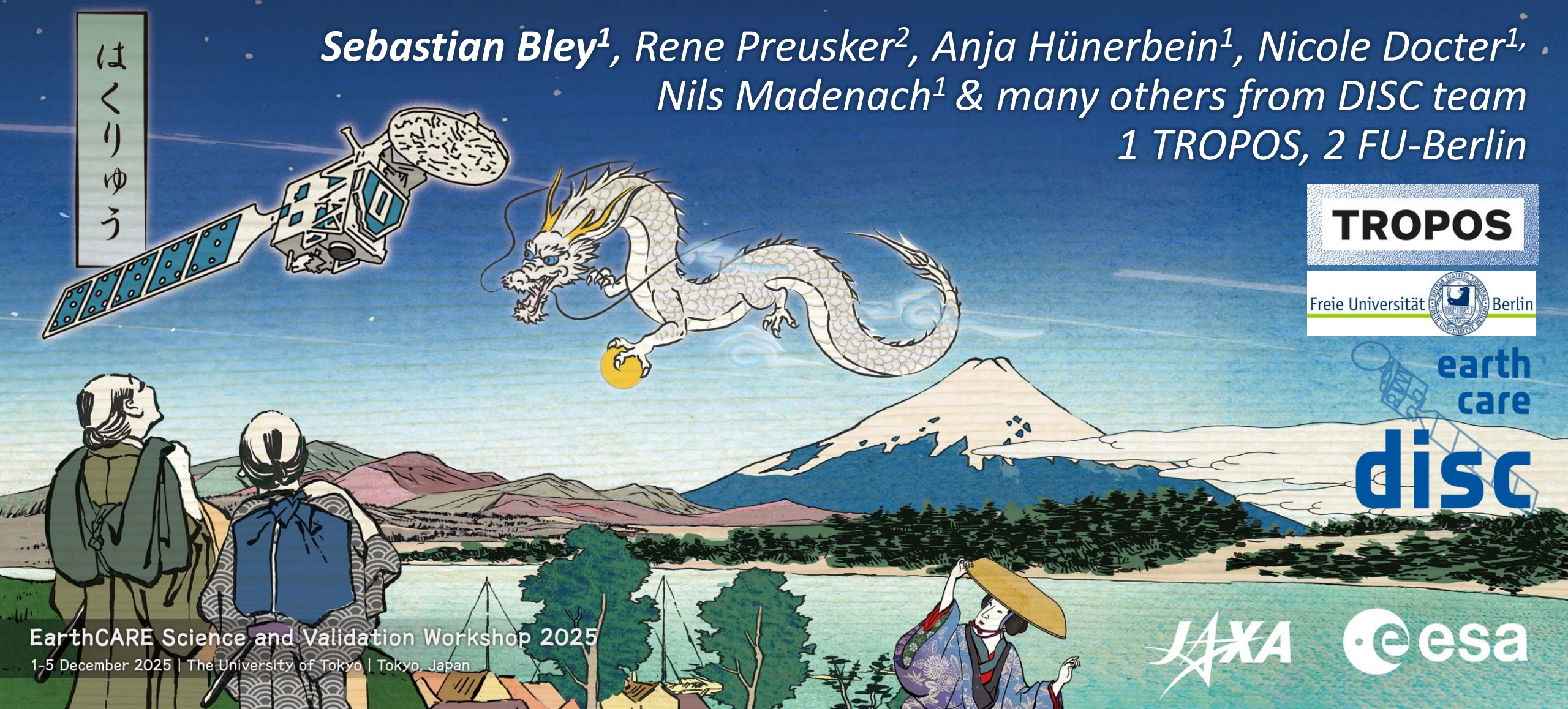
EarthCARE MSI Level-1 status and radiometric performance

Sebastian Bley[1], *Rene Preusker*[2], *Anja Hünerbein*[1], *Nicole Docter*[1],
Nils Madenach[1] *& many others from DISC team*
1 TROPOS, 2 FU-Berlin



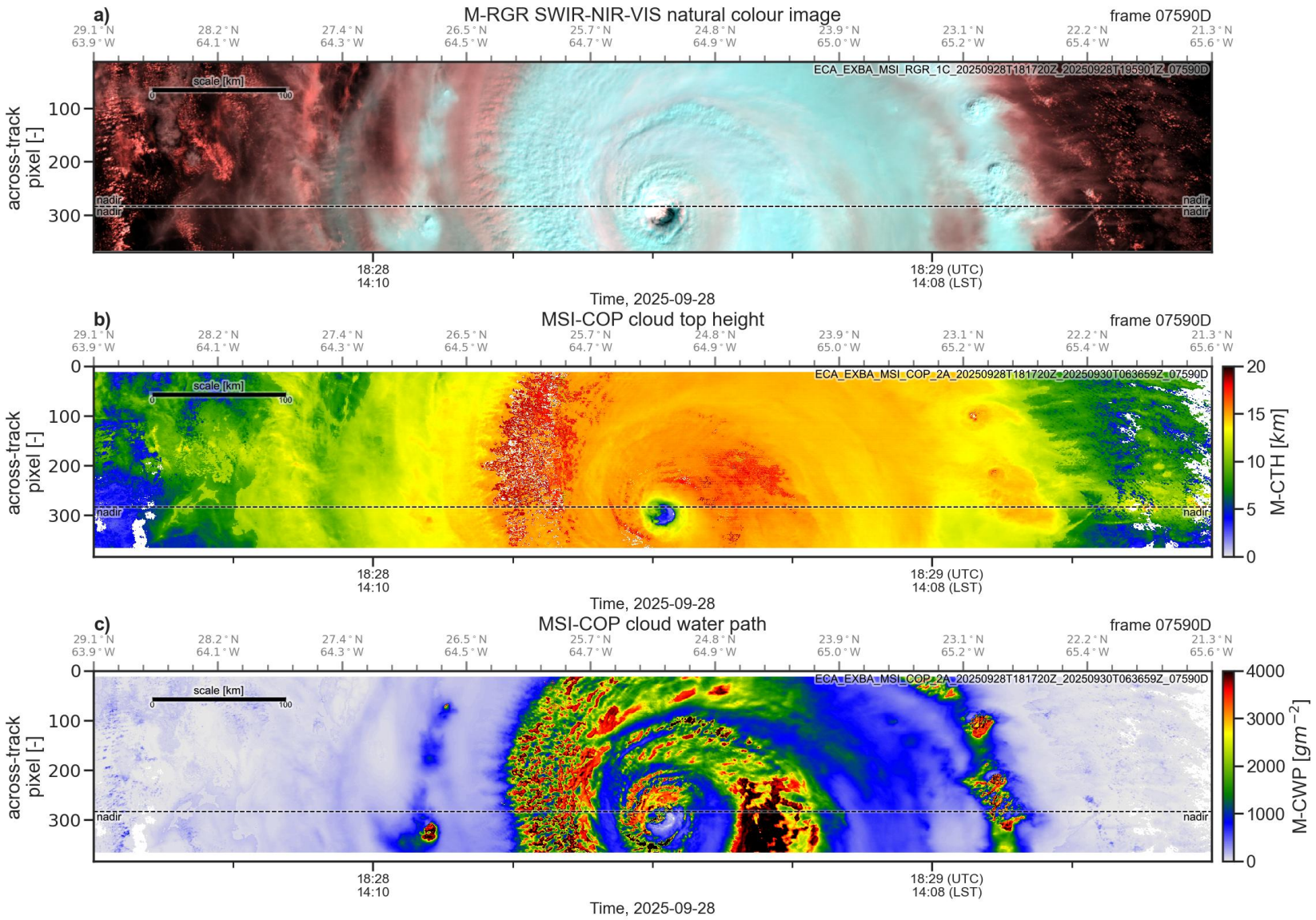
EarthCARE Science and Validation Workshop 2025
1-5 December 2025 | The University of Tokyo | Tokyo, Japan

Outline

- First year of MSI-in orbit data
- MSI L1 processor status
- Radiometric performance and issues
- Ad-hoc vicarious calibration
- Way forward

First year of in-orbit MSI data

Hurricane Humberto on 28 Sep 2025 (07590D)

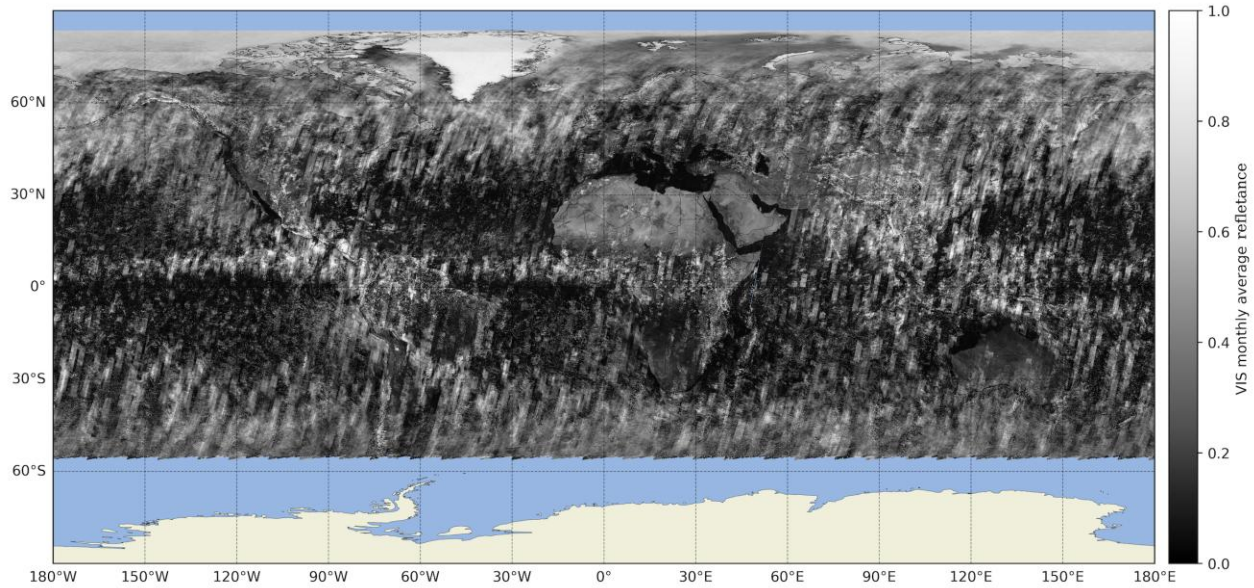


- During first year in-orbit, MSI already demonstrated it's capacities and provided valuable contexual information complementing the other instruments
- Also L2 cloud products show very encouraging results

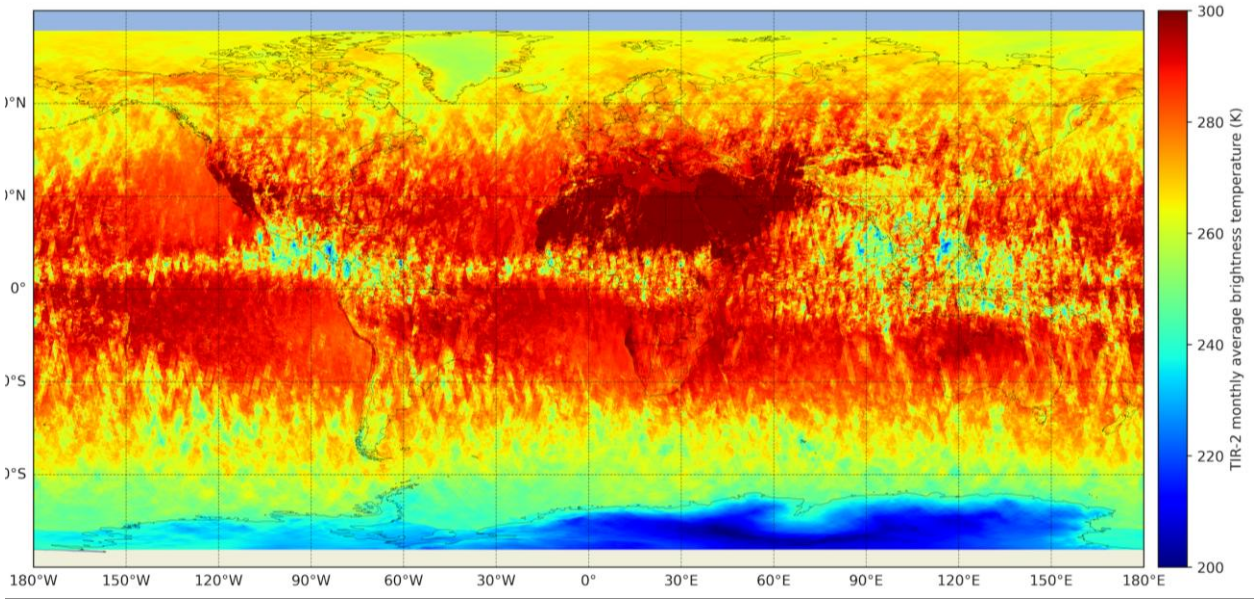
M-COP iterative retrieval: Courtesy of Anja Hünerbein

First year of in-orbit MSI data

June 2025 – VIS reflectance

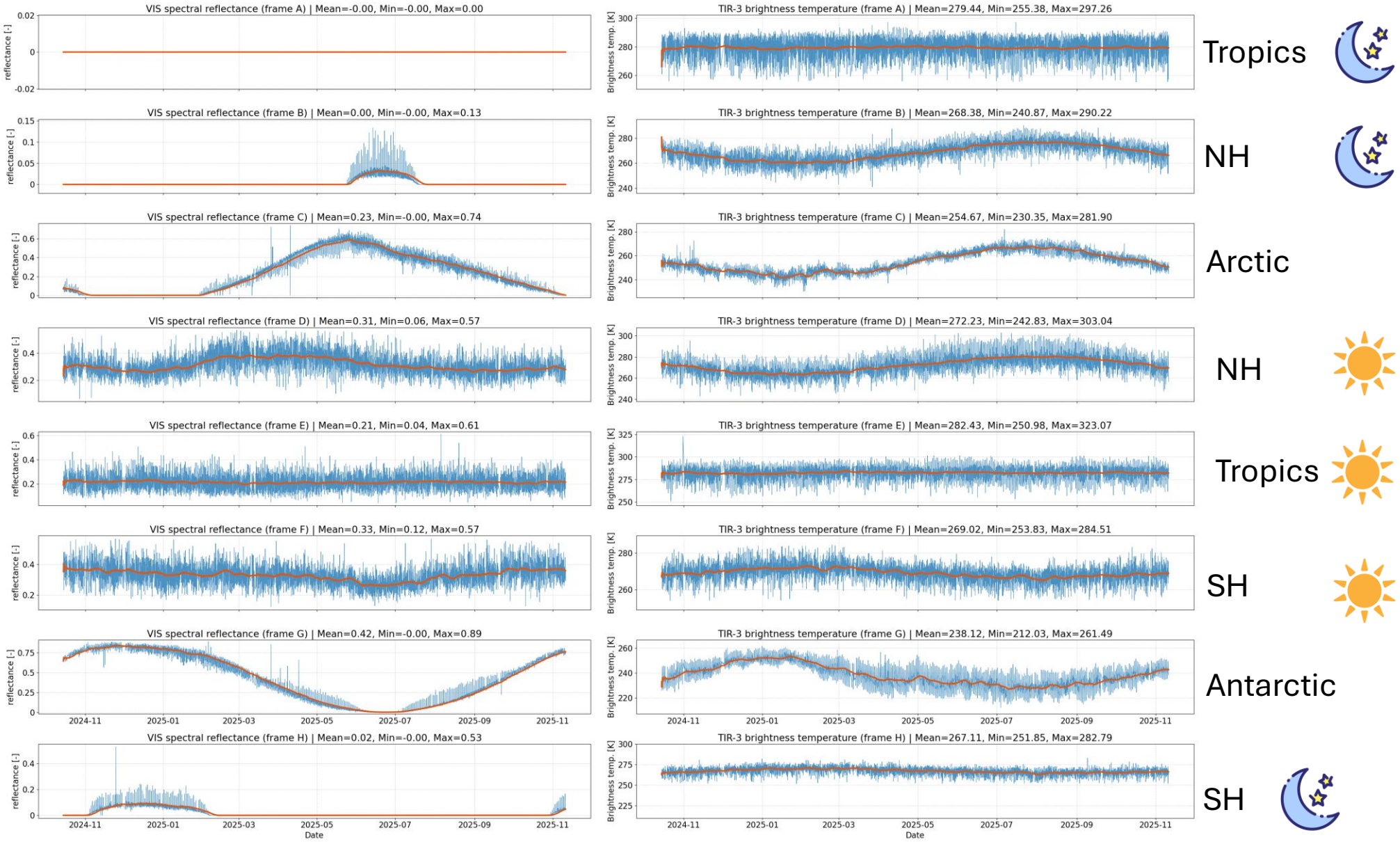


June 2025 – TIR-2 brightness temperature (K)



- "Monthly mean" (due to 28-day cycle only few datapoints in the Tropics) shows bright and warm Artic during NH summer and dark and cold Antarctic (reflectance cut at solar zenith angle < 80 deg)
- Inter-Tropical Convergence Zone (ITCZ) appears as band of bright and cold cloud tops → frequent occurance of deep convection.

First year of in-orbit MSI data



MSI L1 processor status

Processing Baselines			
Baseline	**Start Date (Frame)**	**Stop Date**	**Most important Updates**
BC	18 Nov 2025 (08374A)		-
BA	16 Jul 2024 (00756C)	18 Nov 2025 (08375H)	MSI VNS maintenance gain update and usage of theoretical TSIS-2 based solar (spectral) irradiances; CCDB v15
AF	28 Jan 2025 (03807C)	27 May 2025 (05651B)	Coregistration and diffuser BSDF update; CCDB v14
AF	27 Jan 2025 (03790C)	28 Jan 2025 (03807B)	Only coregistration update; CCDB v13
AE	13 Jan 2025 (03569B)	27 Jan 2025 (03790B)	CCDB v13

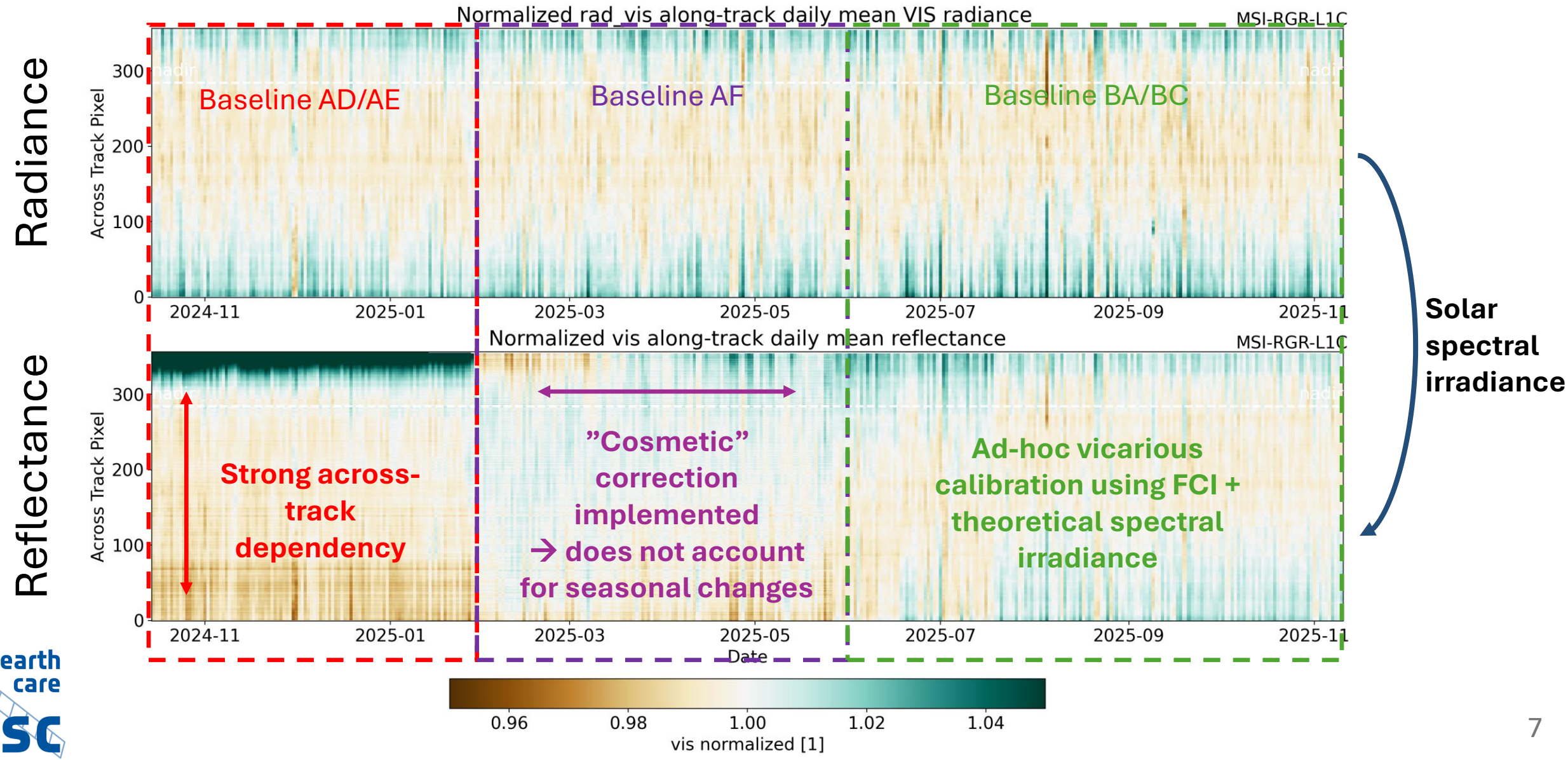
No L1 update in BC – still consistent to BA.

More than 1 year homogeneous dataset

Don't use this data anymore.

→ *For more details, visit **L1 disclaimer** available at EarthCARE Product Data Handbook (https://earthcarehandbook.earth.esa.int)*

Radiometric performance and issues



Radiometric performance and issues

During 2nd ESA - JAXA EarthCARE In-Orbit Validation Workshop in March 2025 in Frascati, decision was made to

- **Replace diffuser based spectral solar irradiance with TSIS-2** based theoretical solar irradiance
  → affects: **solar_spectral_irradiance**

- **Update** MSI **VNS maintenance gains** based on a **first ad-hoc vicarious calibration**
  → affects: **pixel_values** (spectral radiances of VNS bands only)

due to issues in radiometric calibration of VNS bands (based on satellite intercomparison with FCI and AHI, time series and solar diffuser investigations)

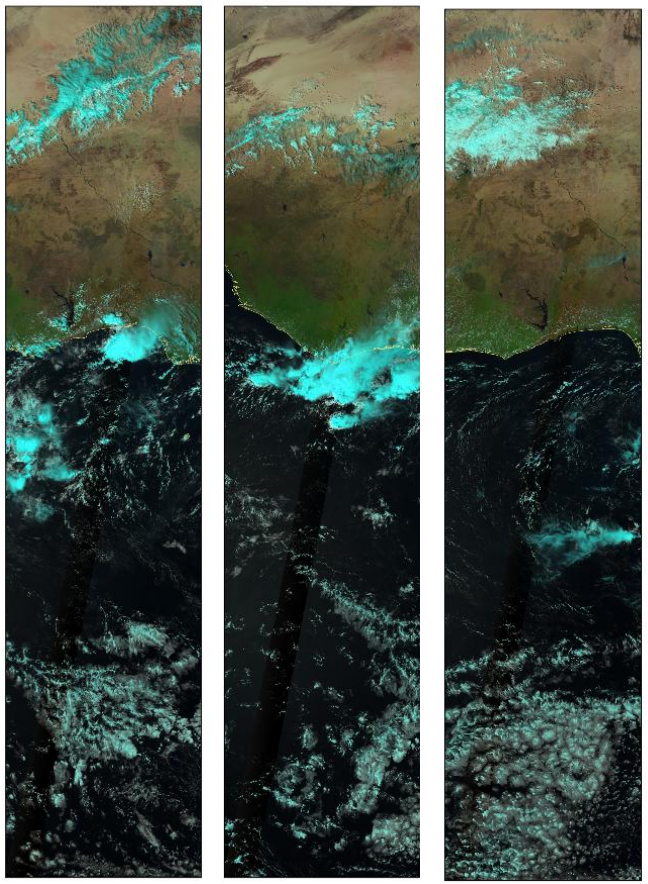
Implemented in BA

VNS ad-hoc vicarious calibration

- Ad-hoc vicarious calibration of radiance at nadir via comparison to MTG FCI adaptation of maintenance gain (single factor)
- Ad-hoc is ad-hoc is ad-hoc and not a clean solution
  - no consideration of the SMILE
  - no independent verification
  - no temporal / aging model
- **simple SBAF** (= spectral band adjustment factors) **only for clouds above ocean**, generated using the *MSI tool* (RTM tailored for MSI) and *FCI tool*

→ Sebastian's talk tomorrow 17:20 in L1 validation splinter: Ad-hoc vicarious calibration and verification using FCI

VNS ad-hoc vicarious calibration

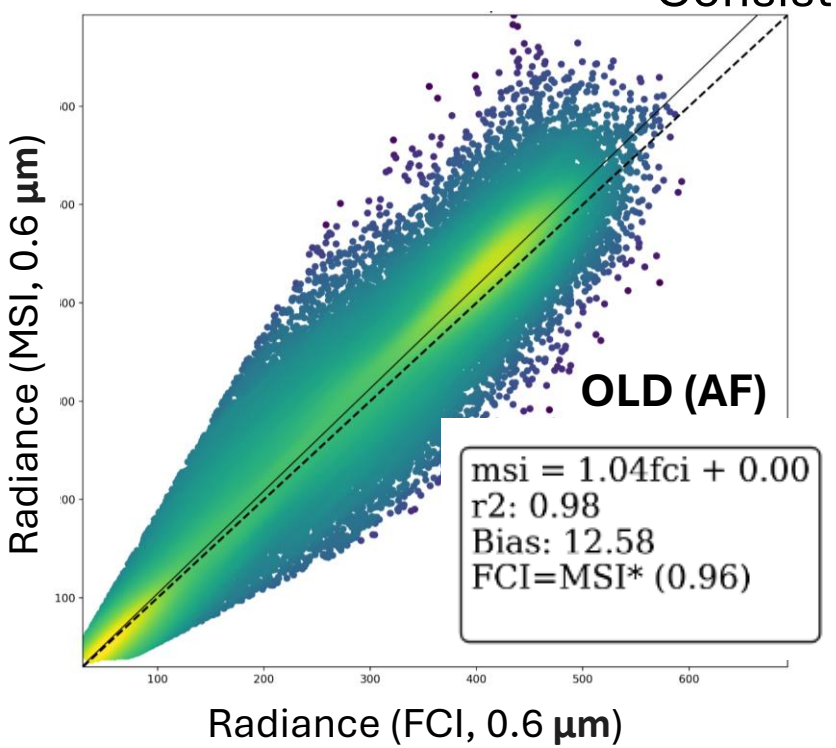


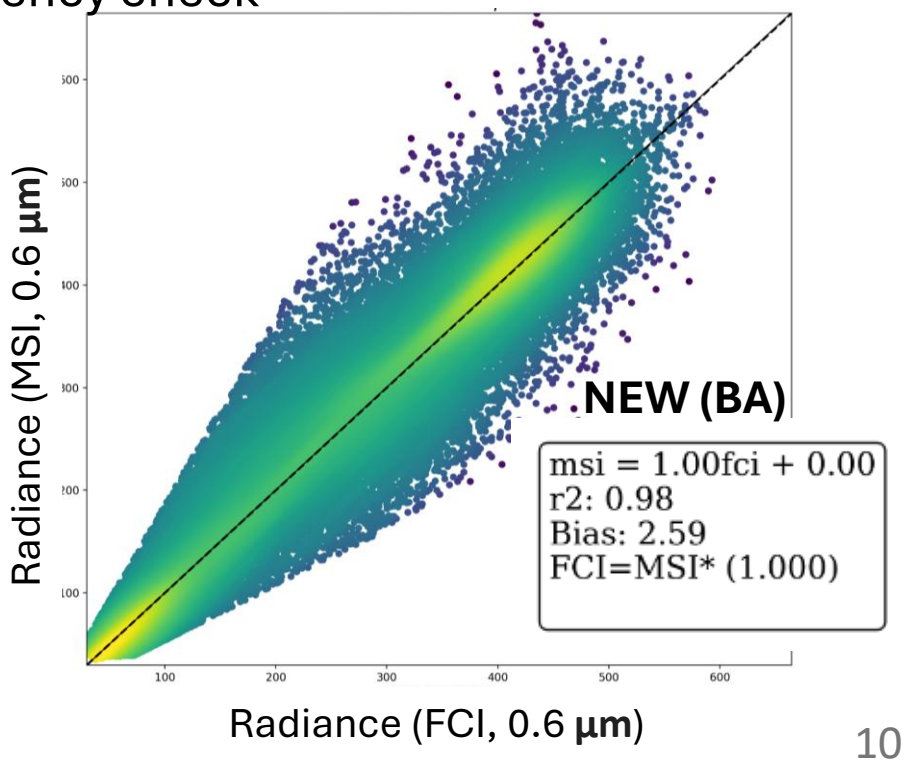
- VNS ad-hoc calibration factors are calculated for the VNS calibration maintenance gains based on: **03977E, 03993E and 04086E (baseline AF)**

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

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

Consistency check





MSI L1 verification and impact on L2 products

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

→ **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)

→ **Nicole's Poster 59 on Thursday 16:30-18:00**: Latest improvements and current status of the MSI-based aerosol product M-AOT

→ MSI Level-1 paper in preparation.

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

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[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

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Conclusions

- Swath dependency in radiometry observed in sun/diffuser view (radiometric calibration up to 20% off in reflectance)
- Solar irradiance varies up to 5% within few days

➢ Temporary solution implemented in BA: Use **synthetic solar spectrum** instead of diffuser measurements + **ad-hoc vicarious calibration using FCI**

➢ Goal of **2% absolute radiometric accuracy** can be reached through vicarious calibration

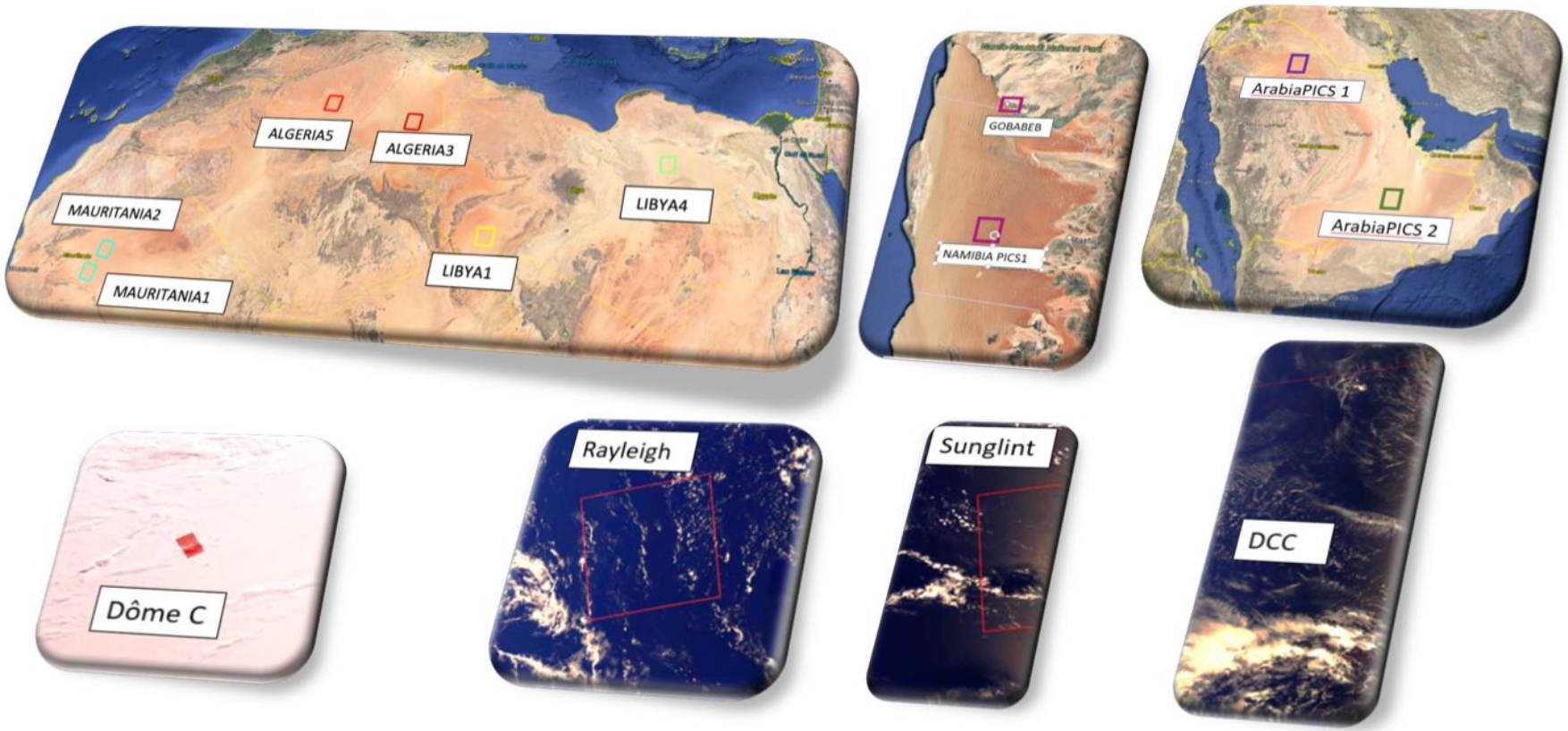
➢ Implemented in spring 2025 → **now available through BA for the full mission dataset** (No L1 change through baseline BC)

→ This ad-hoc vicarious calibration does not replace a comprehensive vicarious calibration!

→ We need additional independent validation of MSI L1 data!

Way forward

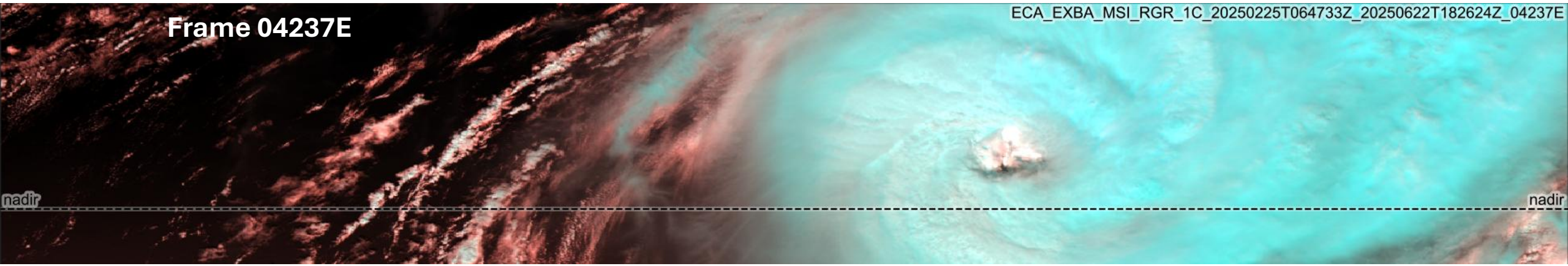
Vicarious Calibration Operational Service (VICALOPS) activity started through ESA

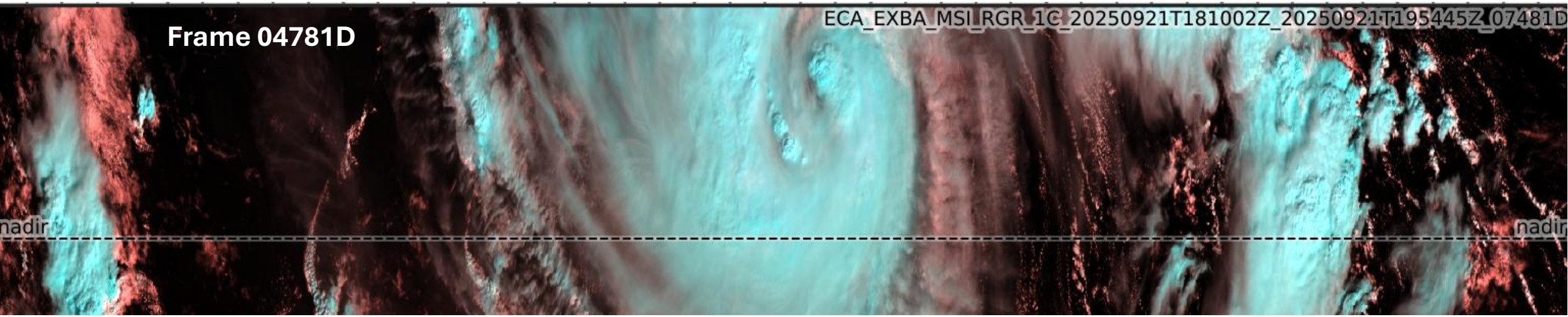


- VICALOPS is the new ESA service dedicated to radiometric calibration
- SMILE already implemented for MSI
- First results expected by end of this year

Courtesy of Béatrice Berthelot et al. 2024

Thank you!



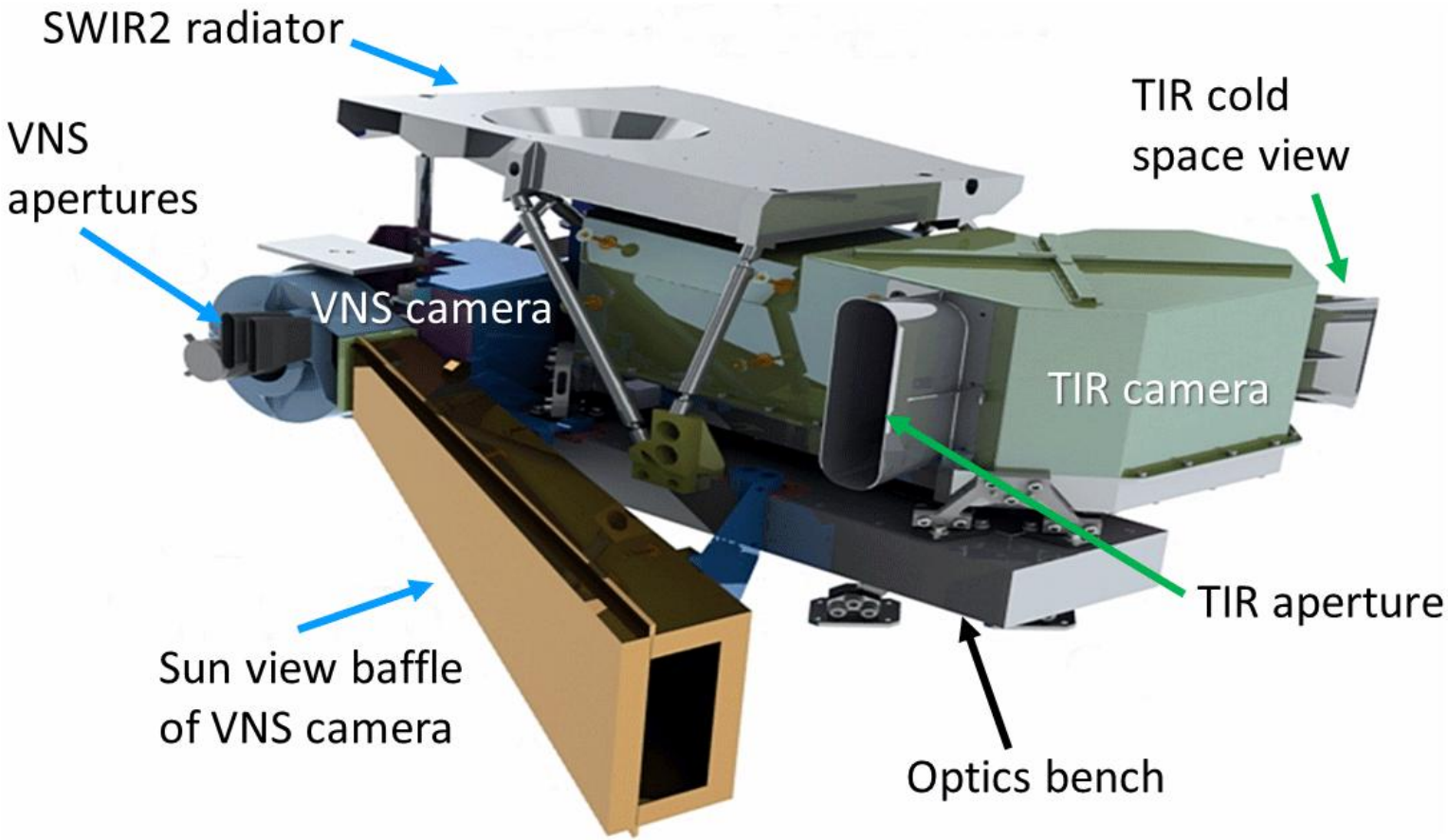


earth care disc

Backup

Radiometric performance and issues

- Swath dependency in radiometry observed in sun/diffuser view
- Not visible in radiances (Earth view only)
- Reflectances (ratio spectral radiance vs diffuser spectral irradiance) essential for L2 products
- Radiometric calibration up to 20% off in reflectance
- Solar irradiance varies up to 5% within few days



MSI optical bench, Tobias Wehr et al. 2023

Replacement of diffuser measurements

- Input file **MSI_SDX_1B** (replacing daily diffuser calibration file MSI_SD2_1B in BA processing of MSI L1) **contains a fixed theoretical solar irradiance** for MSI based on TSIS-2 **at a sun-Earth distance of 1 AU**
  - MSI response function convolved with TSIS-2 spectral solar irradiance using:

$$I_{\lambda,c} = \frac{\int I_\lambda \cdot r_{\lambda,c}\, d\lambda}{\int r_{\lambda,c}\, d\lambda}$$

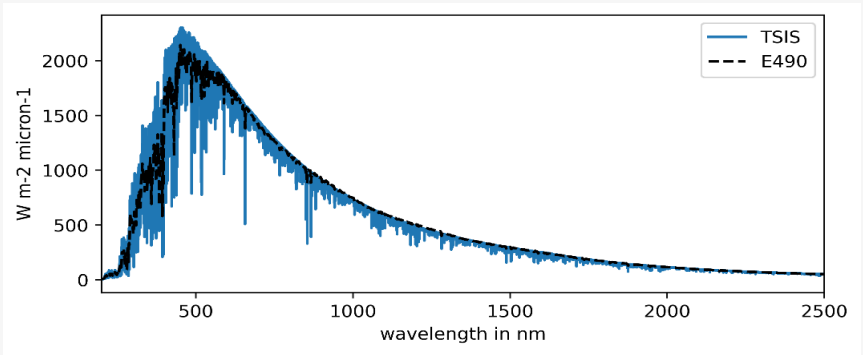
$I_{\lambda,c}$ spectral solar irradiance for an MSI across-track pixel and band

I_λ high-spectral solar irradiance database **TSIS-2**

$r_{\lambda,c}$ normalized MSI response function for each MSI across track pixel and band

Solar Irradiance Reference Spectrum at the Total and Spectral Solar Irradiance Sensor (TSIS) Spectral Irradiance Monitor (SIM) and Compact SIM (CSIM) absolute irradiance scale
https://lasp.colorado.edu/lisird/data/tsis1_hsrs_files

Version 2 - 2022-11-30 - Laboratory for Atmospheric and Space Physics

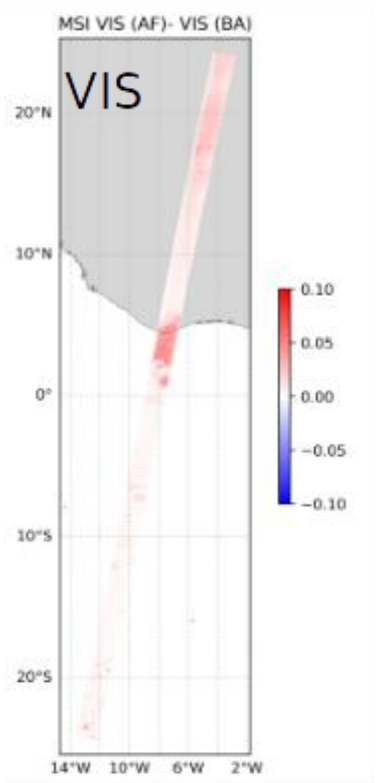


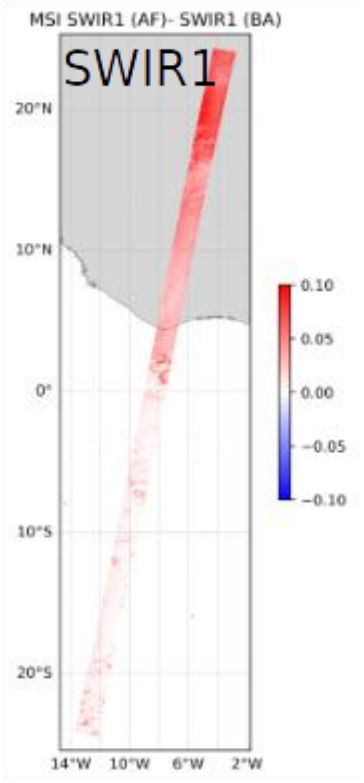
- MSI_SDX_1B solar irradiance is then used within frame based L1 processing to calculate **spectral solar irradiance taking the actual sun-Earth-distance** of the corresponding day-of-year **into account**

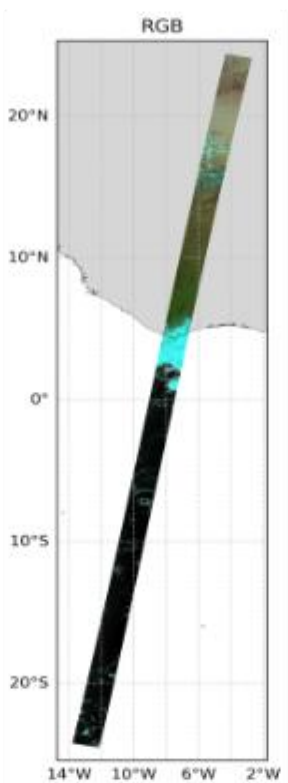
Impact on L2 cloud products

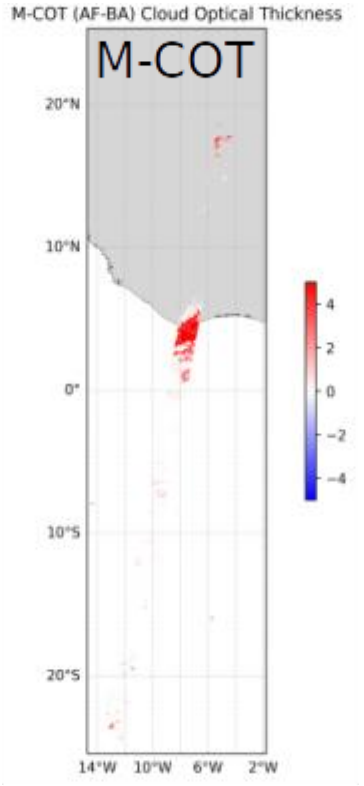
- L1 M-RGR impacting M-CLD change from **AF-BA: Decrease in COT, increase in Reff**

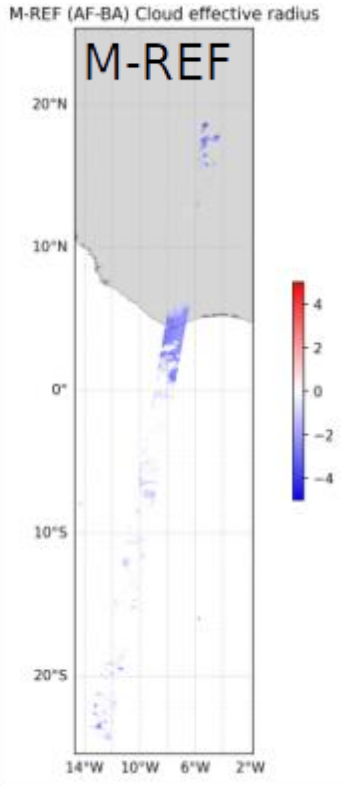
Frame 03993E

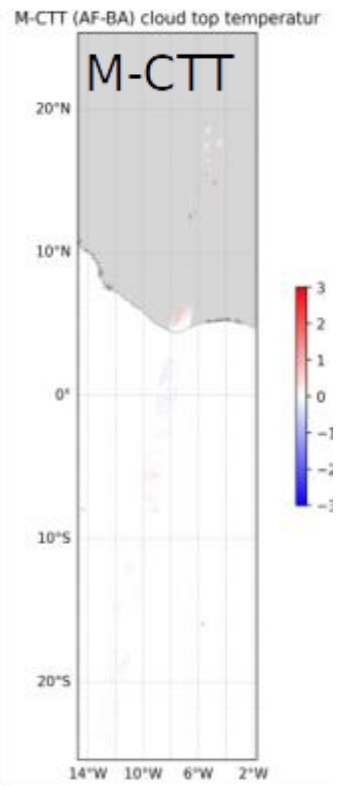












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  - no consideration of the SMILE
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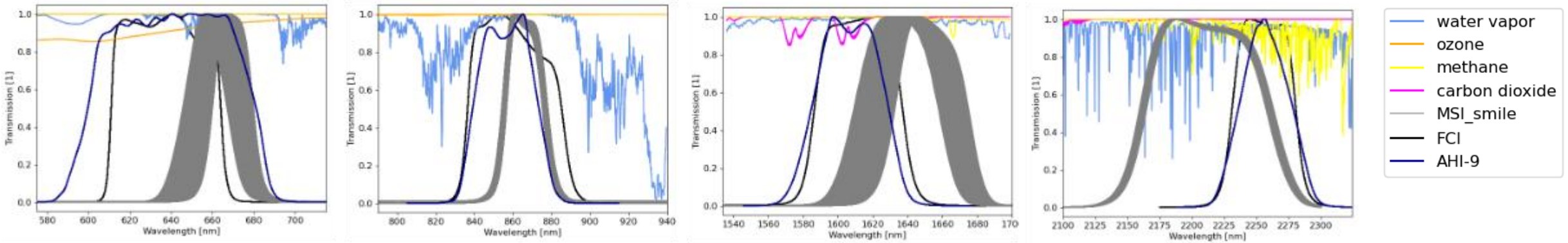
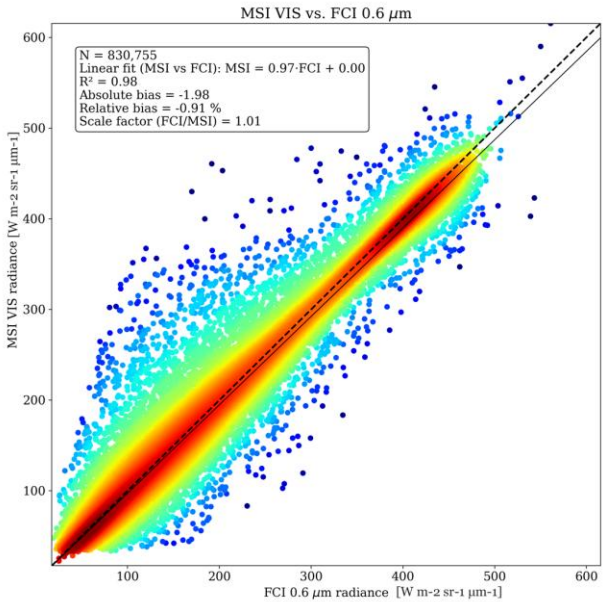
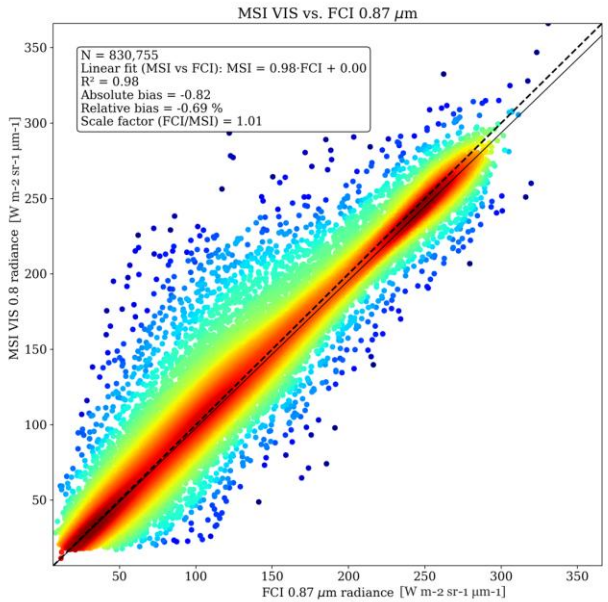
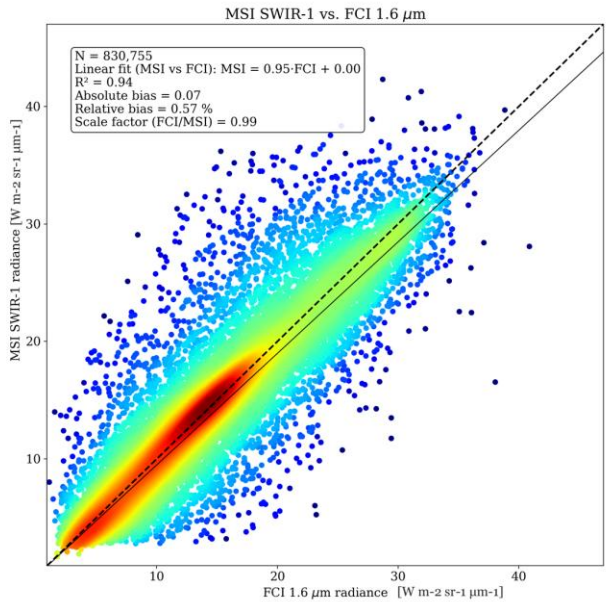


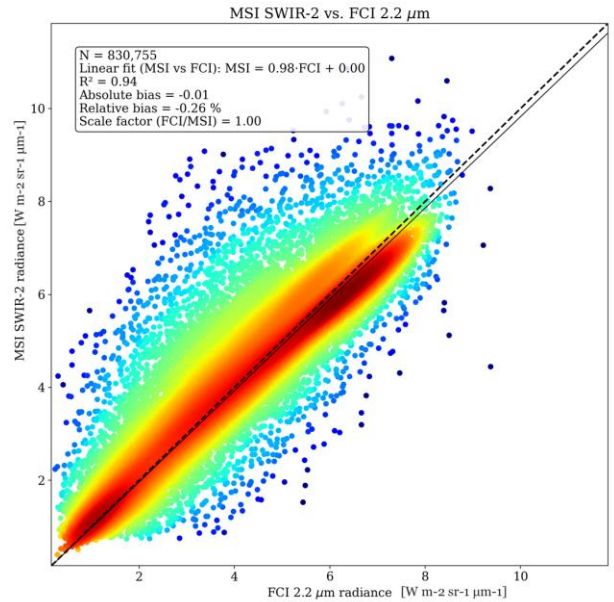
→ **Nils' Poster 42 Friday 10-11:30**: Statistical Validation of EarthCARE MSI L1 Data Using MSI Forward Simulator at ACTRIS Stations

MSI L1 BA product verficiation

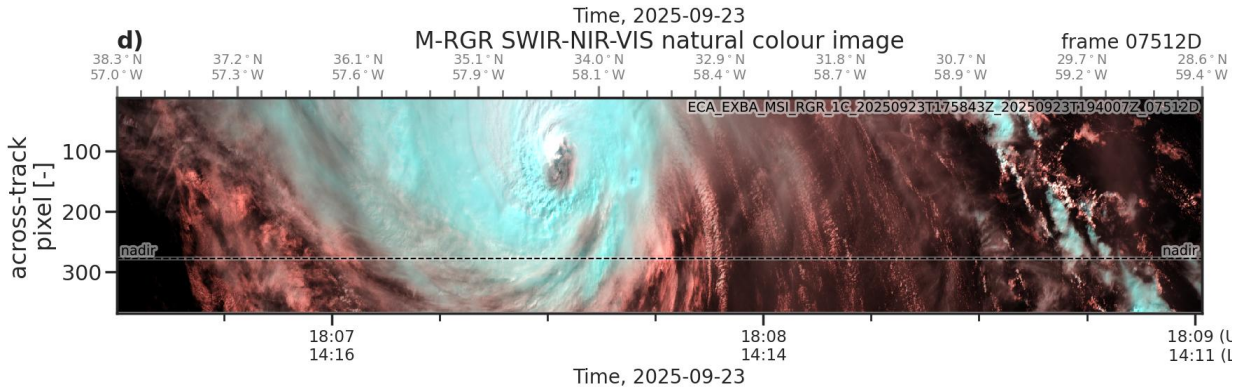








Backup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Time, 2025-09-23
M-RGR SWIR-NIR-VIS natural colour image
frame 07512D
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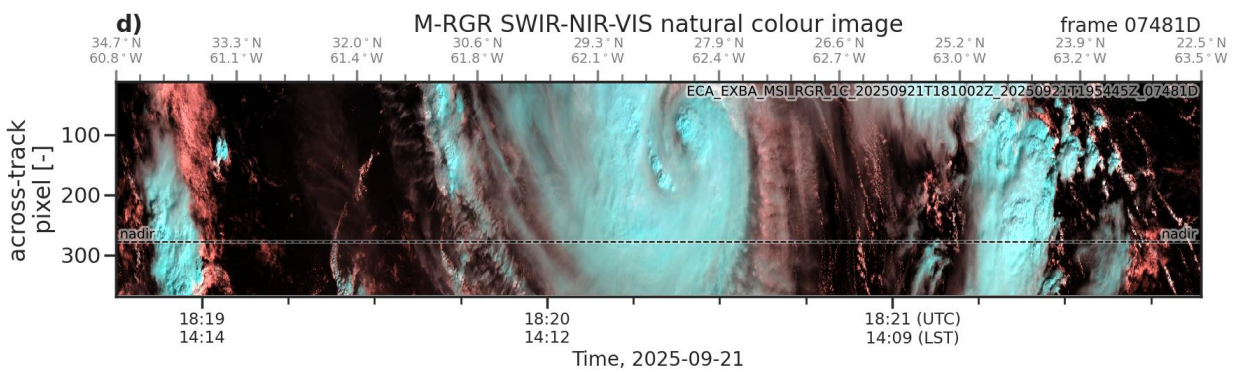
across-track pixel [-]
nadir
Time, 2025-09-23


d)
M-RGR SWIR-NIR-VIS natural colour image
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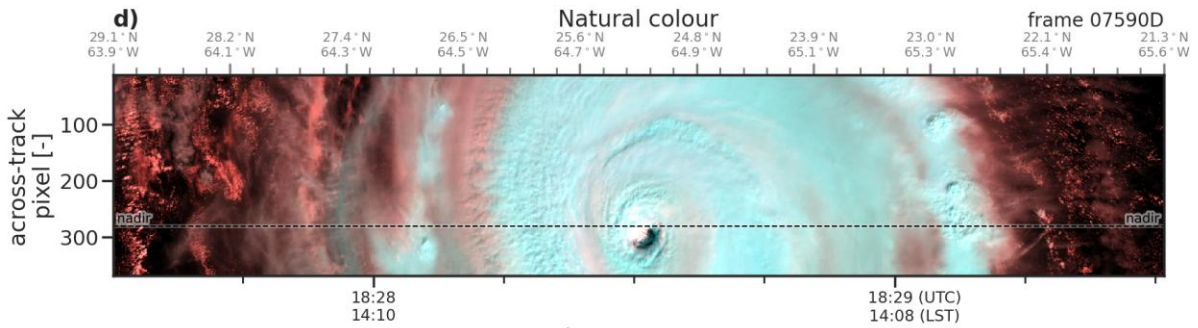
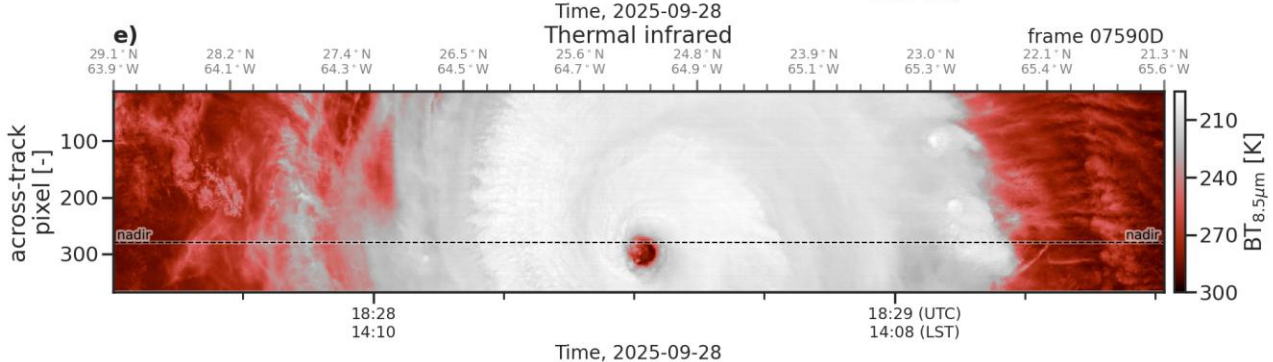
nadir
Time, 2025-09-21


d)
Natural colour
frame 07590D
across-track pixel [-]
nadir
Time, 2025-09-28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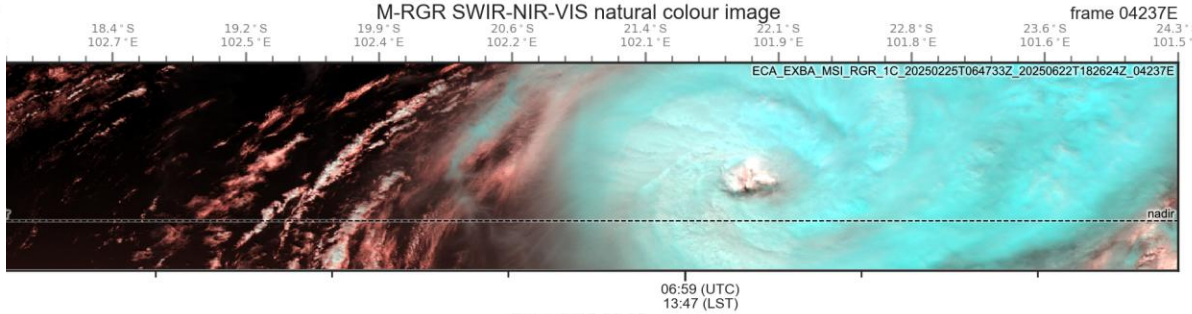
nadir
BT8.5μm [K]
Time, 2025-09-28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M-RGR SWIR-NIR-VIS natural colour image
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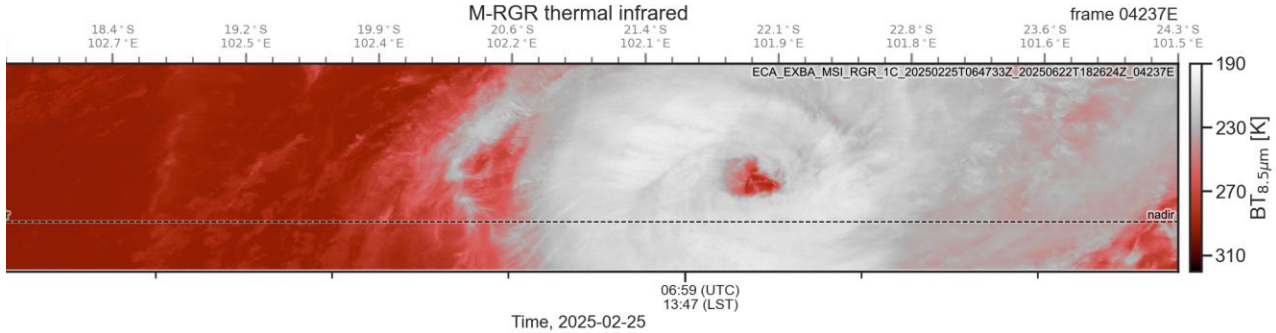
nadir
Time, 2025-02-25


M-RGR thermal infrared
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nadir
BT8.5μm [K]
Time, 2025-02-25