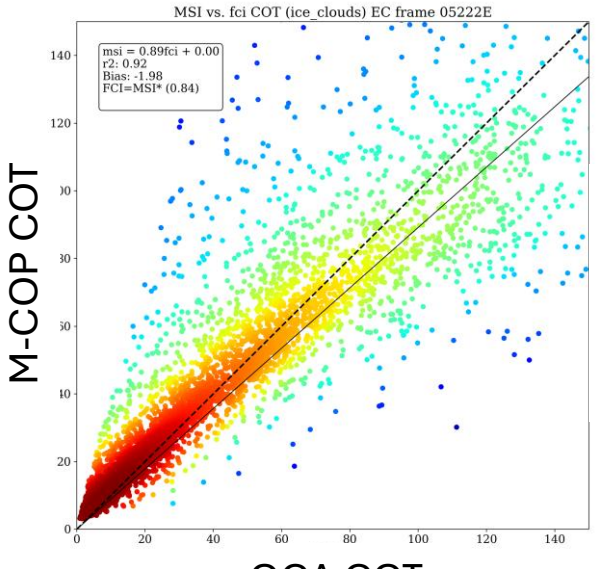


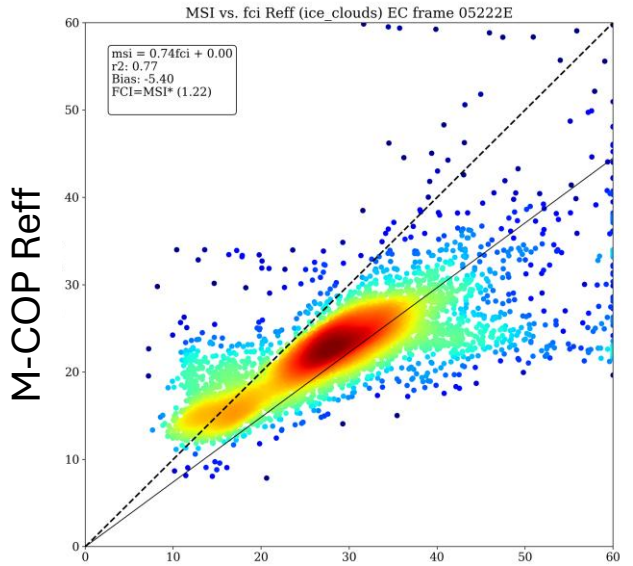
29 April 2025
Frame 05222E
Level-1: BA
Level-2a: BA

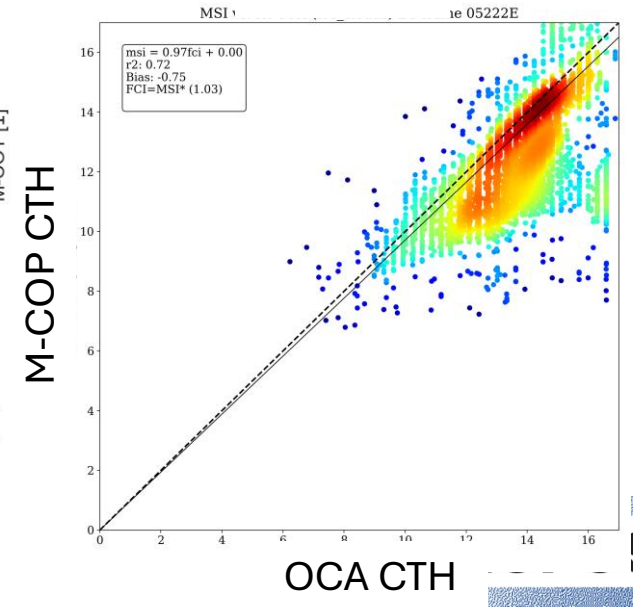
TROPOS
Freie Universität Berlin

Case study: M-COP vs. FCI Optimal Cloud Analysis (OCA)



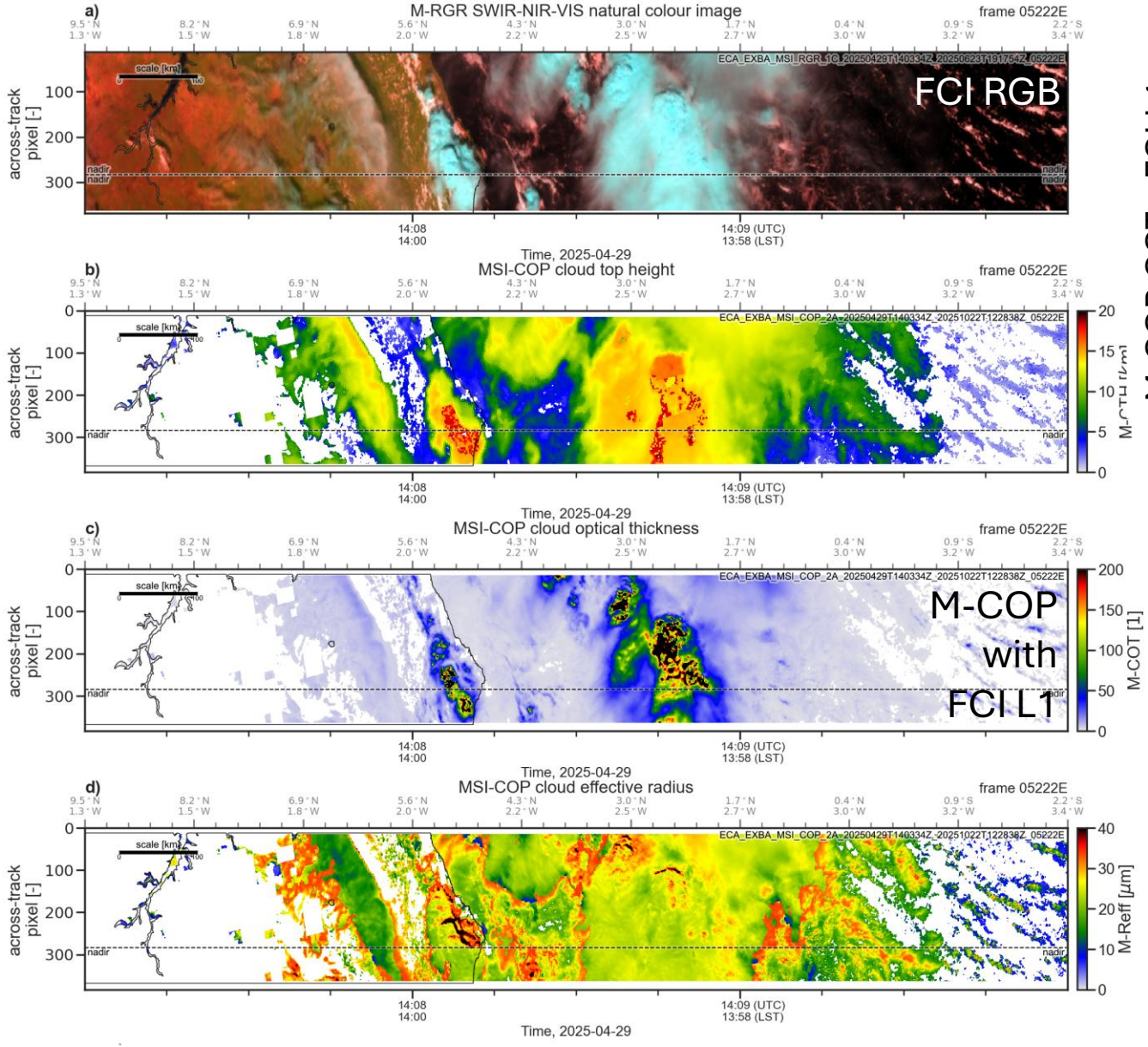


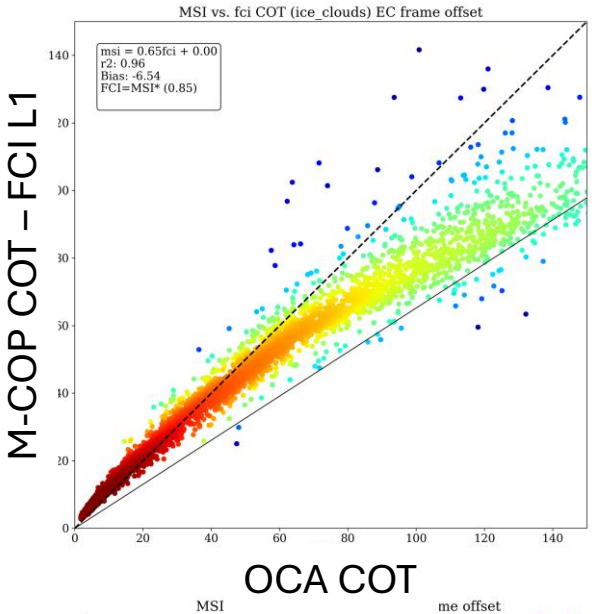


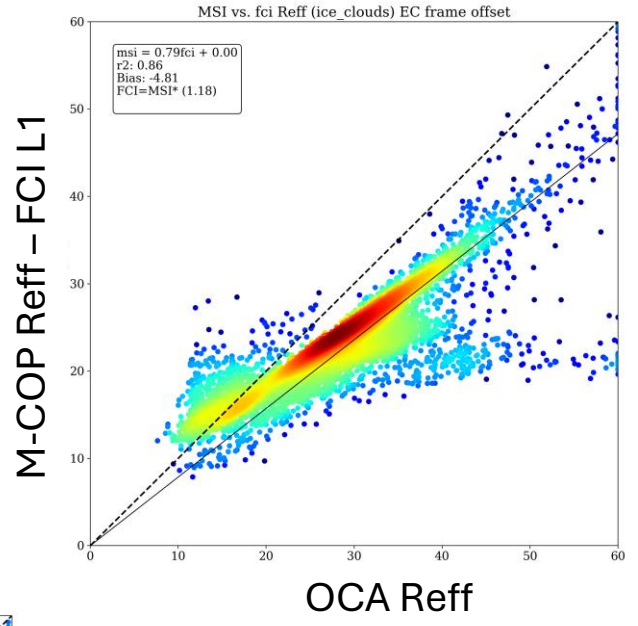


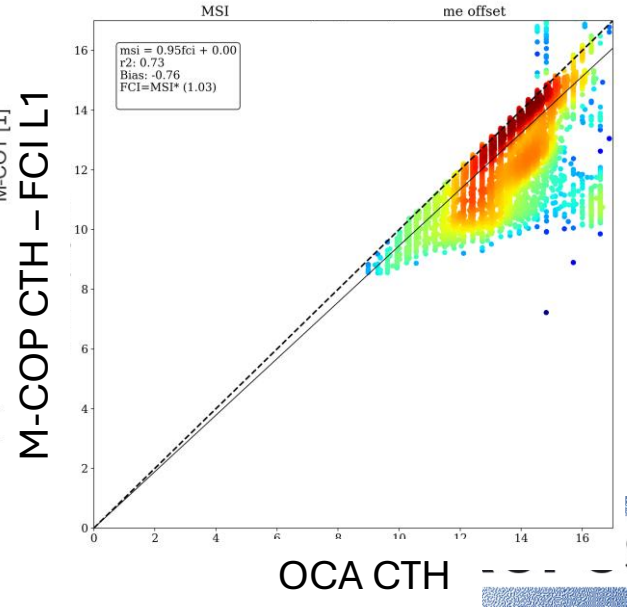
29 April 2025
Frame 05222E
Level-1: FCI L1C
Level-2: OCA
Scatterplot:
Ice clouds only

Case study: M-COP with FCI L1 input vs. OCA



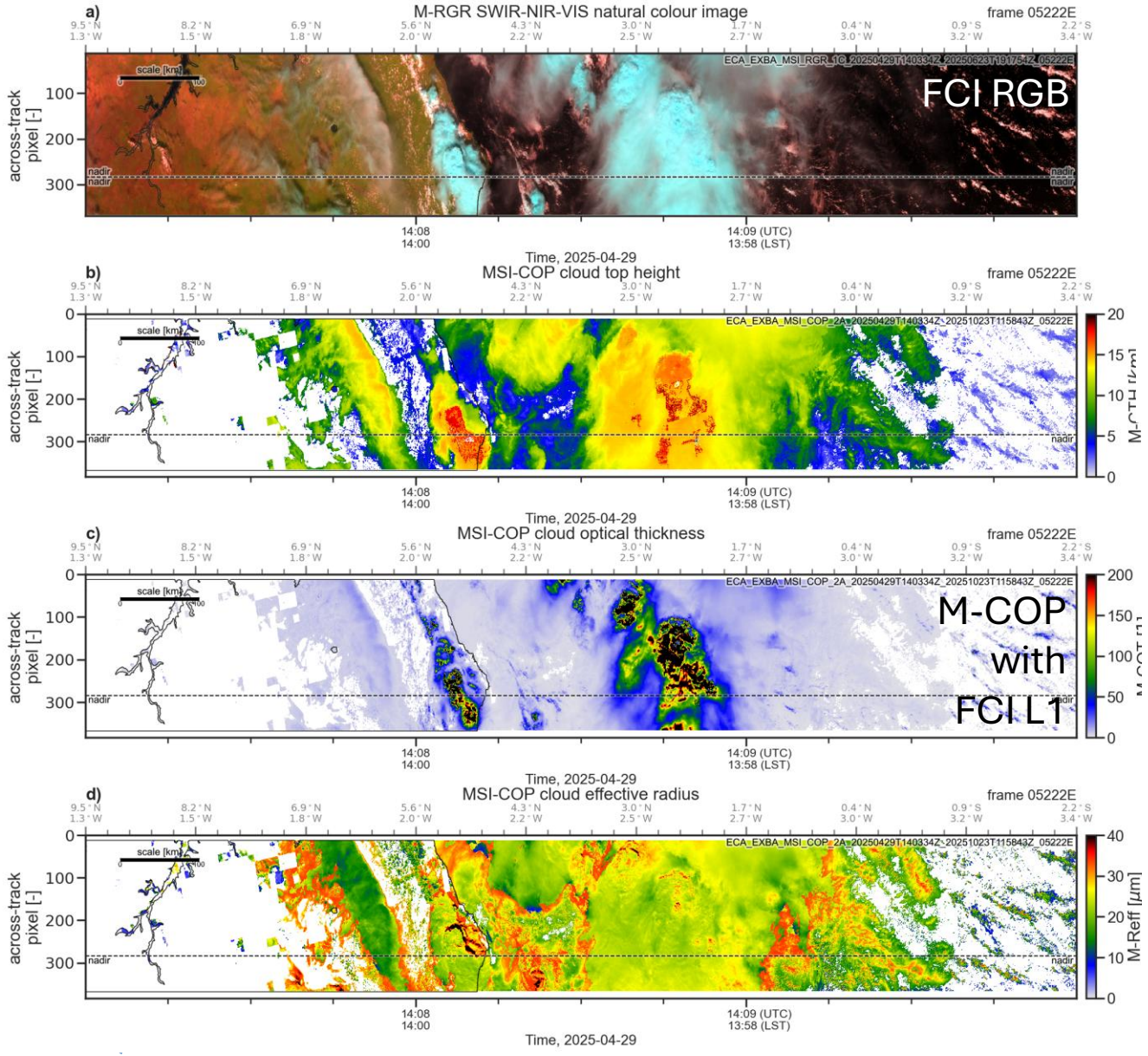


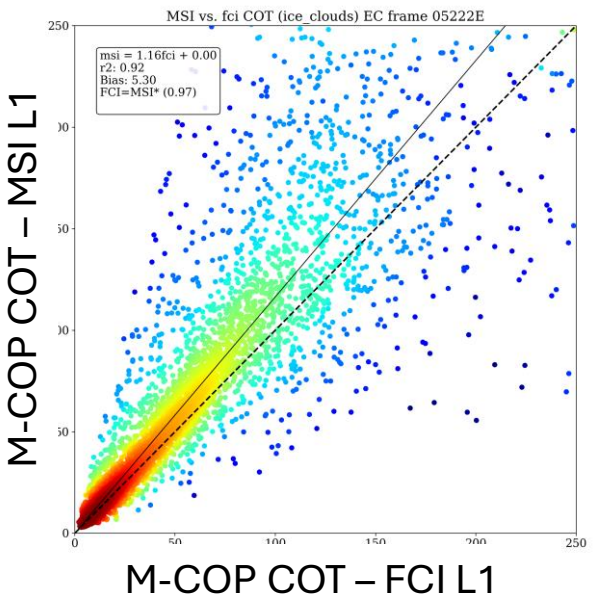


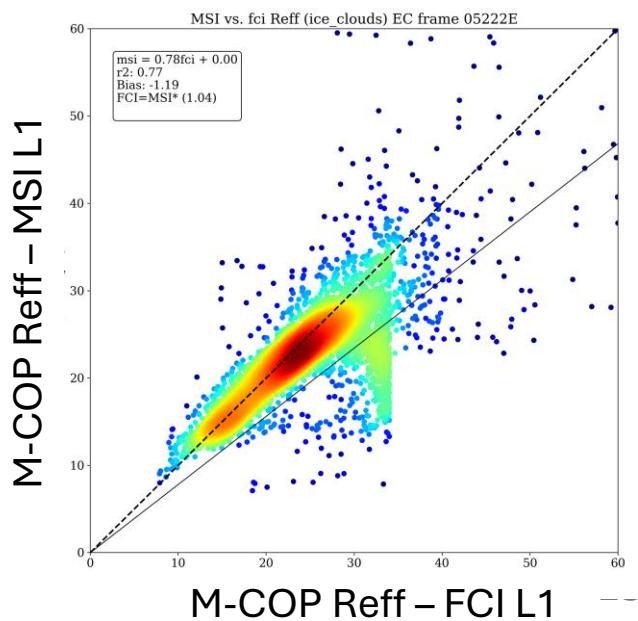


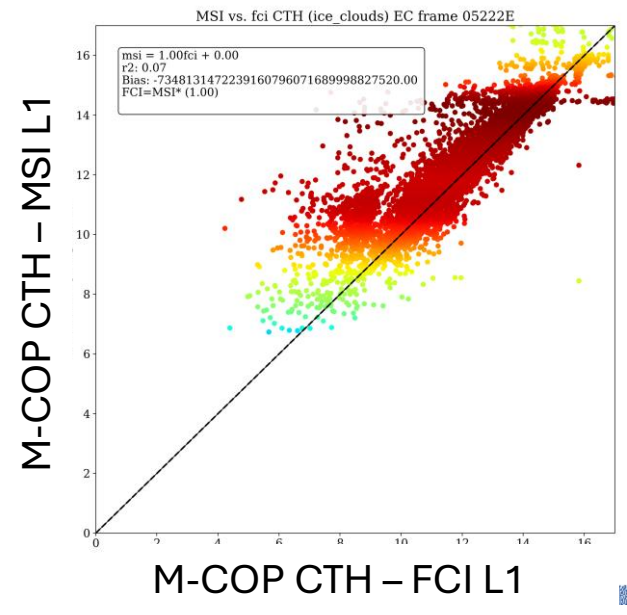
29 April 2025
Frame 05222E
Level-1: FCI
Level-2a: M-CLD with FCI L1 input
Scatterplot: Ice clouds only

Case study: M-COP with FCI L1 input vs. M-COP MSI









29 April 2025
Frame 05222E
Level-1: FCI
Level-2a: M-CLD with FCI L1 input
Scatterplot: Ice clouds only

Conclusions and recommendations

- Comparison of MSI L1 BA radiances with corresponding FCI radiances shows very good agreement for cloud scenes with mean relative differences of less than 1%

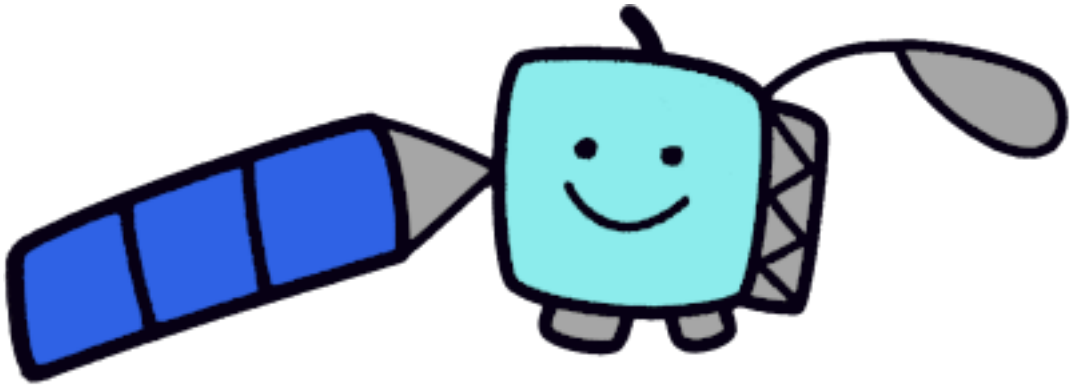
- MSI calibrated L1 BA products can only be as good as the FCI reference (10% offset in SWIR-2 transferred)

- Independent reference data from airborne or other satellite instruments needed - also comparison against EarthCARE profile measurements (e.g., MSI vs. ACM-CAP).

→ **Gregor's Poster 50 on Thursday 16:30-18:00**: Potential of combining MSI (M-COP) with the EarthCARE synergy (ACM-CAP) derived cloud properties

→ **Anja's Poster 56 on Thursday 16:30-18:00**: Current Status and Enhancements of Cloud Retrieval Algorithms from EarthCARE's Multi-Spectral Imager (MSI)

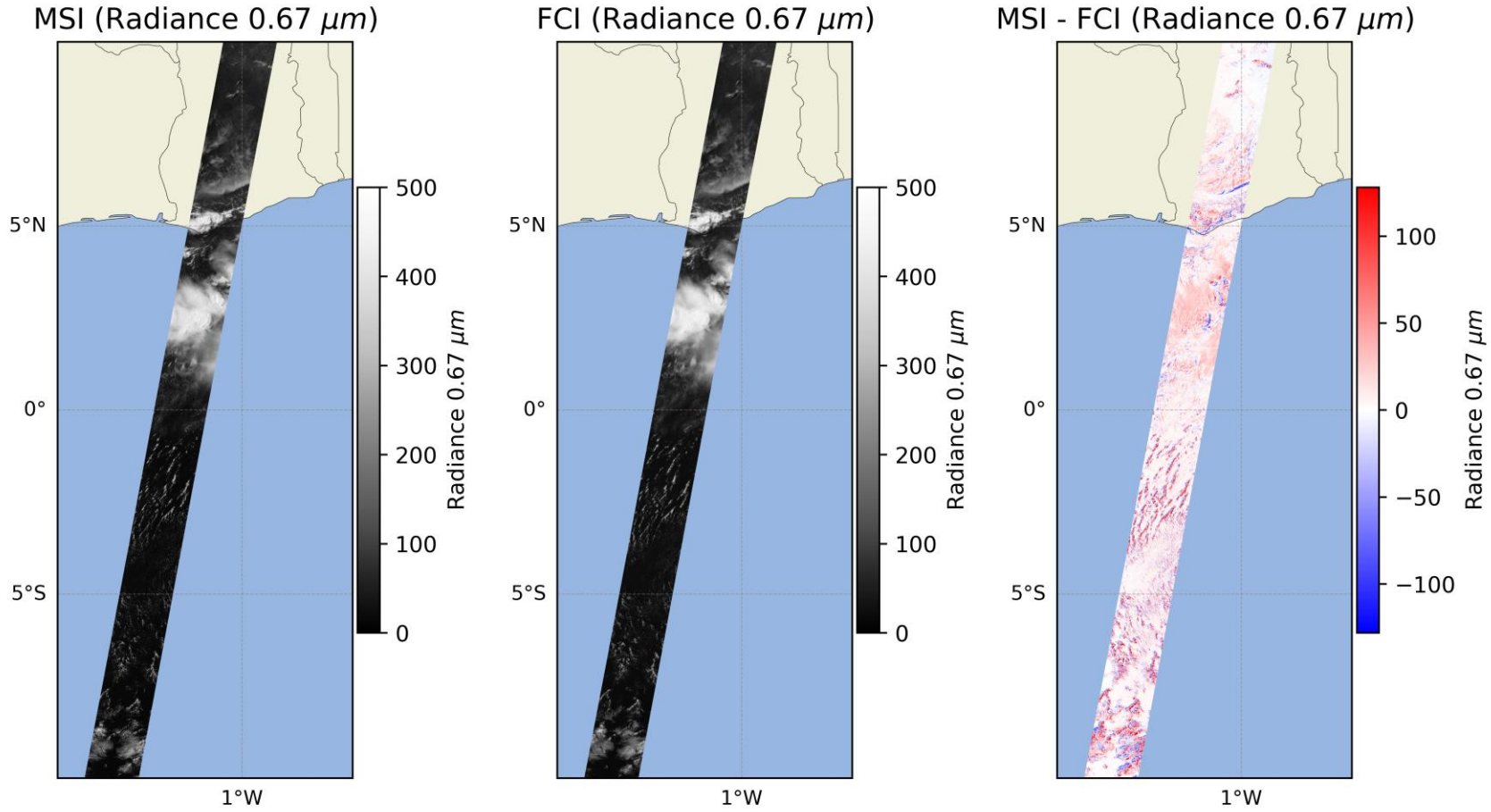
Thank you!



Backup

Case study: L2 cloud product validation

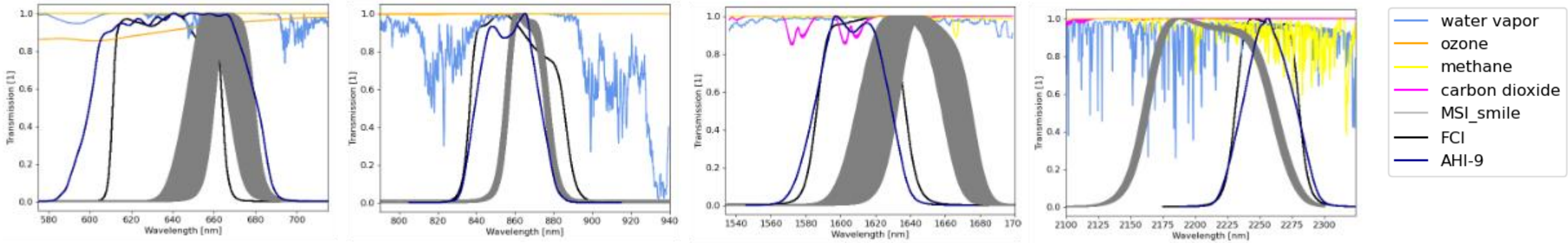
- Approach 1: Compare MSI (M-COP) with FCI cloud products (OCA)
- Approach 2: Compare M-COP with FCI L1 + geometry input with FCI OCA
- Approach 3: Compare M-COP operatinal with M-COP run with FCI L1 + geometry input



Ad-hoc vicarious calibration - Methodology

- **SBAFs** (= spectral band adjustment factors) **only for clouds above ocean**, generated using the *MSI tool* (RTM tailored for MSI) and *FCI tool*

VIS NIR SWIR-1 SWIR-2



- Simulations carried out 31.590 cases of liquid and ice clouds (Reff=10, 30 µm):
  - COT: 0, 0.5, 2, 4, 8, 16, 32, 64, 100
  - CTP: 200, 500, 800 hPa
  - VZA: 0°, 5°, 10°, 15°, 20°
  - SZA: 10°, 15°, … , 65°, 70°
  - RAA: 0°, 10°, … 160°, 170°

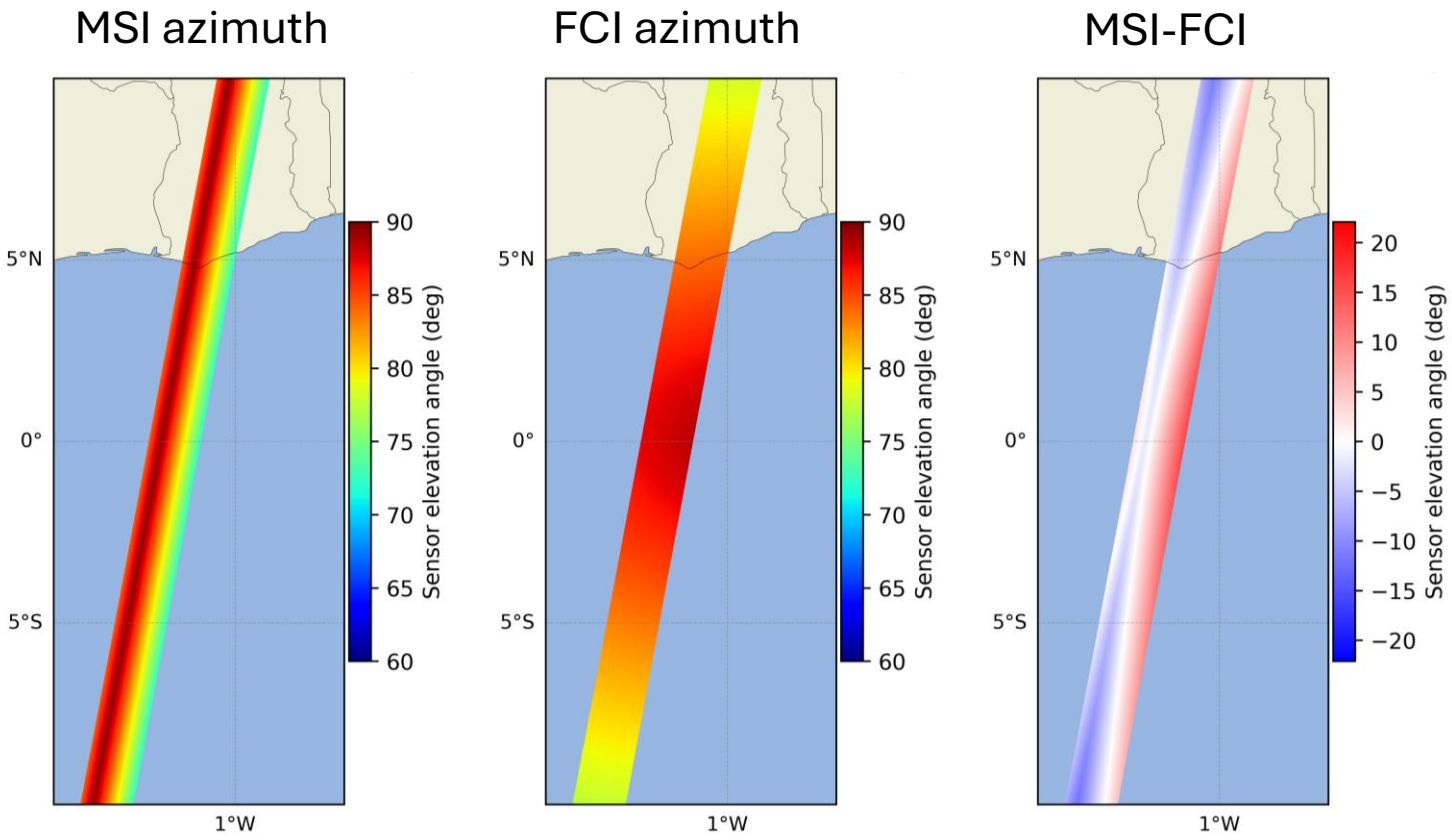
BAND	MSI-VIS/FCI-VIS-06	MSI-NIR/FCI-VIS-08	MSI-SWIR1/FCI-NIR-16	MSI-SWIR2/FCI-NIR-22
SBAF	1.045	0.996	1.06	0.925

→ **Nils' Poster 42 Friday 10-11:30**: Statistical Validation of EarthCARE MSI L1 Data Using MSI Forward Simulator at ACTRIS Stations

Ad-hoc vicarious calibration - Methodology

QC filtering

1. **Restrict viewing geometry deviations.**
   i. SVA < 10 deg
   ii. abs(SVA_{FCI}-SVA_{MSI}) < 10 deg
2. **Focus on cloud scenes only (**MSI cloud fraction within one FCI pixel = 1)
3. **Apply pixel homogeneity filter (**STD of MSI reflectance within one FCI pixel < 0.1 following Doelling et al. 2002)



Introduction and take home

Why verify MSI Level-1 data quality?

Small radiance differences can blow up in band differences/ratios

→ big impacts on cloud & aerosol retrievals.

What is the truth?

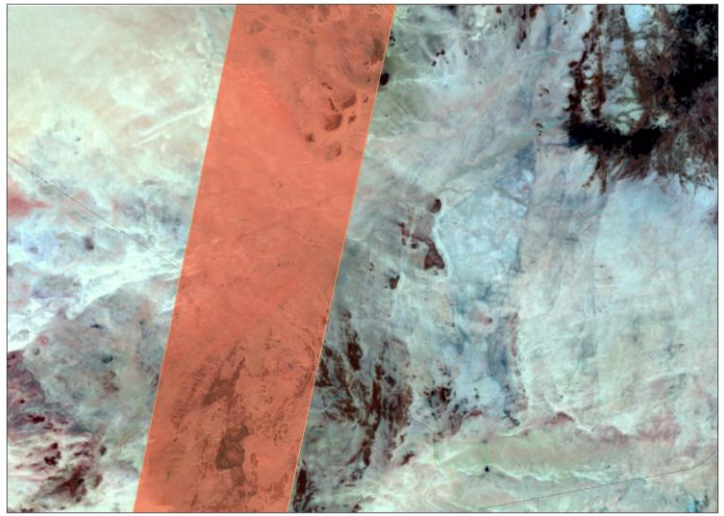
Vicarious calibration is only as good as its reference.

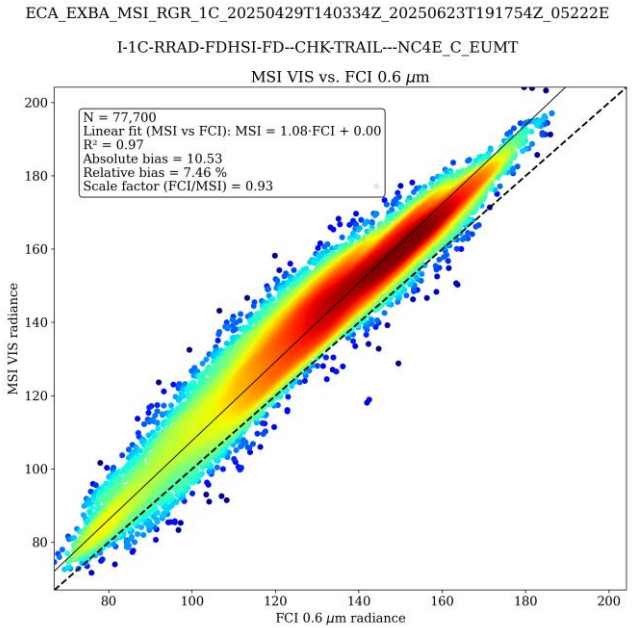
Does ad-hoc vicarious calibration solve everything?

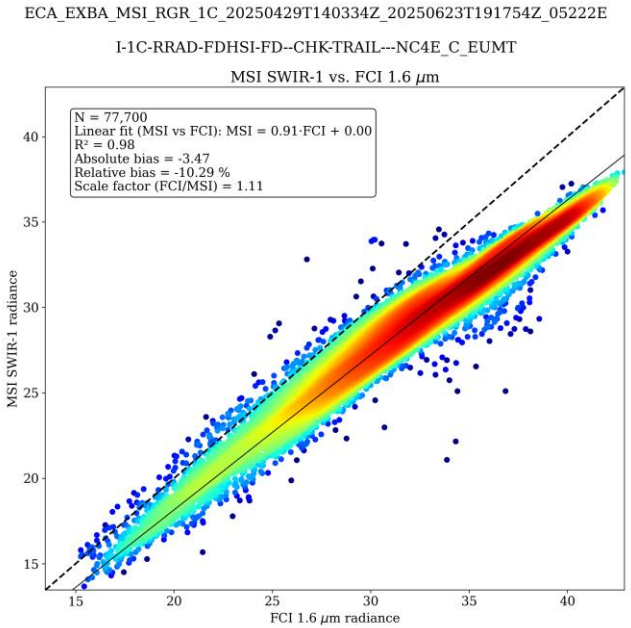
No, the instrument might degrade over time → Radiometric calibration must stay active throughout the whole mission

How about other areas than clouds?

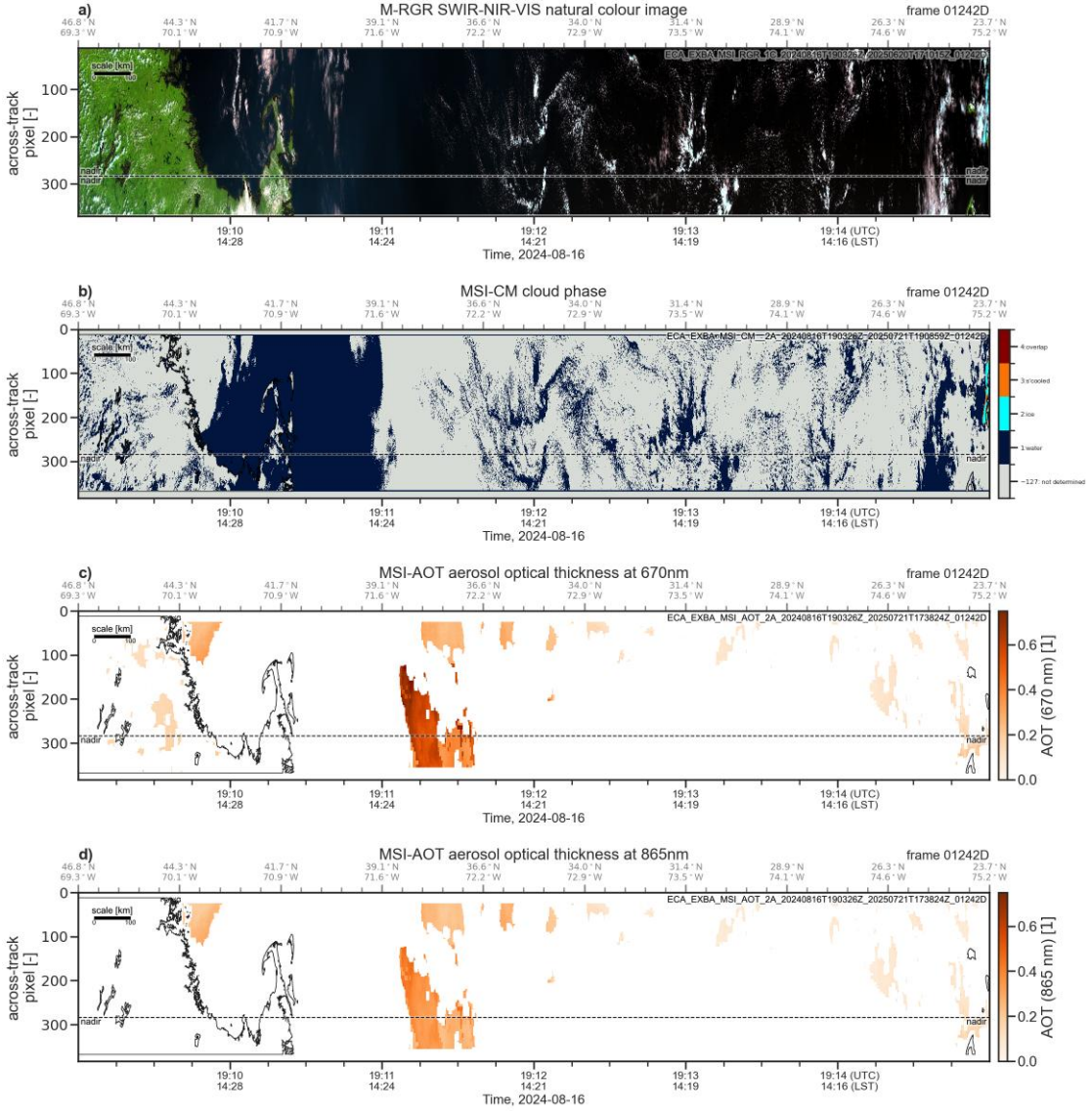
Desert



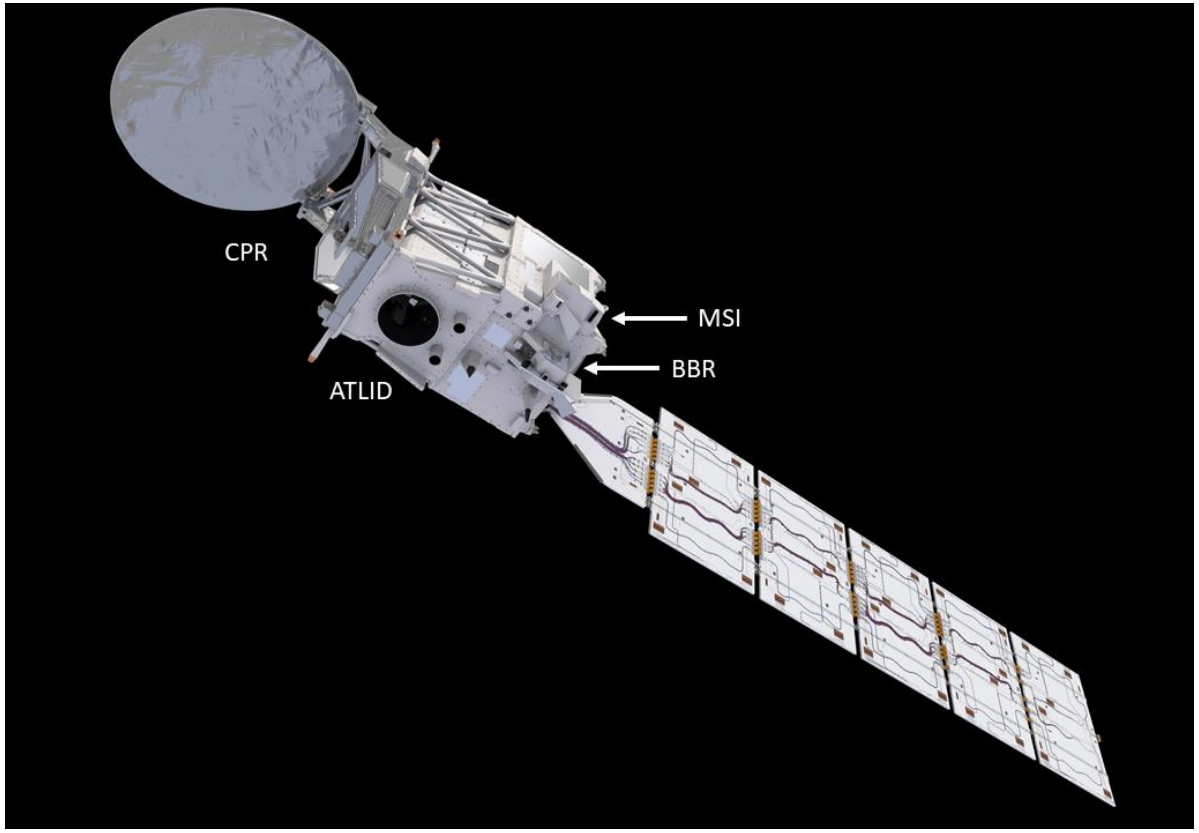




AVIRIS-NG imager onboard Gulfstream III during ARCSIX



MSI versus FCI



- 7 spectral channels (0.6-12.0 µm)
- 150 km swath with 500 m pixel size
- Every 28 days
- L1 data since July 2024

- 16 spectral channels (0.3-13.3 µm)
- Full disc with 0.5-2 km pixel size
- Every 10 min
- L1 data since October 2024