



Koninklijk Meteorologisch Instituut België

Institut Royal Météorologique
Belgique

Königliches Meteorologisches
Institut Belgien

Royal Meteorological
Institute of Belgium

BRAVO

Progress Meeting (7) - WP3

Christine Aebi, Almudena Velazquez Blazquez,
Edward Baudrez and Nicolas Clerbaux

12 December 2025

Work Package number:	WP3
Work Package Title:	Accuracy assessment of unfiltered radiances L2 BM-RAD product.
Responsible entity:	RMIB
WP responsible person	Aebi
Project phases (0,A,B,C,D,E):	E
Beginning and end dates of WP	01.12.2024 – 31.12.2025
Total FTE allocated to the WP	13 PM (1.08 FTE)
Objectives of the WP: Quantitative evaluation of the L2 BM-RAD radiance product, so establishing input data quality for the BBR flux estimation.	
<p>Inputs:</p> <ul style="list-style-type: none"> • Tools from WP1. • L2 BM-RAD data (commissioning and beyond) • CERES (SSF) and GERB (HR) data <p>Description of work and schedule:</p> <ul style="list-style-type: none"> • Basic, qualitative, evaluation of the BM-RAD product, including visualization (context from MSI images). • Comparison unfiltered radiances with the Earth targets defined in WP1. • Comparison with coangular co-incident observations from GERB and CERES to assess absolute level (calibration), and scene type consistency (spectral response/unfiltering). • Long term stability monitoring of the instrument response will be established using stable Earth targets. <p>Excluded tasks:</p> <p>Deliverables and dates:</p> <ul style="list-style-type: none"> • Matched databases of coangular radiances for reference and further analysis (30.06.2025). • BBR L2a quantitative assessment report (31.12.2025). • Recommendation for BM-RAD processor evolution. <p>Risks: Availability of co-angular collocated observations from CERES RAPS campaigns</p>	

- Presentations at the 3rd EarthCARE Validation Workshop in December 2025.
- Automated data download at RMIB.
- Monitoring of various parameters in L1 and L2 (including new baseline-releases).
 - Focus on BM-RAD, but also BMA-FLX.
 - Analysis of changes per month.
 - Stability checks and checks for ageing.
- Analysis of the Narrowband-to-Broadband (NB2BB).
- Continuation of the analysis with GERB and CERES data.
- Image of the month.
- Outlook

Comparison of the BBR products with the Cloud and Earth's Radiant Energy System (CERES) products
 Nicolas Clerbaux, Almudena Velazquez Blazquez, Edward Baudrez, and Christine Aebi
 Royal Meteorological Institute of Belgium (RMI)

Introduction : the EarthCARE Broadband Radiometer

The Broadband Radiometer (BBR) instrument:

- 3 views (fore, side, aft) for improved observation of the instantaneous TOA fluxes.
- For each view array of 36 microbolometer detectors providing broadband total wave (0.25-10µm) and shortwave (0.25-4µm).
- Very fine grid of resolution: 500 of 800x/1300x across track and 3000x along track.
- Flexibility to integrate the measurements in any domain, e.g. 30 kmx10km, in the nadir swath (18km).
- BBR primary use is for the radiative "diagnosis", i.e. to check that the radiation product ACM RT is consistent with the BBR observations in the domain.
- The BBR products are publicly available and can be used for other applications like product validation, quantification of climate forcing and feedbacks, especially at small scale (e.g. radiative effect of aviation contrails).

The BBR products include:

- B-SDR** : Derivative SW and LW radiances (i.e. images with 20 columns).
- B-PCR** : SW and LW radiances in 4 Fourier domains (e.g. 18x12km).
- BM-RAD** : Un-filtered SW and LW radiances in different domains.
- BMA-FLX** : SW and LW fluxes for the 3 views + broadband fluxes in different domains.

The BBR in the EarthCARE ground segment (European part):

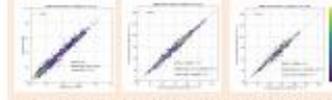


Level-1 radiance comparison with CERES FLASHplus Edition1

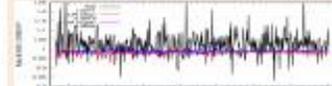
Localisation of the nadir swaths. Nadir Derivative (SDR) similar to the SDR with SW.

SW slope: -0.020
 LW slope: -0.989 (right)
 LW slope: -0.989 (left)

Radiances comparison - only possible for the nadir telescope



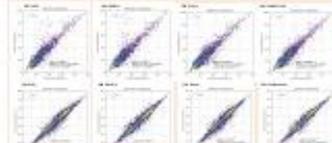
Time series of daily ratio -> No evidence of temporal degradation or bias



Level-2 flux comparison with CERES SSF Edition1

Ratio of BBR / CERES

View	SW	LW
Fore	1.020	0.979
Side	1.022	0.979
Aft	1.017	0.979
Combined	1.020	0.979

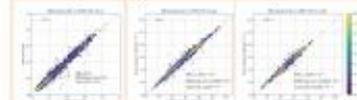


Level-2 radiance comparison with CERES SSF Edition1

Nadir Swaths. Nadir Derivative (SDR) method

- SDR with Terra (Sw: 0.25-4µm, LW: 4-10µm) only at high latitude.
- Frequent SDR with NOAA-20 (Sw: 0.25-4µm, LW: 4-10µm) and Aqua (Sw: 0.25-4µm, LW: 4-10µm).

Radiances comparison (only possible for the nadir telescope)



SW slope: -0.020
 LW slope: -0.989 (right)
 LW slope: -0.989 (left)

-> SW radiances are slightly brighter than CERES (+0.02)

-> LW radiances are slightly lower than CERES (-1.0%)

Summary

- The EarthCARE BBR products are routinely compared with CERES and SDR (not shown on this poster).
- The radiances of the BBR nadir view agree quite well with the CERES products. The SW is about 2.0% higher and the LW about 1.0% lower.
- The flux ratio w/ CERES follow roughly the radiance ratio.
- In the LW flux ratio for the 3 telescopes are very close one to the others but about 1% lower than the radiance ratio.
- In the SW there is a +/- 1% difference between the views that can be due to calibration (i.e. the "B" factor) or, more likely, to the Angular Dependency models collection application.
- Overall the level-1 products (B-SDR, B-PCR) are expected to be useful for the Earth Radiation Budget scientific community.
- The level-2 products (BM-RAD, BMA-FLX) are released to the community and are considered of good quality but improvements of the products are expected in future baseline.

EarthCARE Science and Validation Workshop 2023
 13 December 2023 - The University of Tokyo, Tokyo, Japan



- Poster presentation (with reference to BRAVO):
 - Clerbaux, N. et al.: *Comparison of the BBR products with the Cloud and Earth's Radiant Energy System (CERES) products.*
- Oral presentation:
 - Velazquez, A. et al: *BM-RAD and BMA-FLX updates and validation.*

- Development of a download and archive gap filling tool.
- Based on Spatio Temporal Asset Catalogue (STAC) API - listings are fetched from ESA EO-CAT.
- Authentication to OADS based on Leonard König `oads_download.py`
- Minimal changes necessary to use MAAP downloads instead of OADS.
- Licensed under Apache 2.0 (as `oads_download.py`).
- Single Python file (275 lines), retry mechanism based on `urllib`, support for zipped and unzipped downloads.

→ Work done by Pierre de Buyl (pierre.debuyl@meteo.be)

Monitoring and Evaluation of the BM-RAD product (L2)

- Containing unfiltered solar and thermal radiances (in contrast to the L1 products)
- Containing information about clouds (cover and phase), snow albedo, surface type, etc.
- Available in four different resolutions (small, standard, full, assessment)
- Data availability:
 - Baseline AA: 27/07/2024 – 18/12/2024
 - Baseline AB: 18/12/2024 – 27/05/2025
 - Baseline AC: 27/05/2025 – 08/07/2025
 - **Baseline BA: 27/07/2024 – 18/11/2025**
 - Baseline BC: 18/11/2025 – today

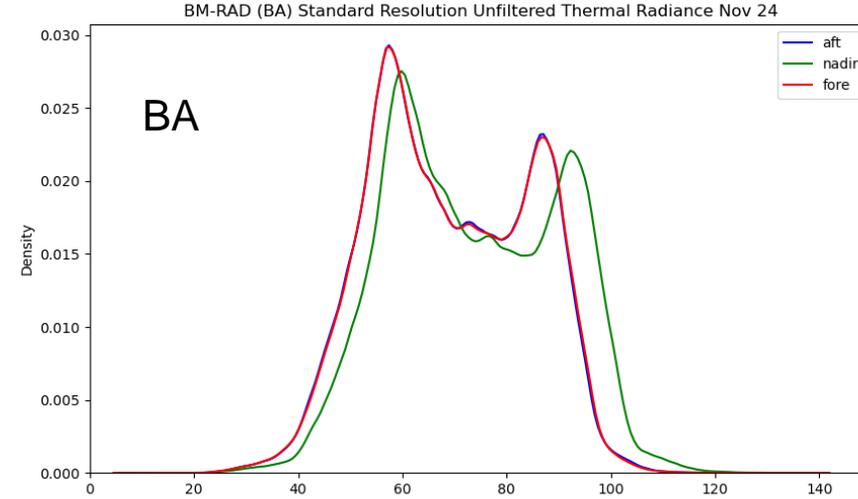
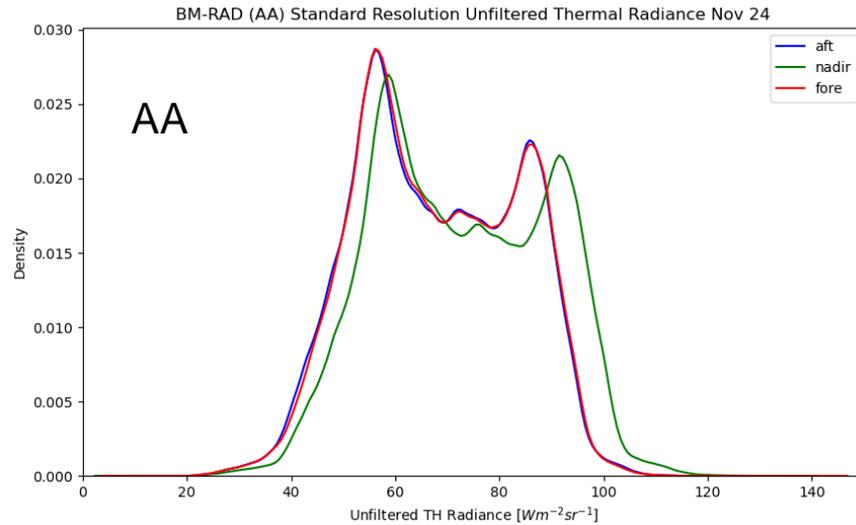
...But: since 20/11/2025 BBR is partly switched off in order to prolong the lifetime of the instrument (planned: five days on and 15 days off).



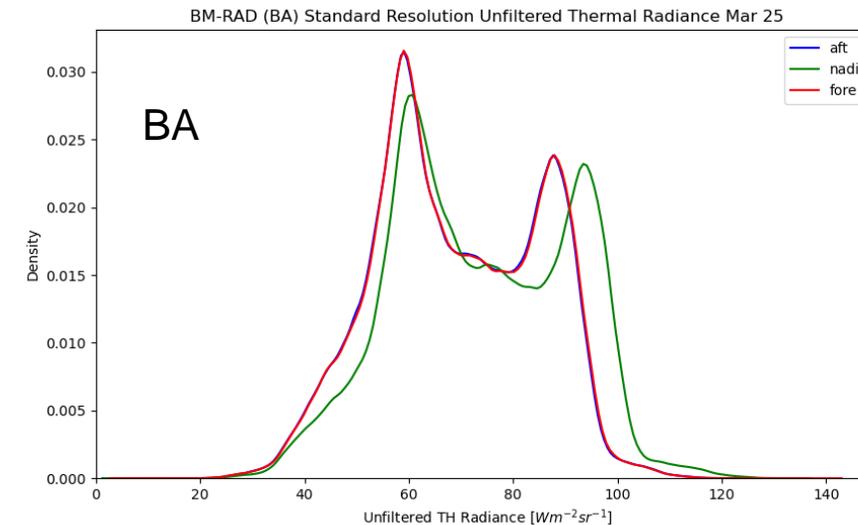
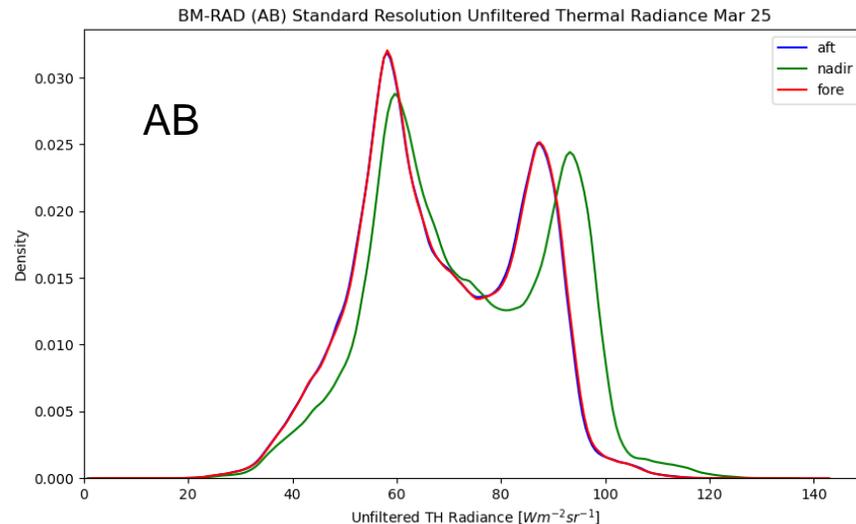
BM-RAD product: TH Unfiltered Radiance, All-day

Standard Resolution

Nov 2024



Mar 2025



Baseline AA:

- Dead pixel included.
- Gaps in the aft-view.

Baseline AB:

- Dead pixel and gaps corrected.

Baseline BA:

- Changes in the SW gain ratio (→ lower SW values, and slightly higher LW values).

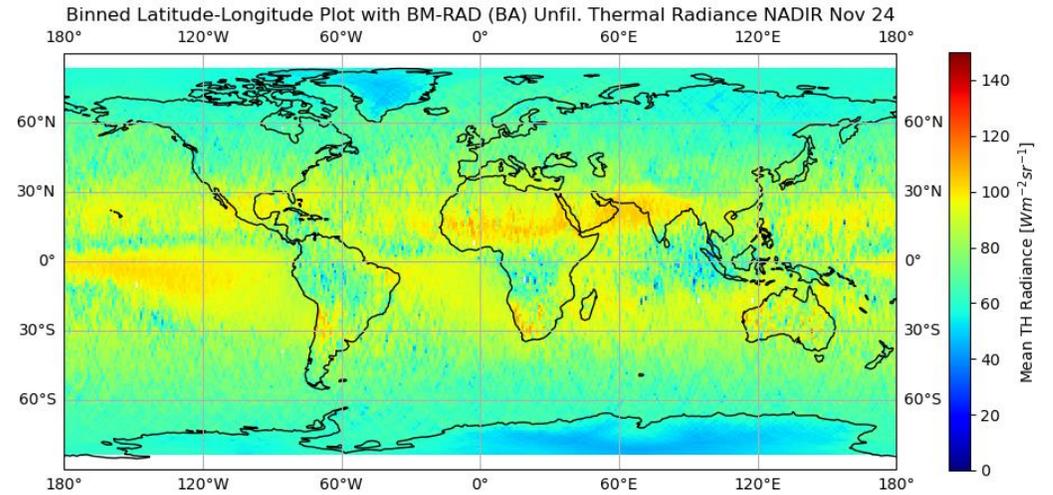
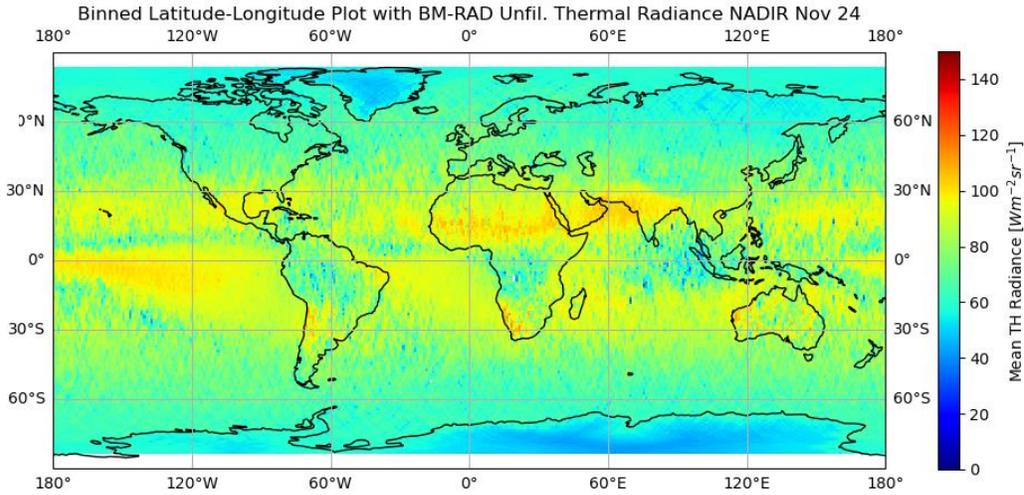


BM-RAD product: TH Unfiltered Radiance, Nadir View, All-day

Standard Resolution

Nov 2024

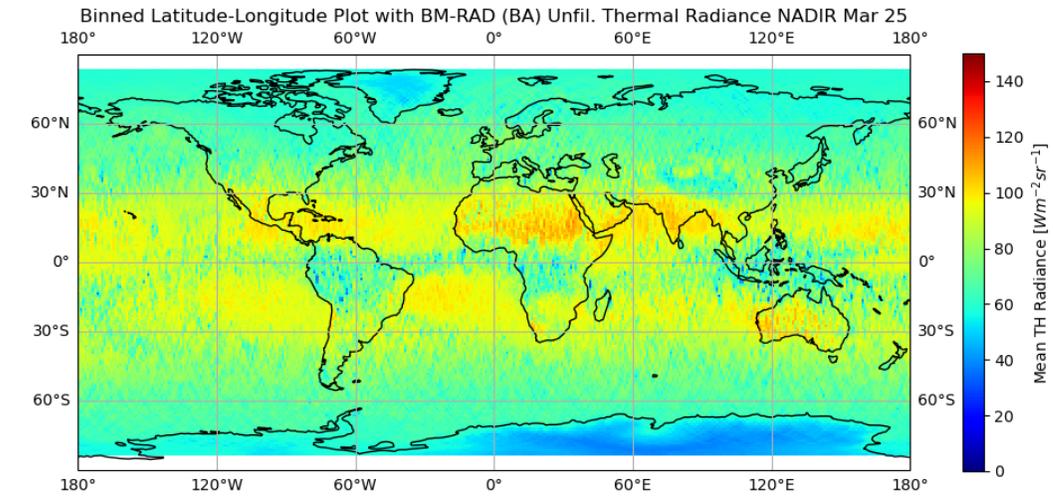
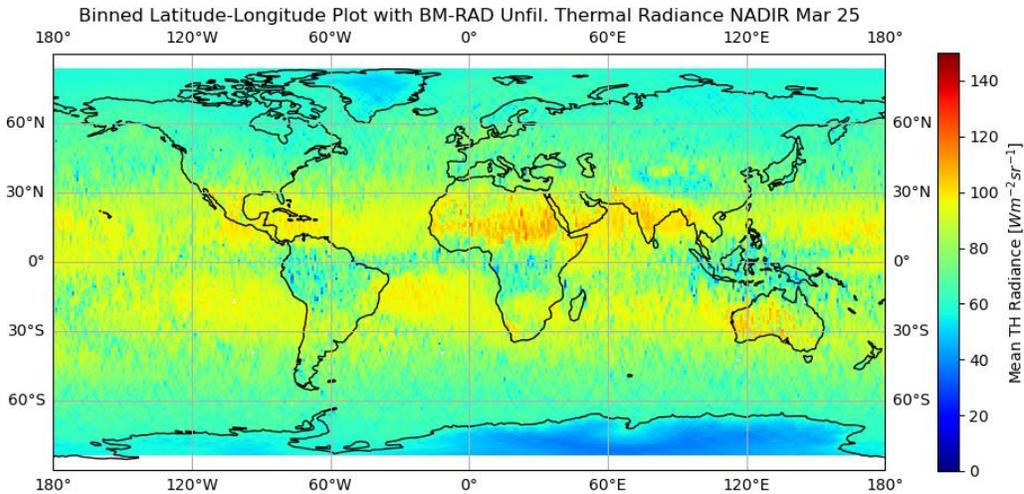
AA



BA

Mar 2025

AB

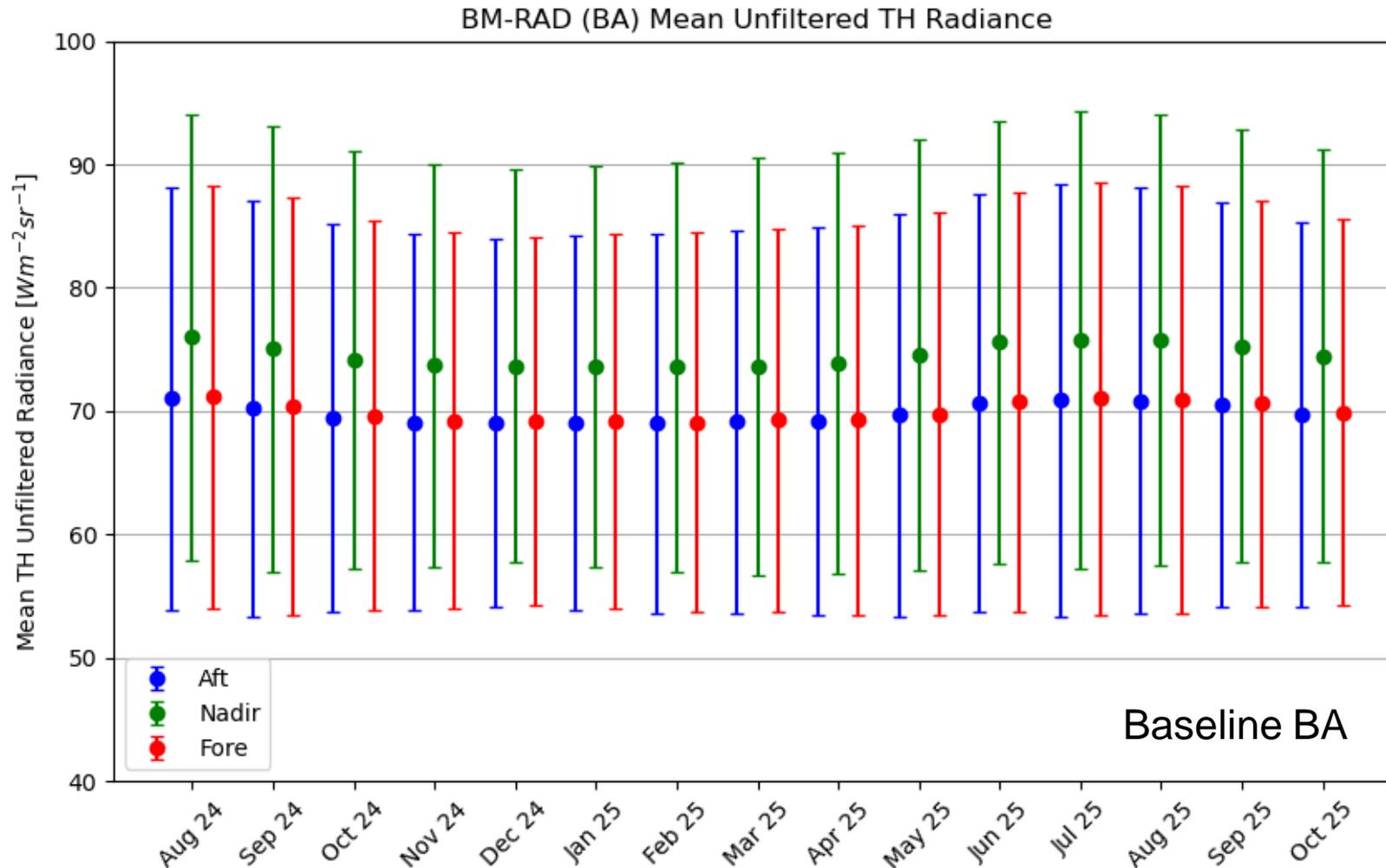


BA



Mean Values of BM-RAD Unfiltered TH Radiances per Month

All-day

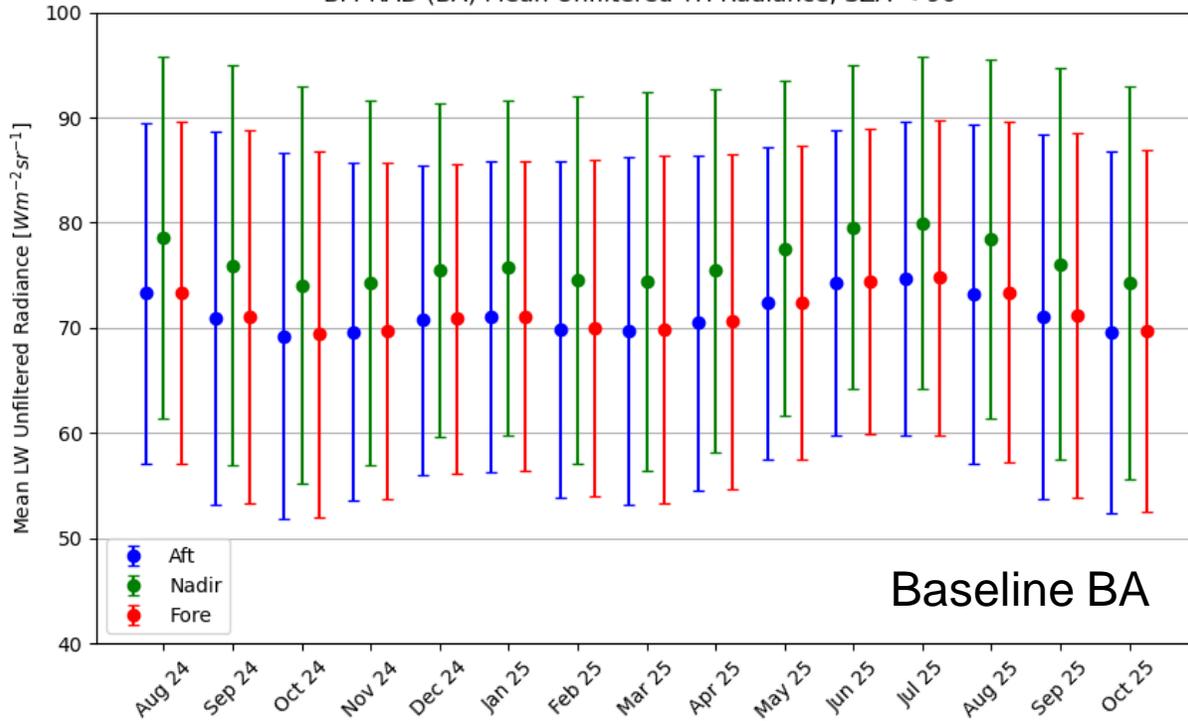




Mean Values of BM-RAD Unfiltered TH Radiances per Month

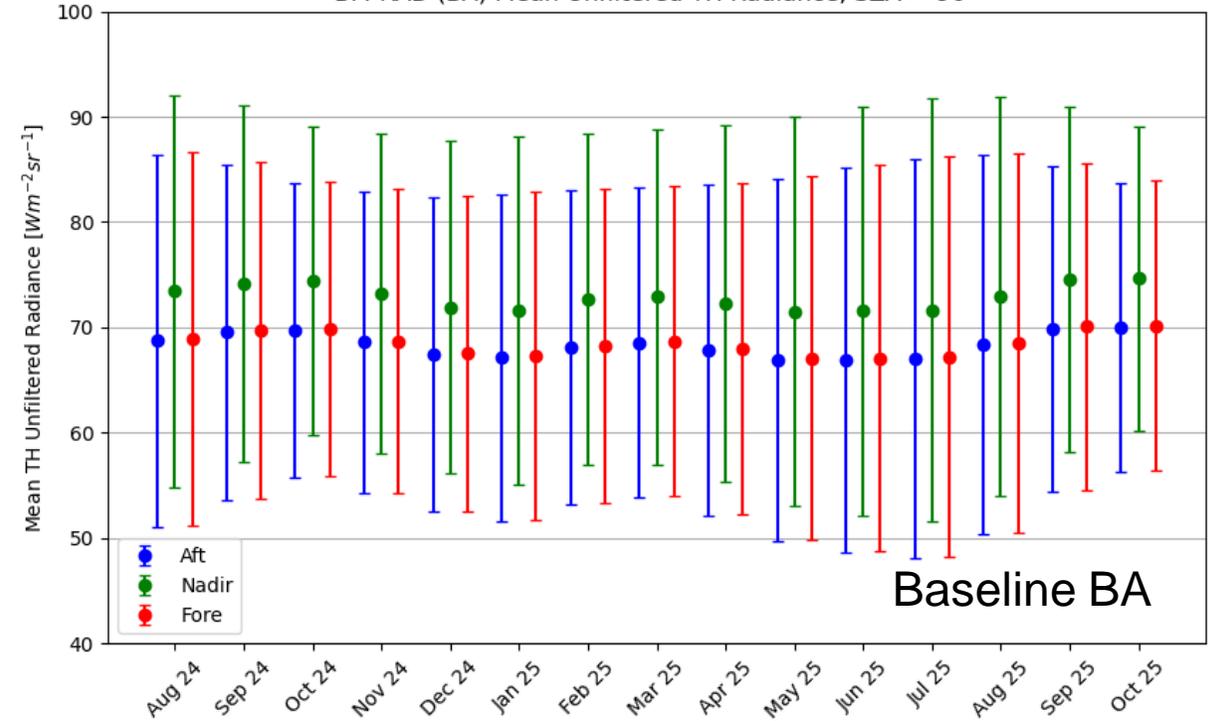
Daytime

BM-RAD (BA) Mean Unfiltered TH Radiance, SZA < 90°



Nighttime

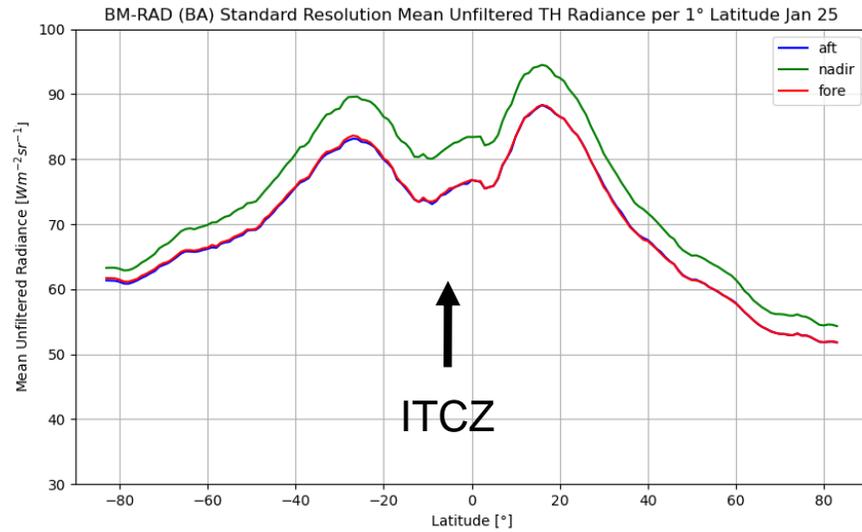
BM-RAD (BA) Mean Unfiltered TH Radiance, SZA > 90°



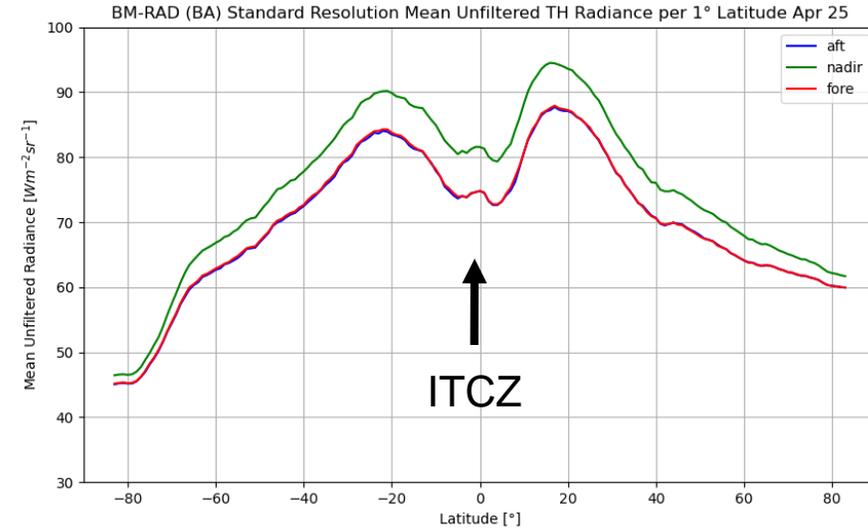


BM-RAD Unfilt. TH Radiance per 1° Lat. Bin, All-day, Baseline BA

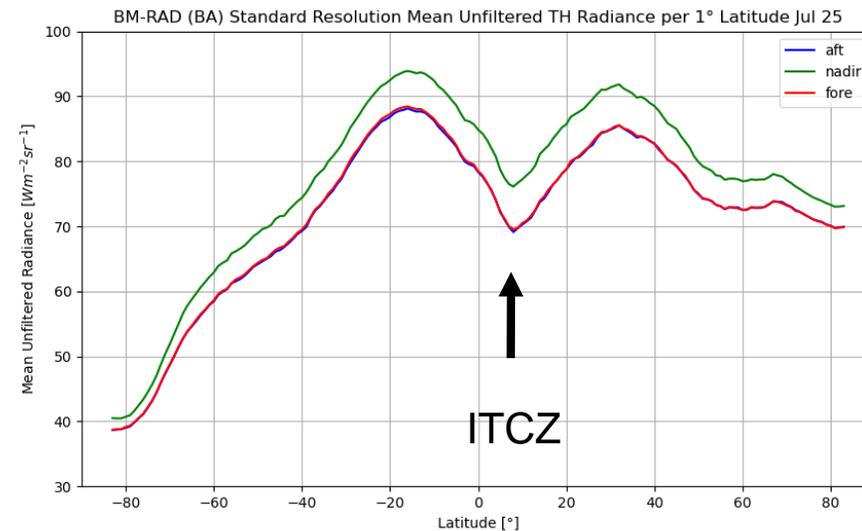
Jan 25



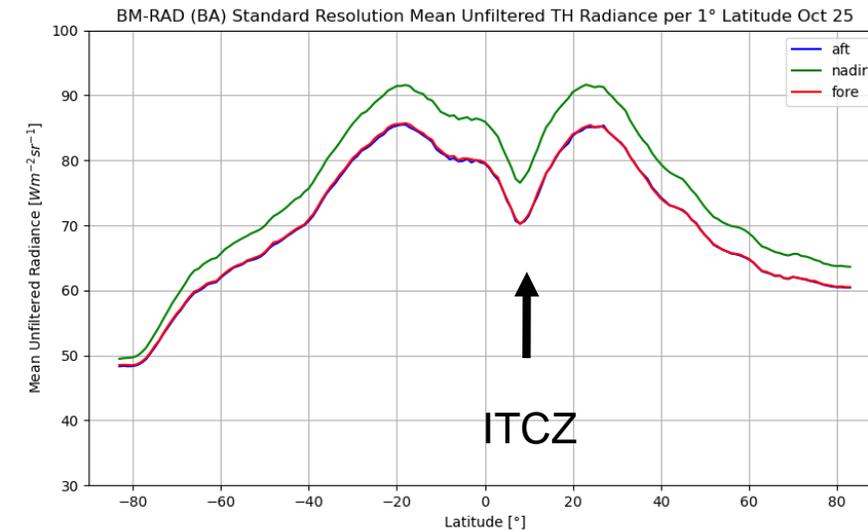
Apr 25



Jul 25



Oct 25



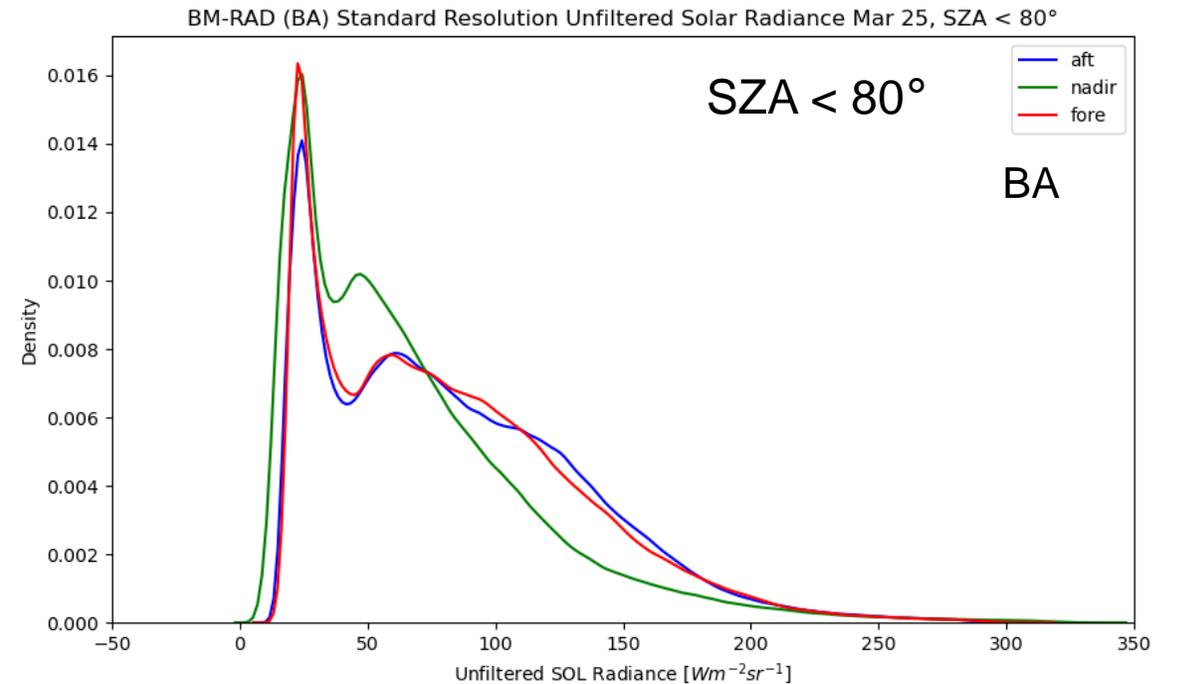
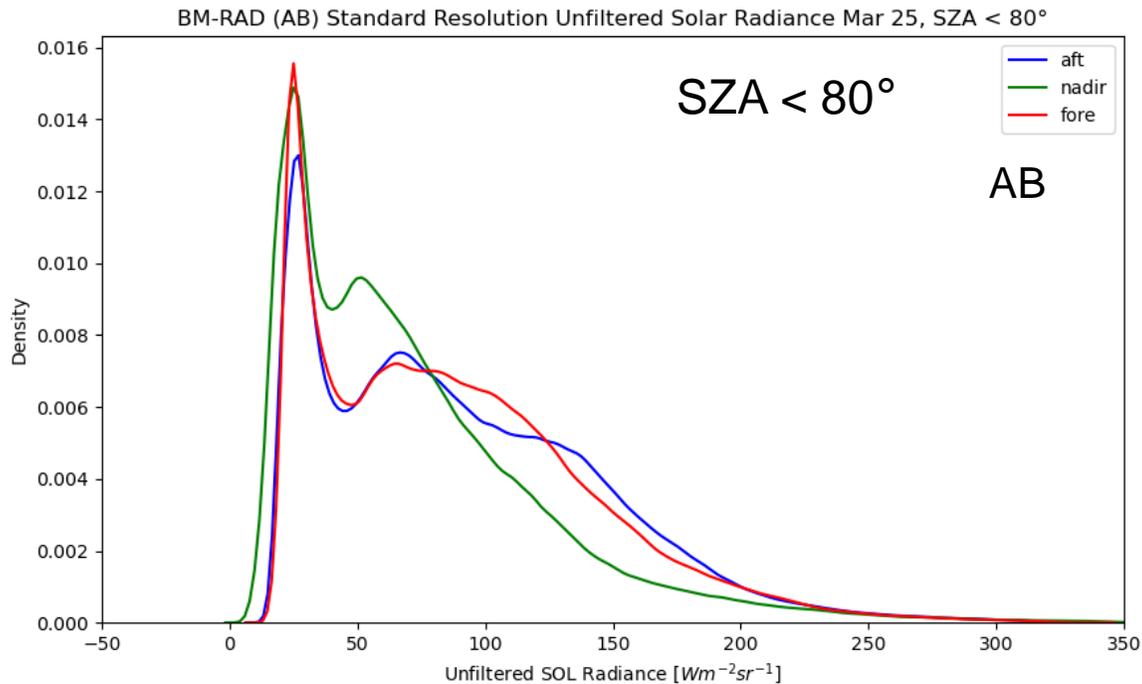


BM-RAD product: SOL Unfiltered Radiance, Daytime

Standard Resolution

March 25

March 25



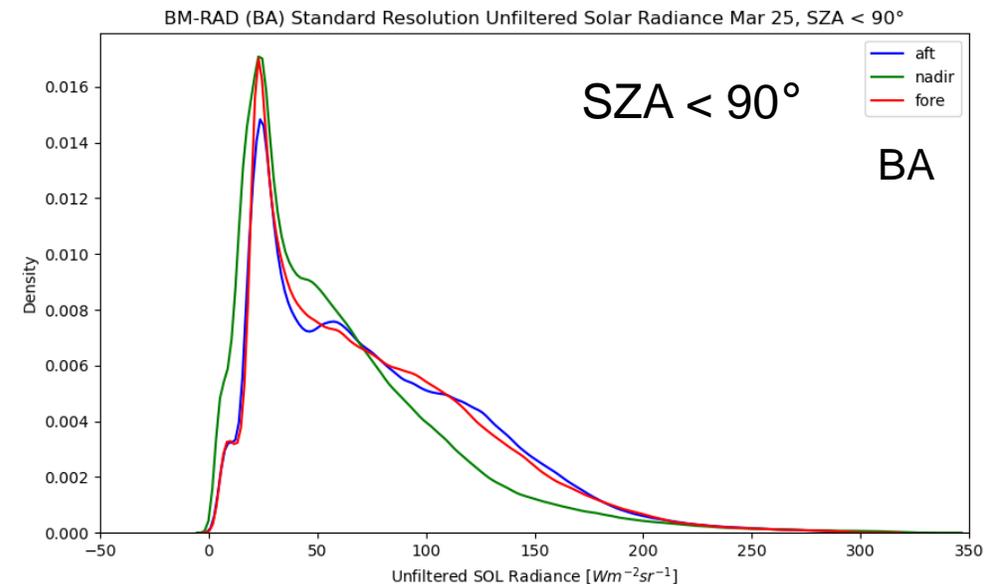
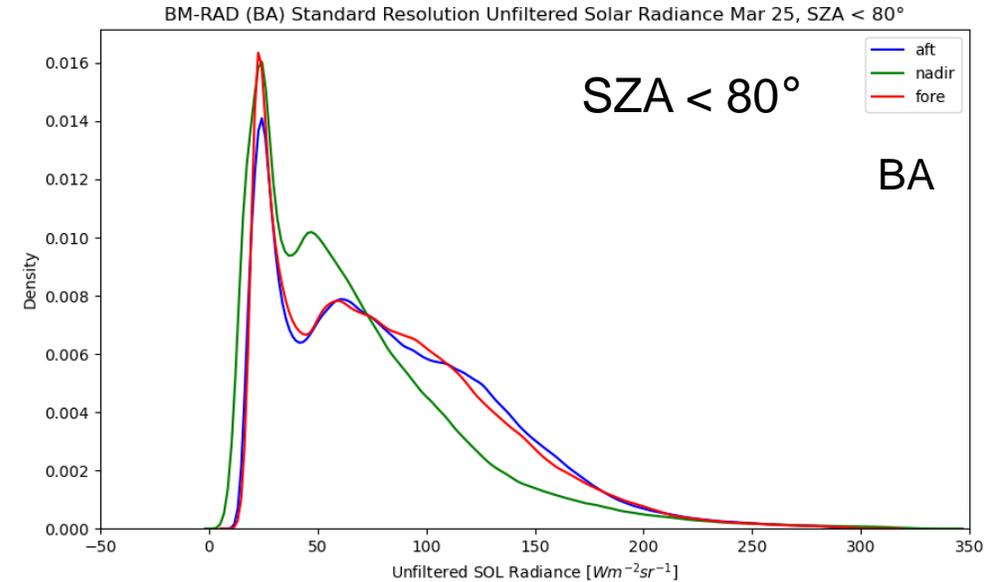
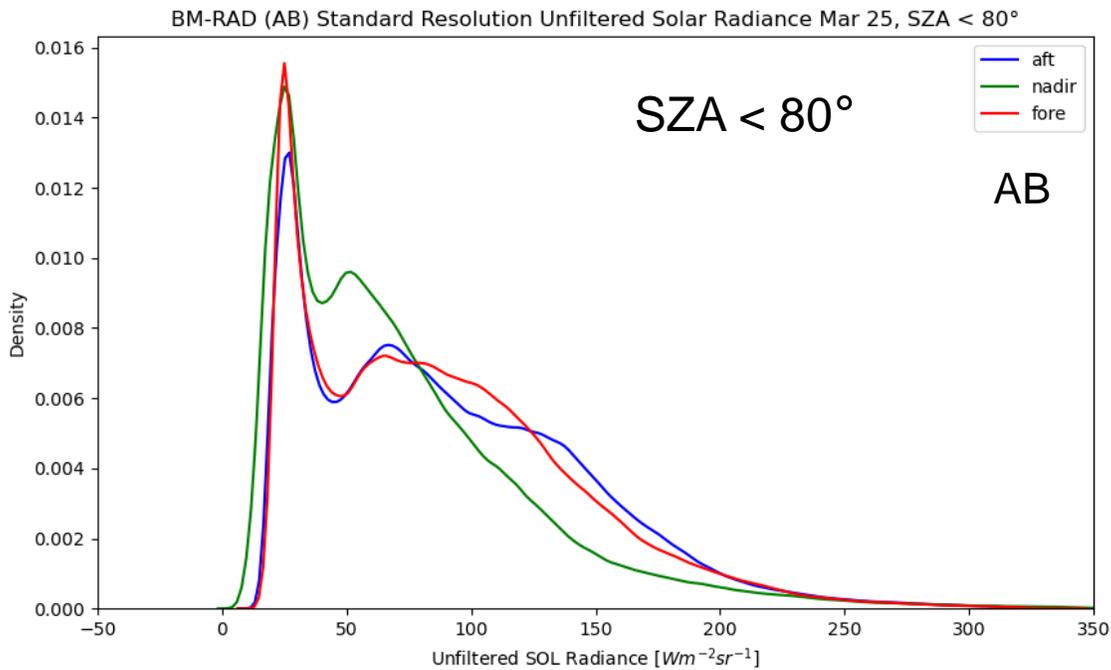
- Slightly lower SOL values in the baseline BA (mainly for high SOL values), due to changes in the SW gain ratio.



BM-RAD product: SOL Unfiltered Radiance, Daytime

Standard Resolution

March 25





BM-RAD product: Sol Unfiltered Radiance, Daytime

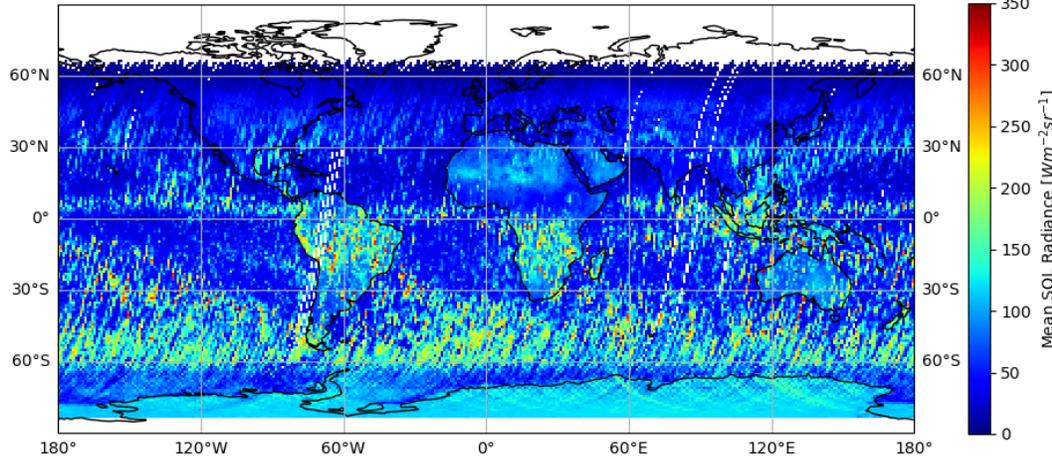
AB

BA

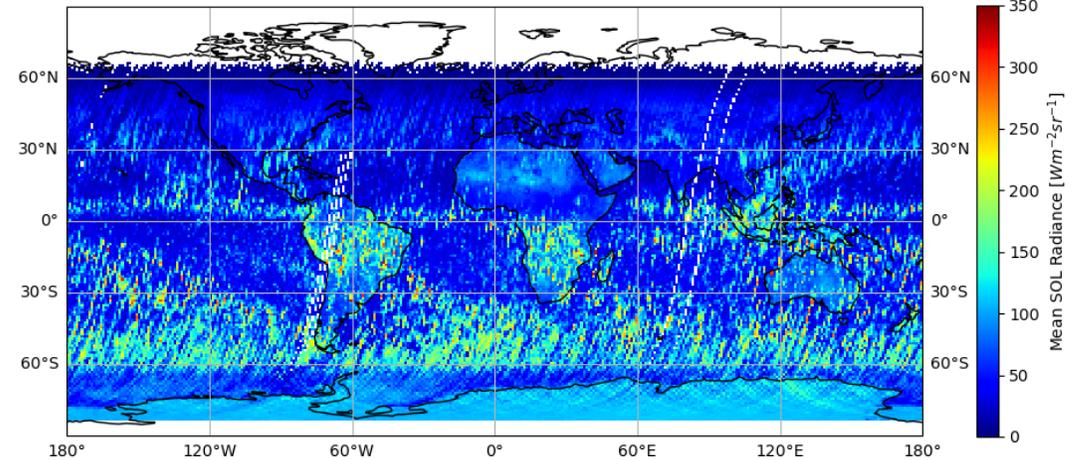
Standard Resolution

Jan 2025

Binned Latitude-Longitude Plot with BM-RAD (AB) Unfil. Solar Radiance NADIR Jan 25, SZA < 90°

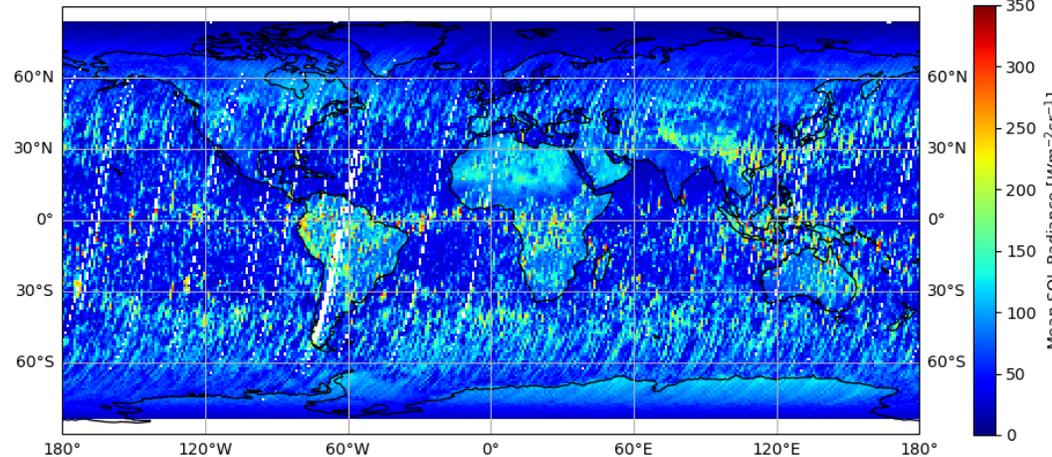


Binned Latitude-Longitude Plot with BM-RAD (BA) Unfil. Solar Radiance NADIR Jan 25, SZA < 90°

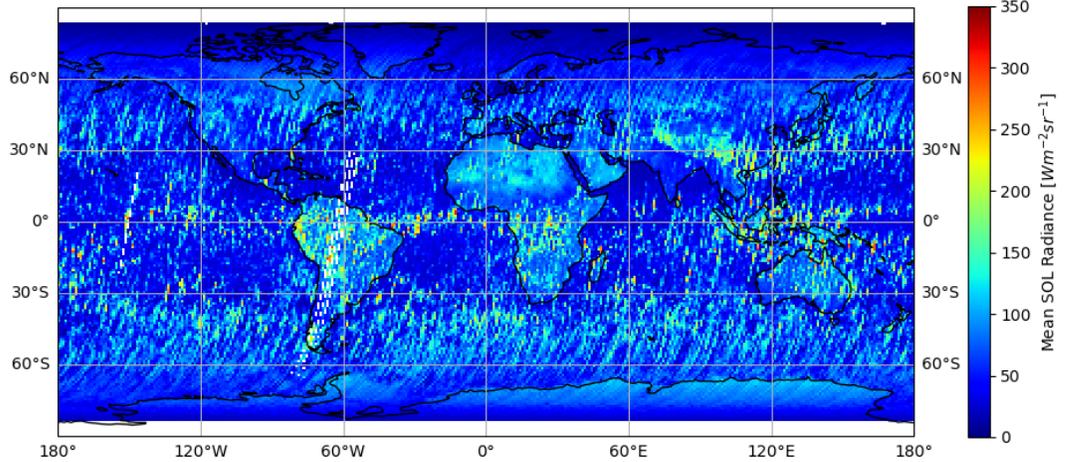


Mar 2025

Binned Latitude-Longitude Plot with BM-RAD (AB) Unfil. Solar Radiance NADIR Mar 25, SZA < 90°

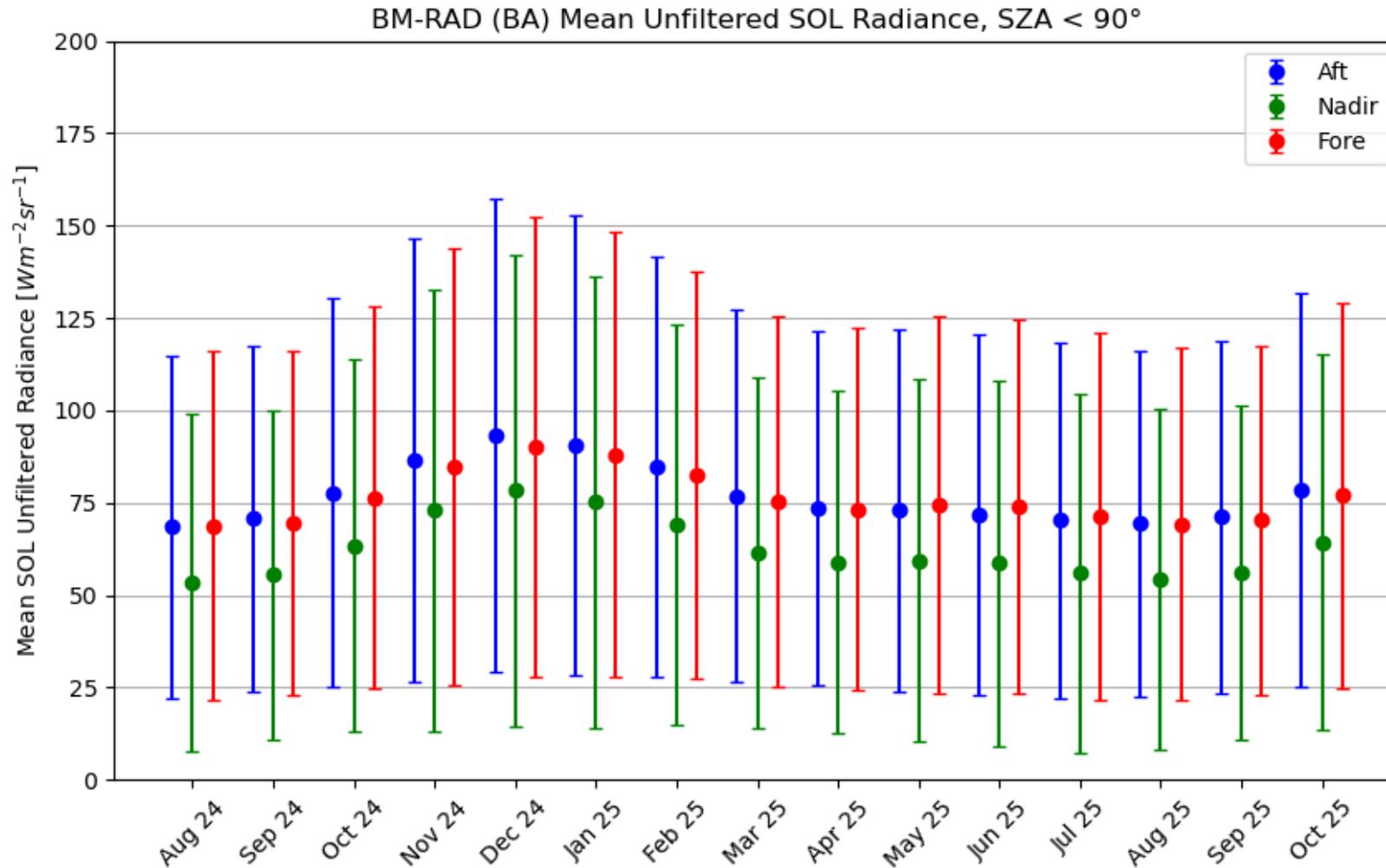


Binned Latitude-Longitude Plot with BM-RAD (BA) Unfil. Solar Radiance NADIR Mar 25, SZA < 90°



Mean Values of BM-RAD Unfiltered SOL Radiances per Month

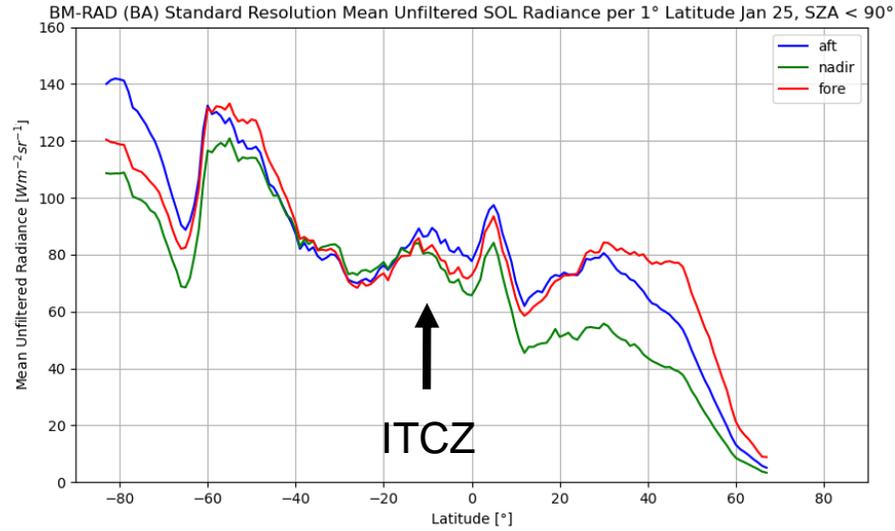
Daytime



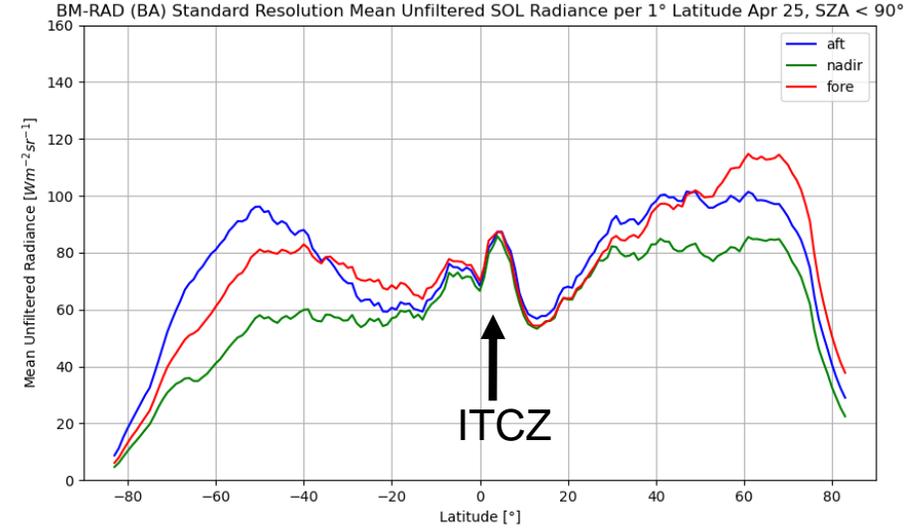


BM-RAD Unfilt. SOL Radiance per 1° Lat. Bin, Baseline BA

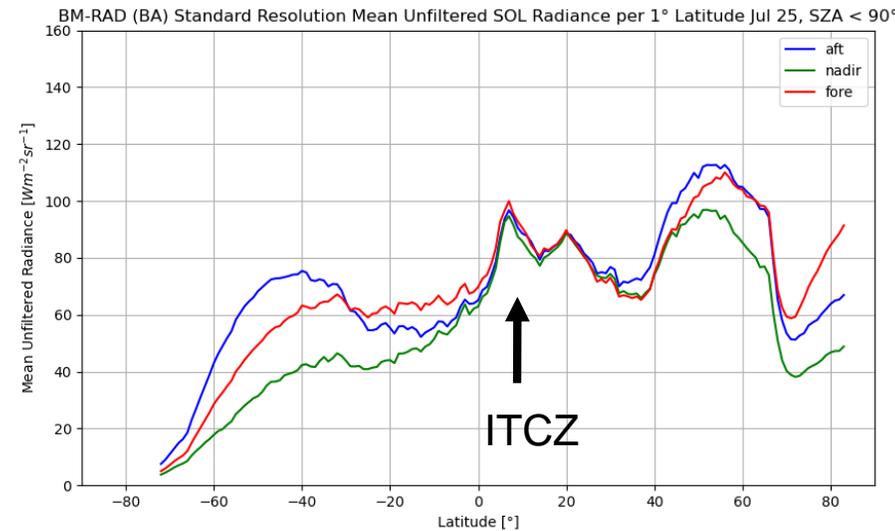
Jan 25



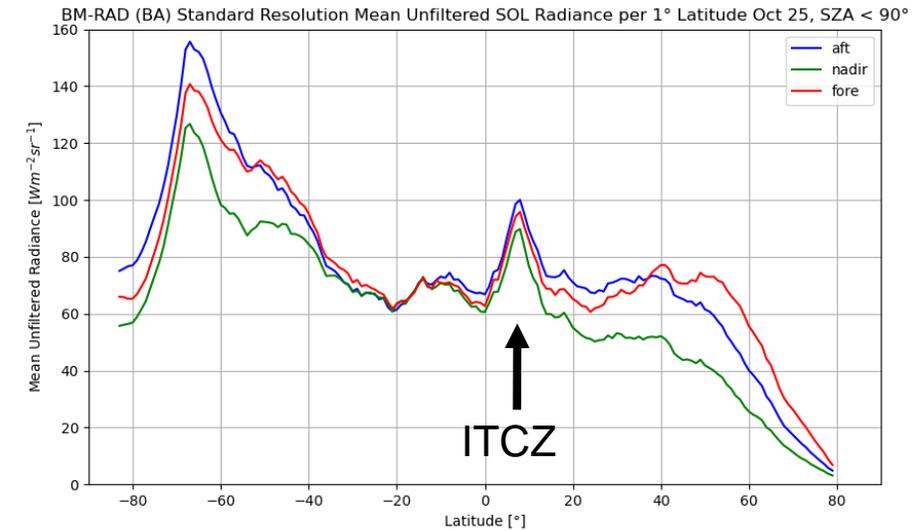
Apr 25



Jul 25



Oct 25



Evaluation of the BMA-FLX product (L2)

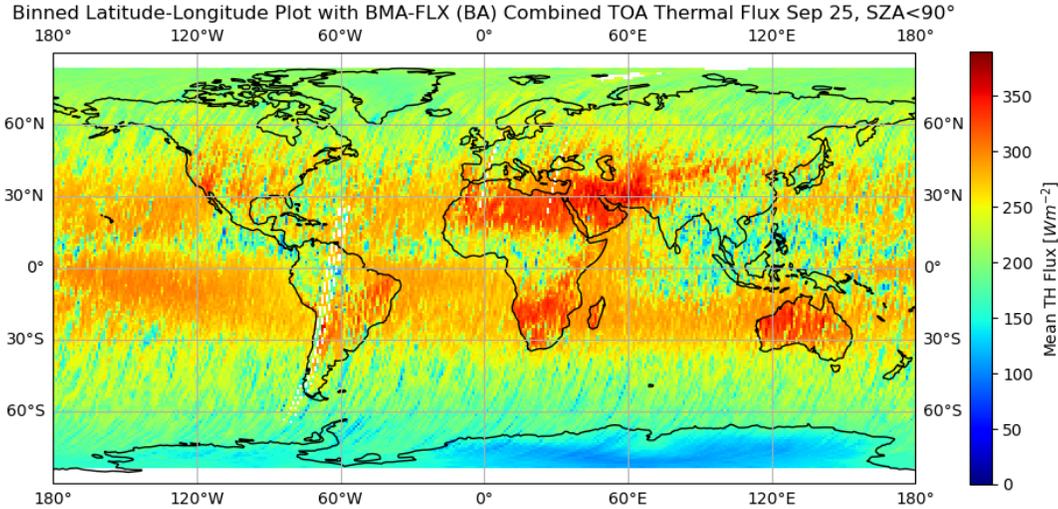
- Containing unfiltered and coregistered solar and thermal radiances (in contrast to the L1 products)
- Containing flux-data (all three views separately and combined)
- Containing information about clouds (cover and phase), snow albedo, surface type, etc.
- Available in four different resolutions (small, standard, full, assessment)
- Data availability:
 - Baseline AA: 27/07/2024 – 09/05/2025
 - Baseline AB: 09/05/2025 – 08/07/2025
 - **Baseline BA: 27/07/2024 – 01/10/2025**
 - Baseline BB: 01/10/2025 – 18/11/2025
 - Baseline BC: 18/11/2025 – today
- Remark: Although no change in the baseline AA, there have been many changes done until today.



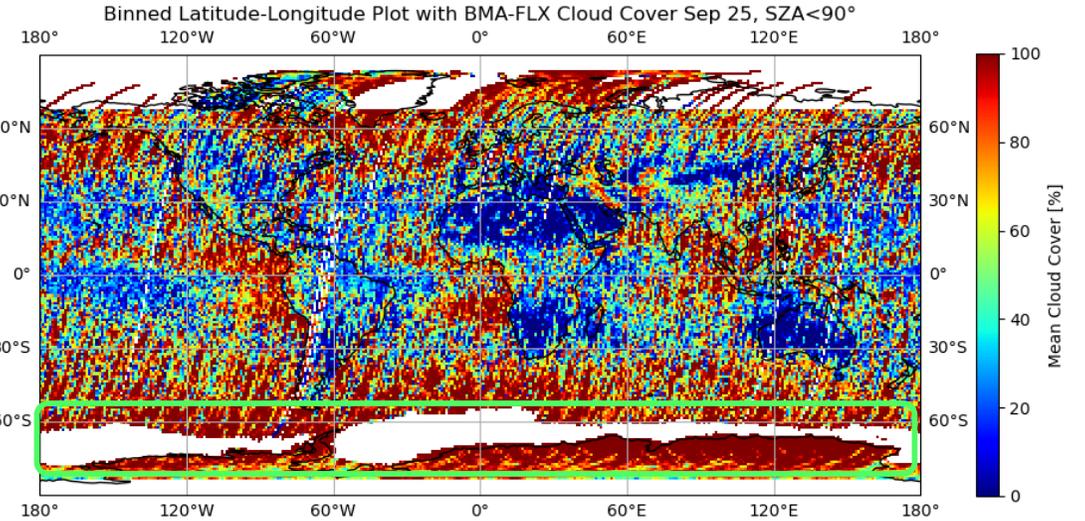
BMA-FLX: Missing Cloud Data → No SOL Flux, Baseline BA

Daytime

TH Combined Flux

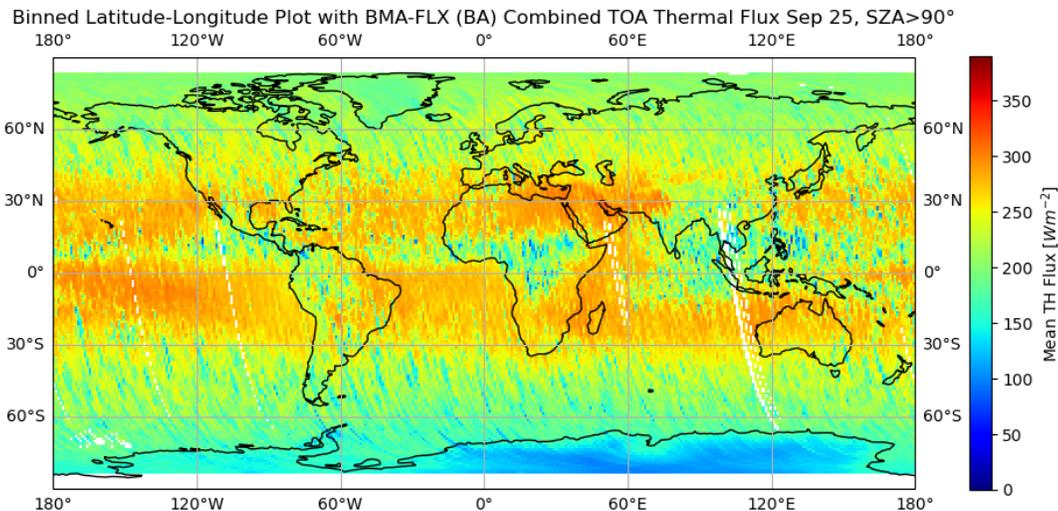


Cloud Cover

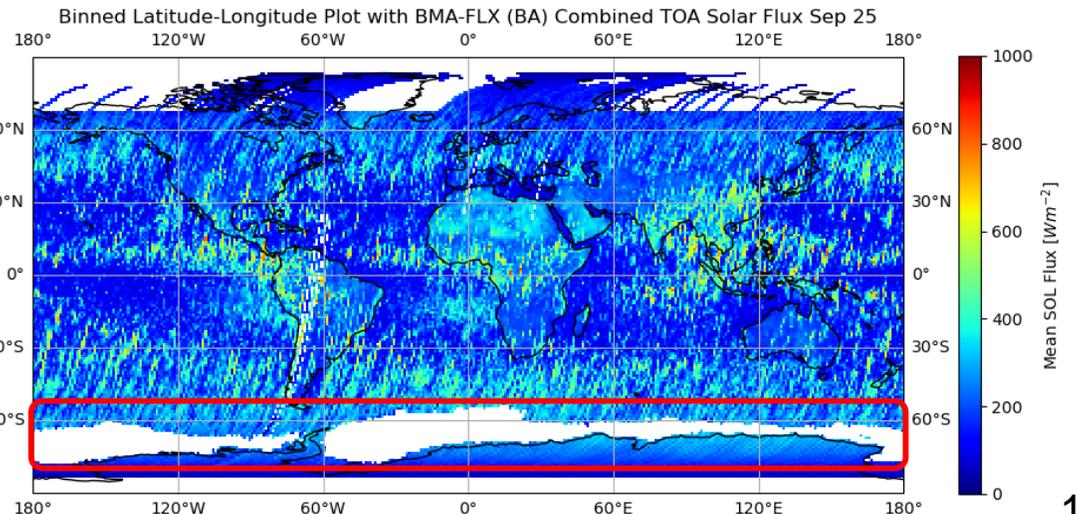


Nighttime

TH Combined Flux



SOL Combined Flux

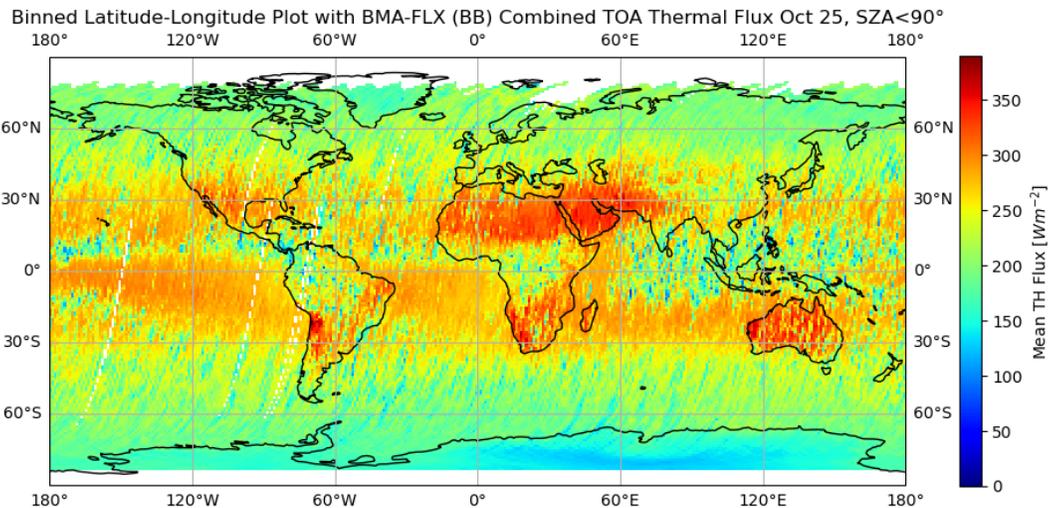




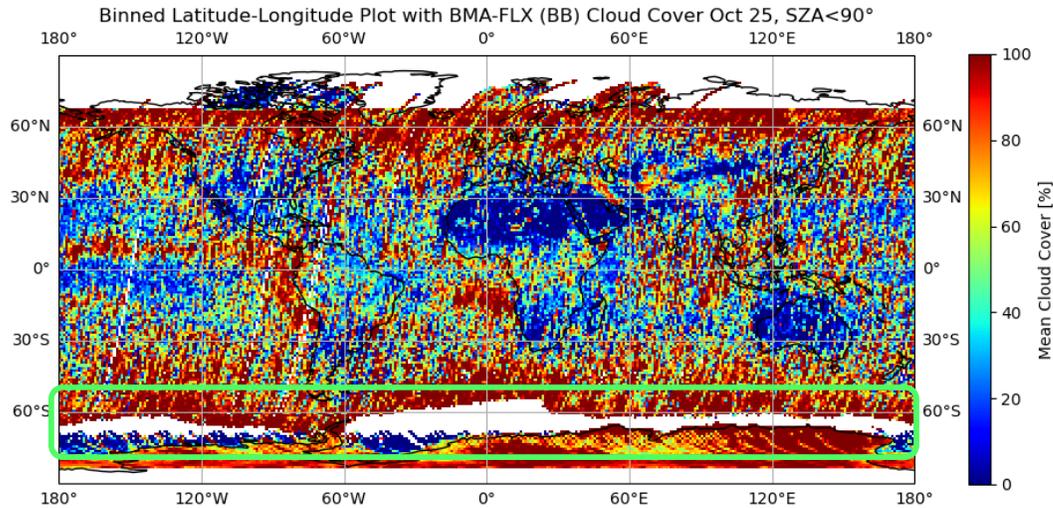
BMA-FLX: Missing Cloud Data → No SOL Flux, Baseline BB

Daytime

TH Combined Flux

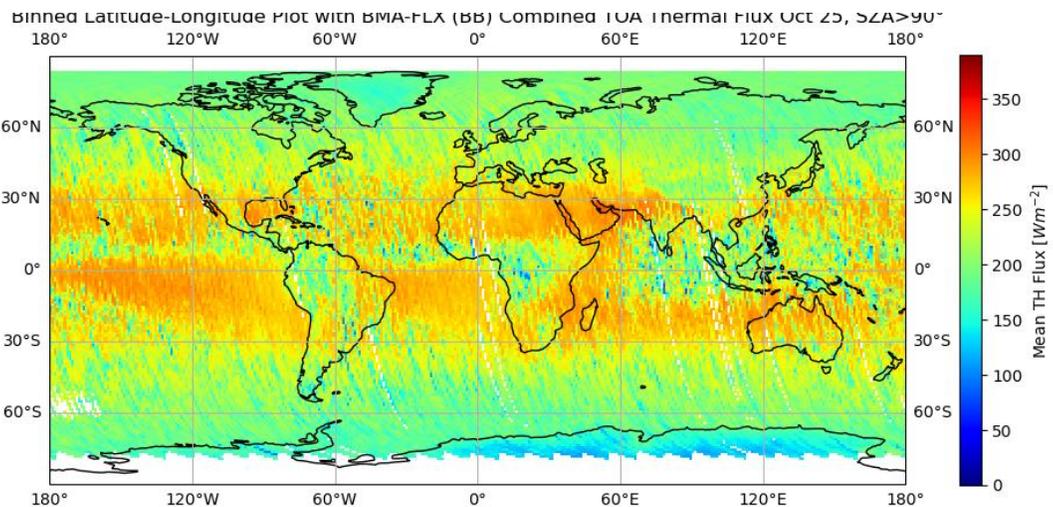


Cloud Cover

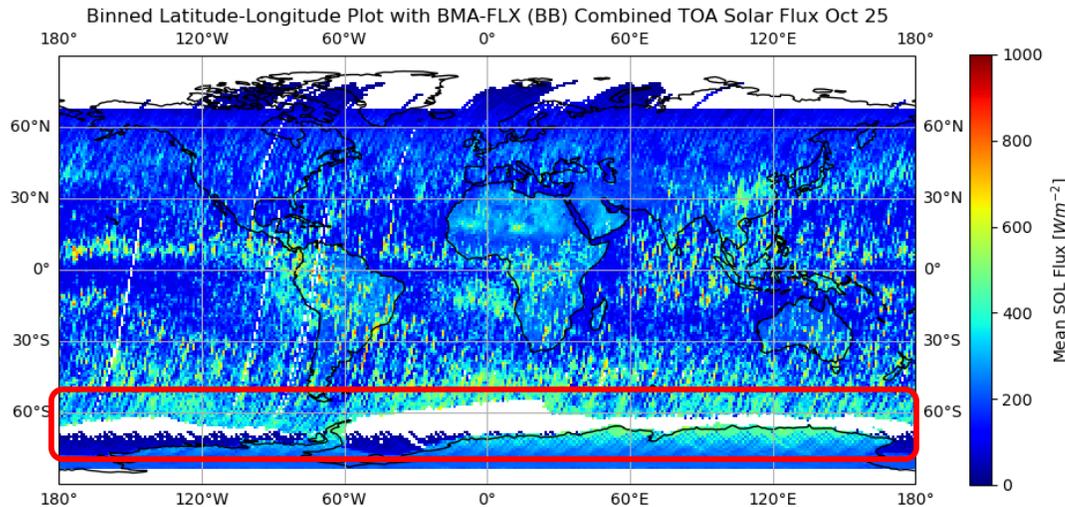


Nighttime

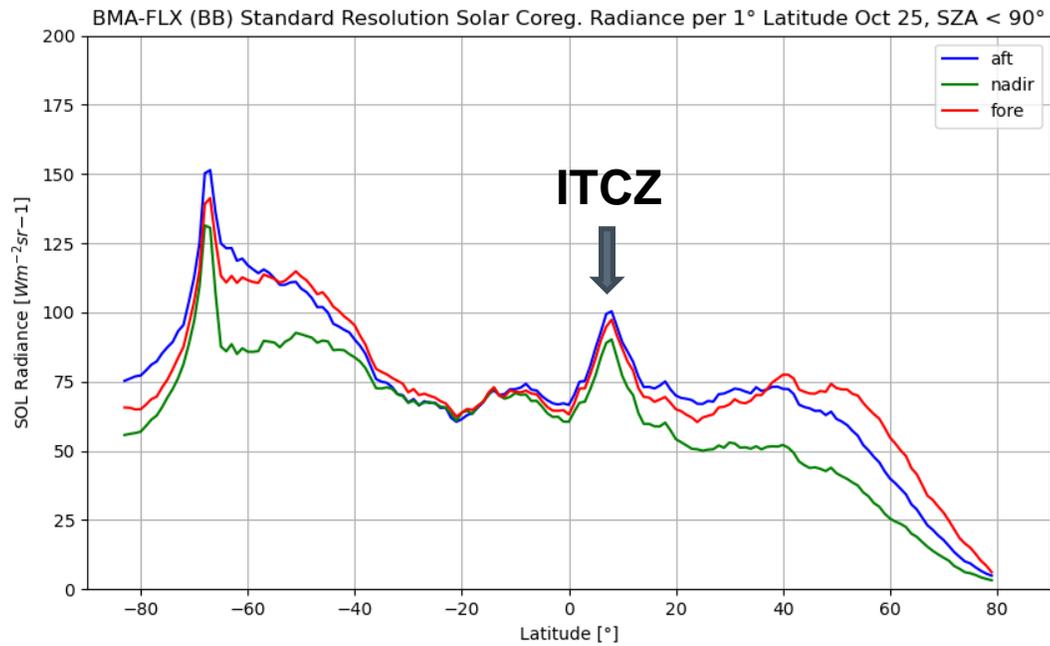
TH Combined Flux



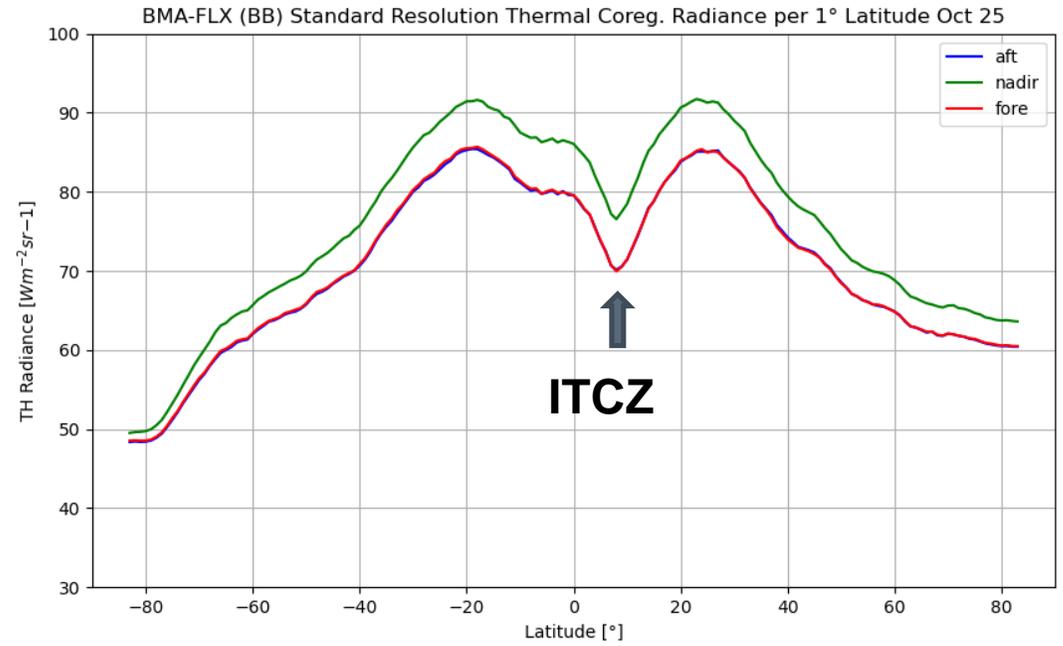
SOL Combined Flux



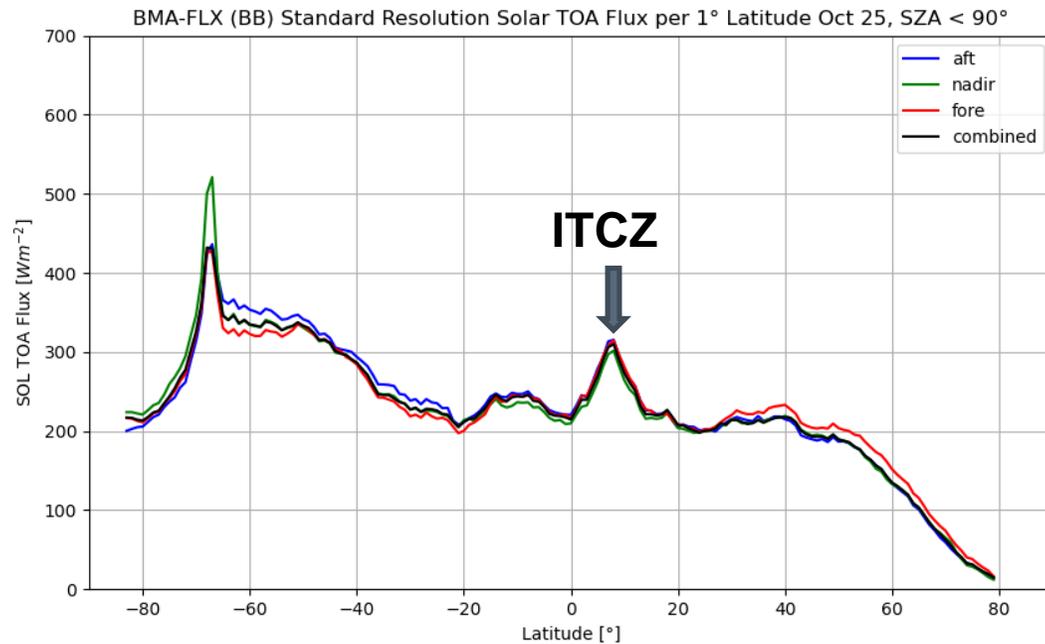
Solar, daytime



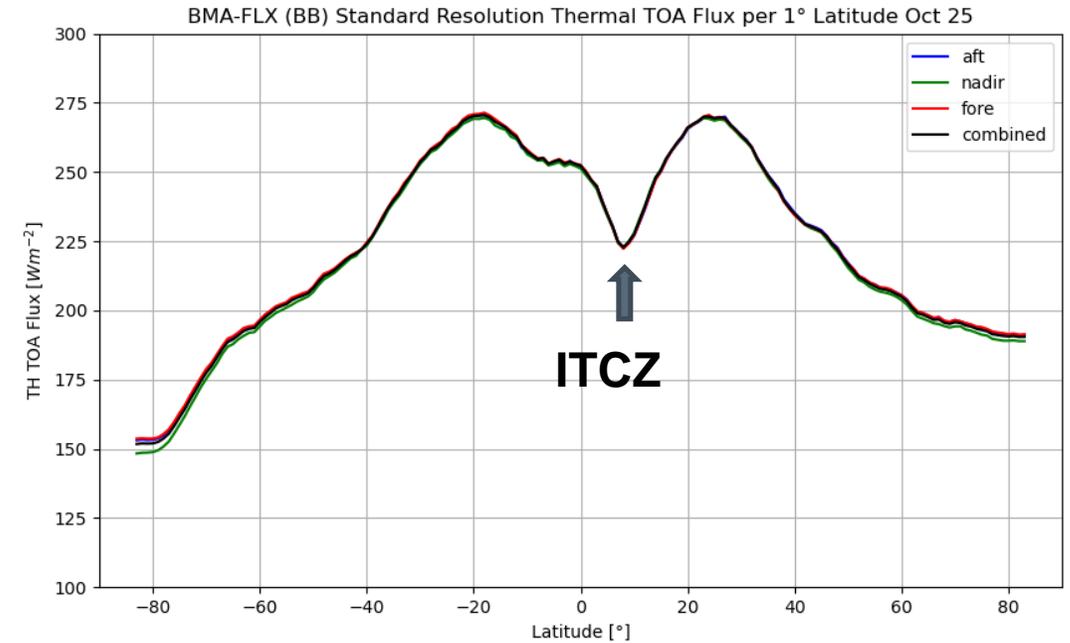
Thermal, all-day



Solar, daytime

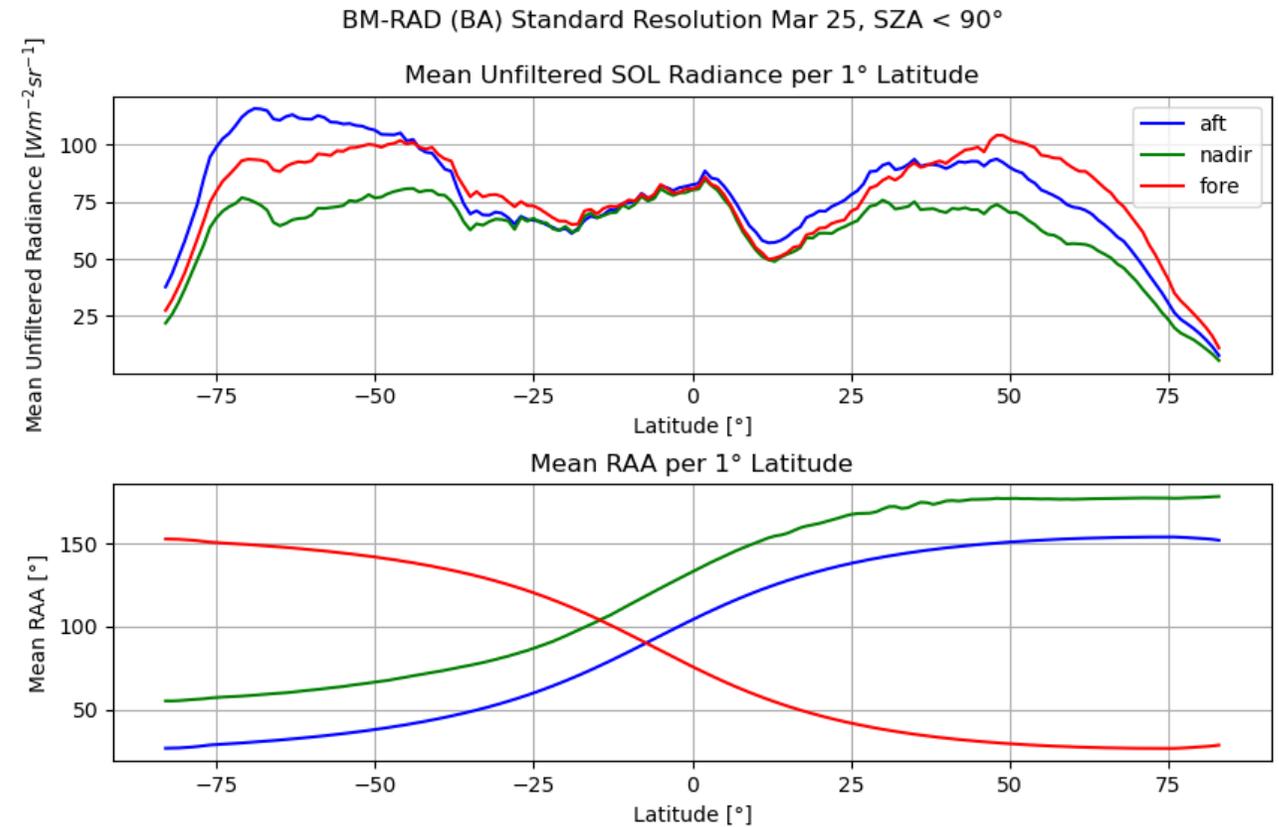
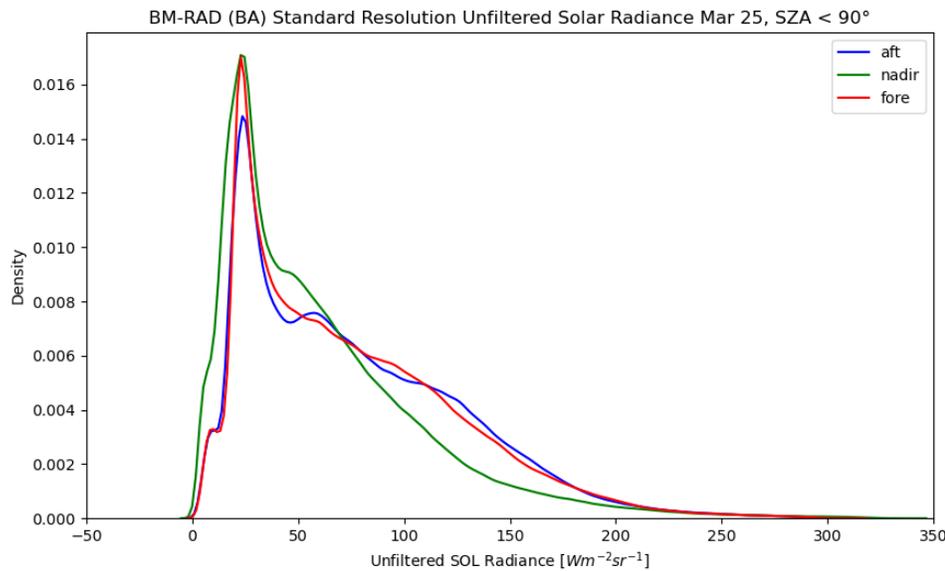


Thermal, all-day



Standard Resolution

March 25, Baseline BA

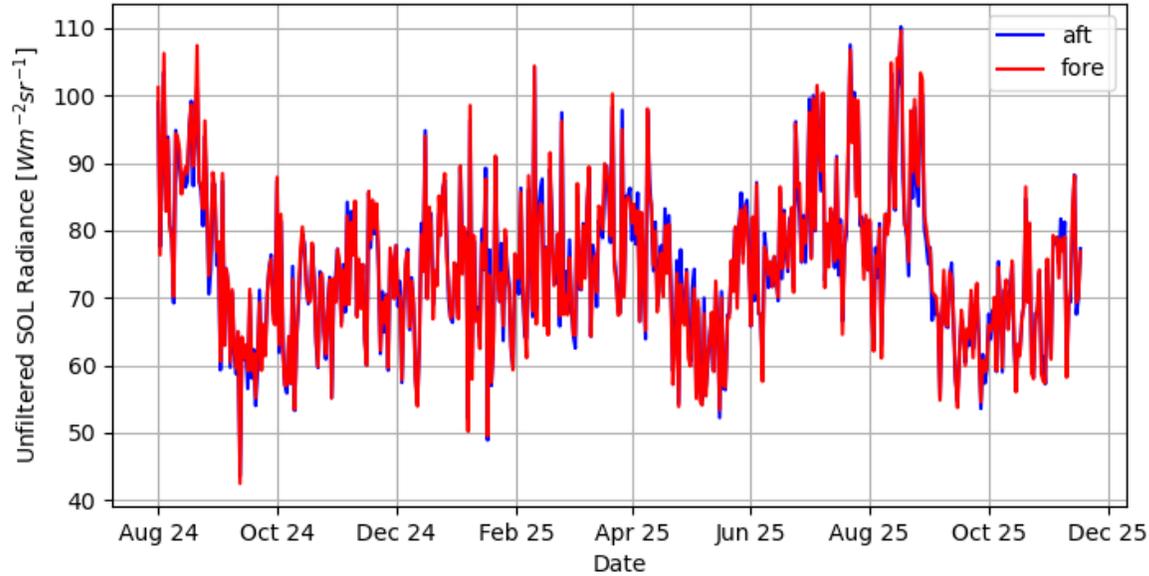


- If relative azimuth angle (RAA) is around 90°, then AFT and FORE view should match.

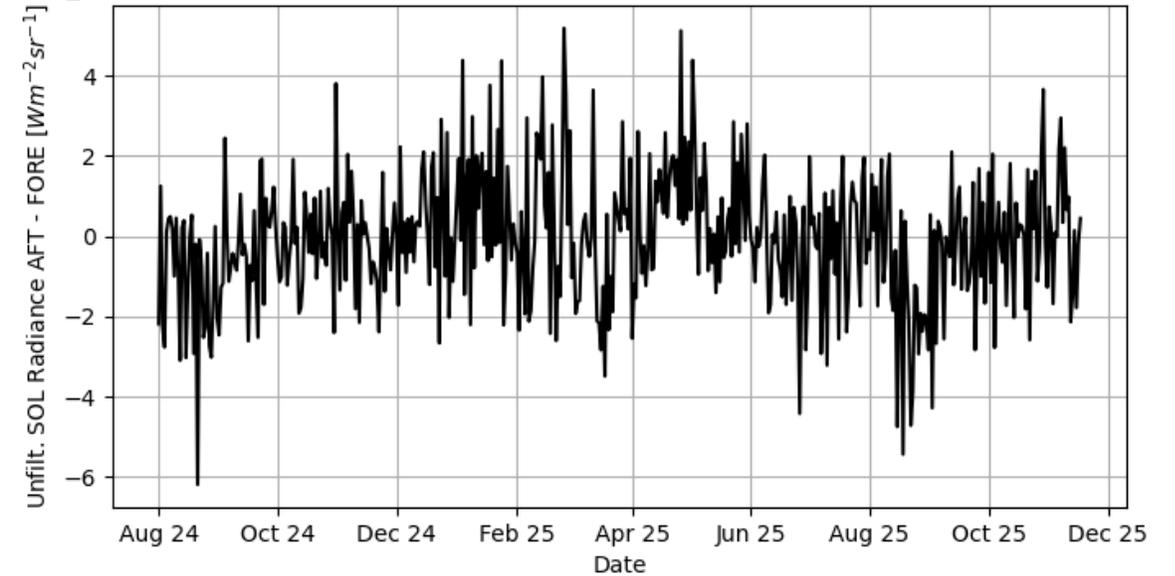


Quality Check: BM-RAD SOL Unfiltered Radiance

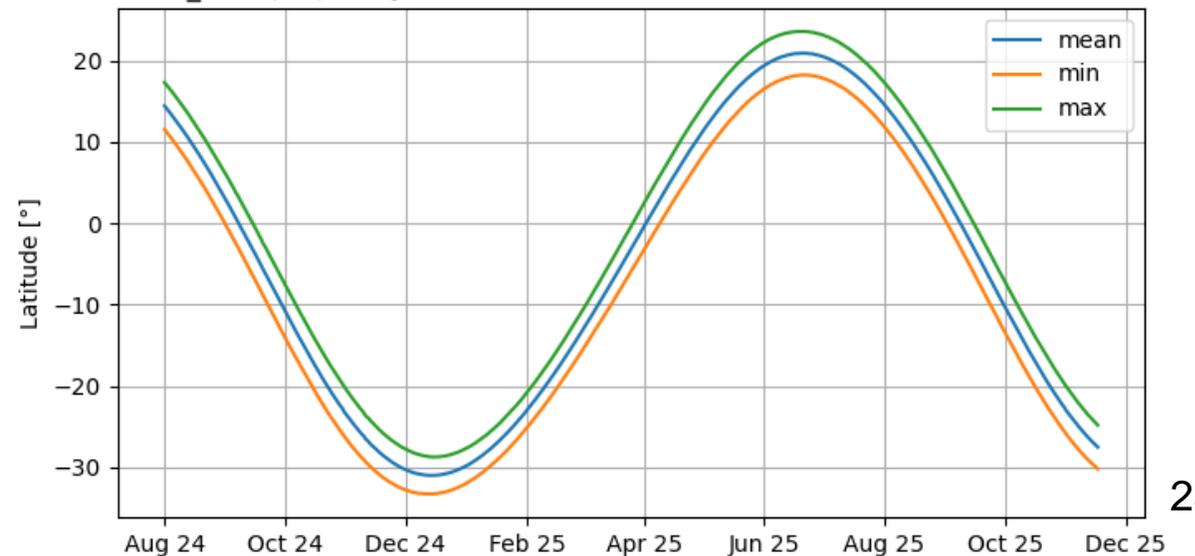
BM_RAD (BA) Daily Mean Unfiltered SOL Radiance for $85^\circ < \text{RAA} < 95^\circ$ and $\text{SZA} < 90^\circ$

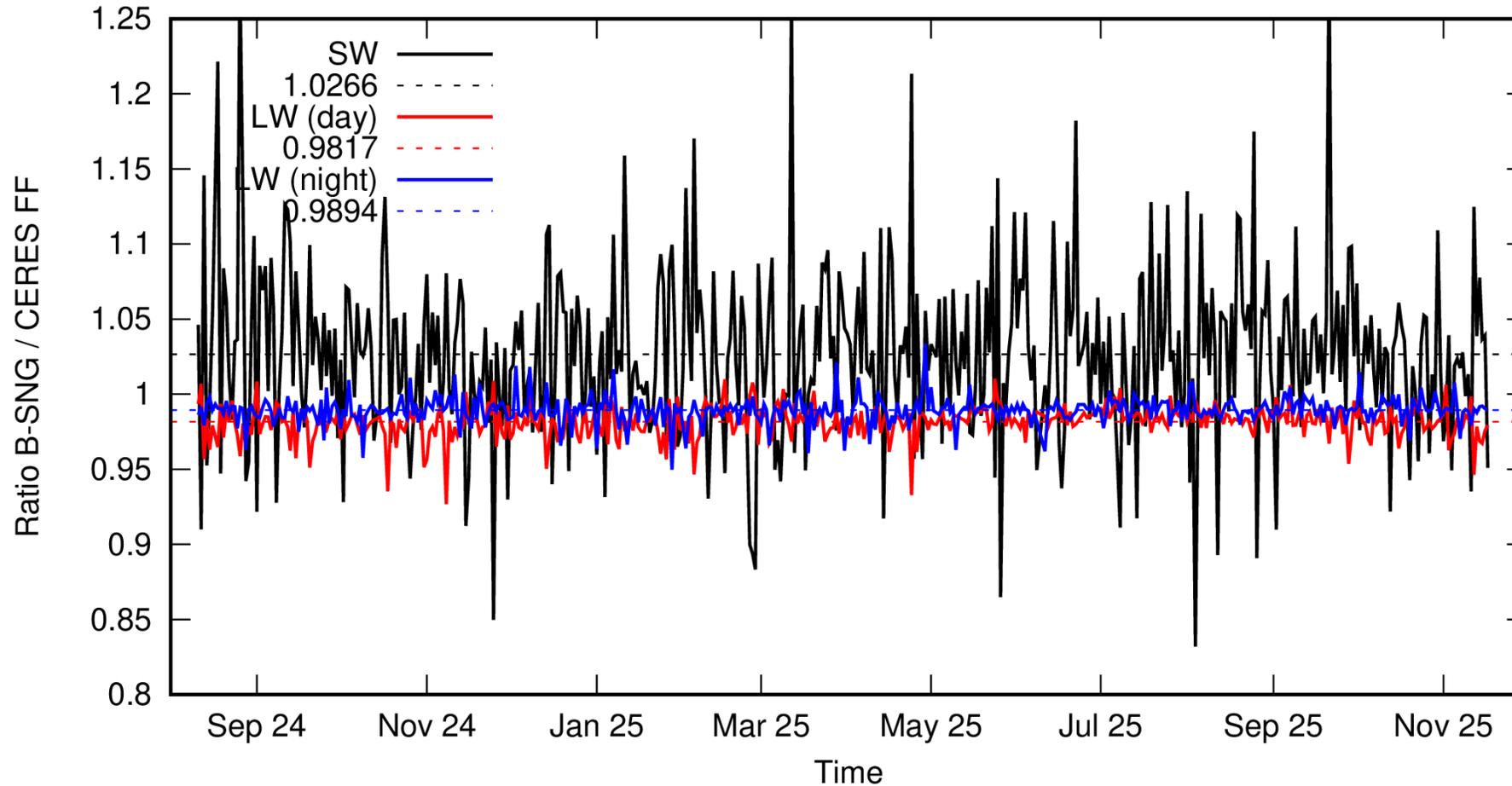


BM_RAD (BA) Daily Mean Diff. Unfilt. SOL Radiance for $85^\circ < \text{RAA} < 95^\circ$ and $\text{SZA} < 90^\circ$



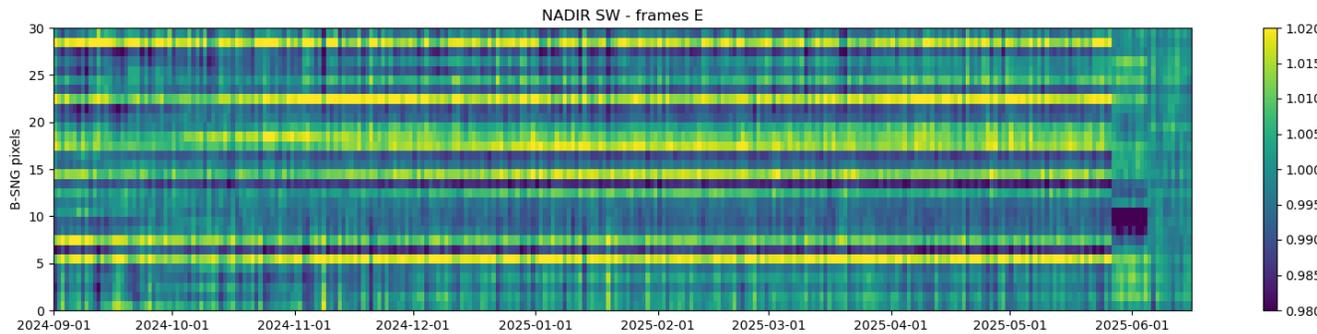
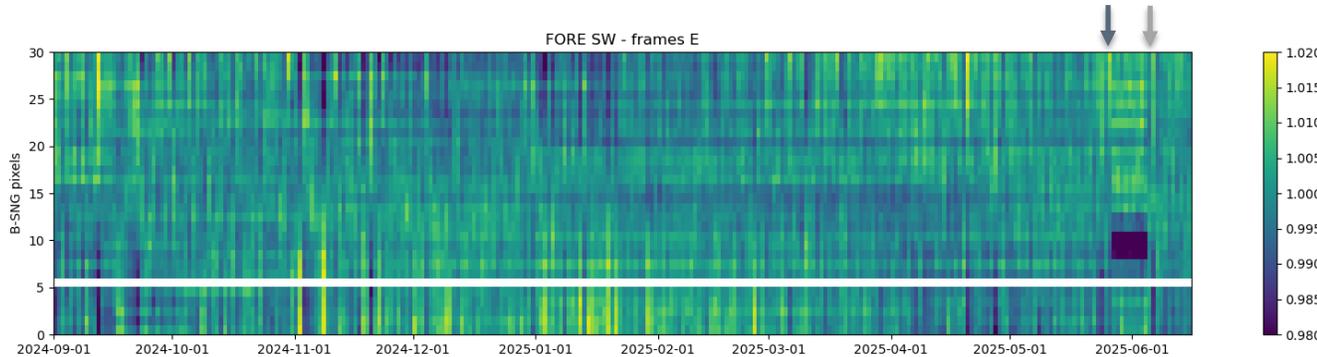
BM_RAD (BA) Daily Mean Latitude for $85^\circ < \text{RAA} < 95^\circ$ and $\text{SZA} < 90^\circ$



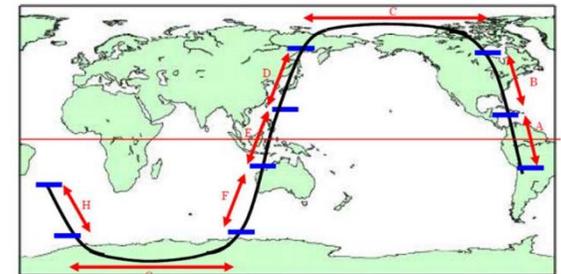
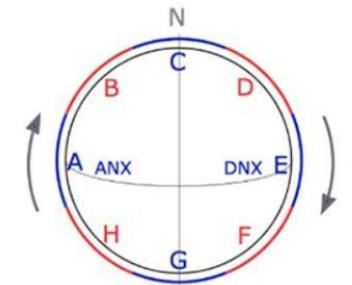


- No indication of temporal degradation so far.

SW
daytime

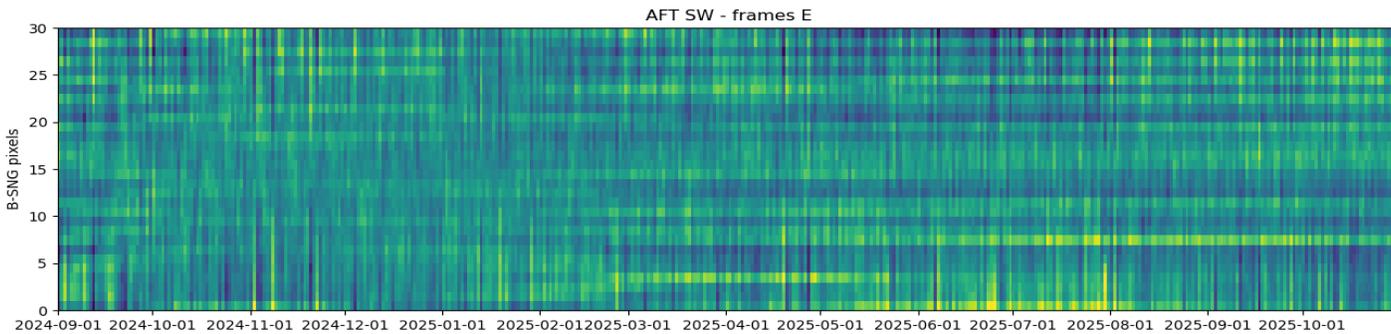
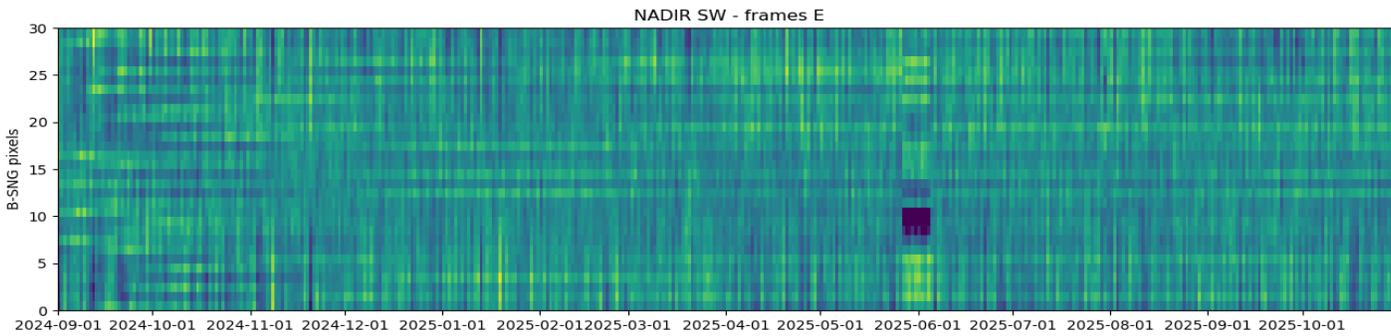
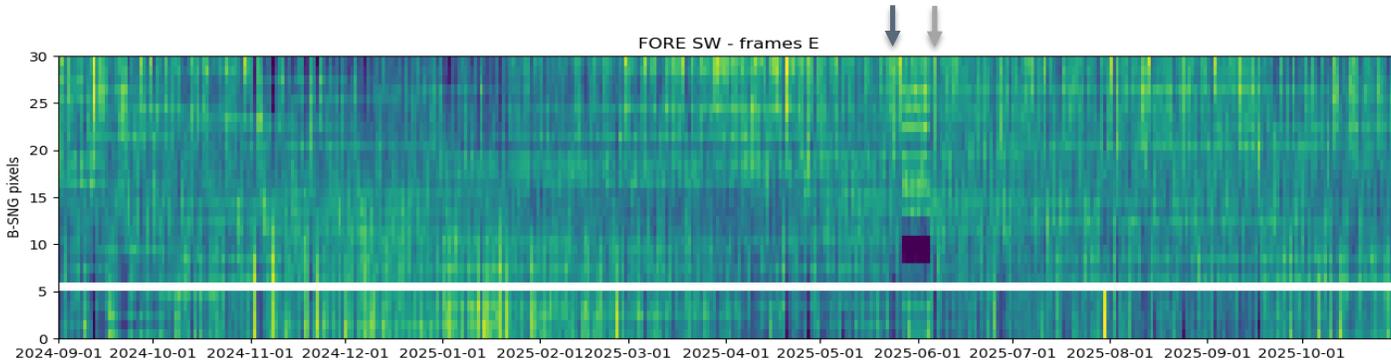


Bug in the stripping correction applied for the fore and nadir views → corrected the 5th June (frame 05793C onwards)

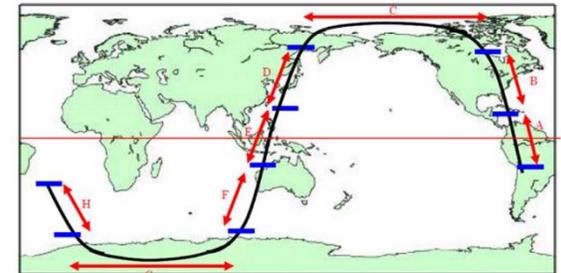
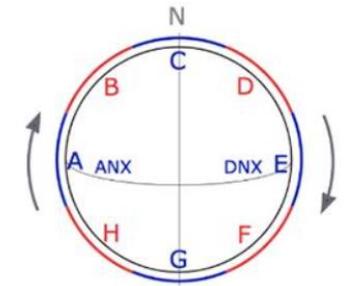


A, B, H: night
D, E, F: day
C, G: day or night depending on the season

SW
Daytime
Frames E

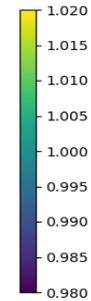
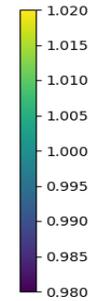
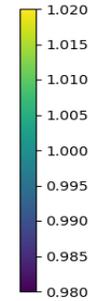
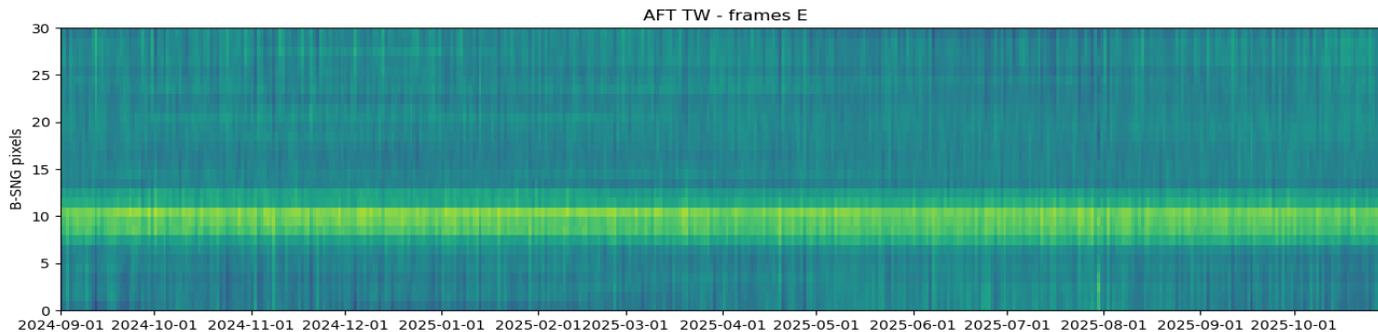
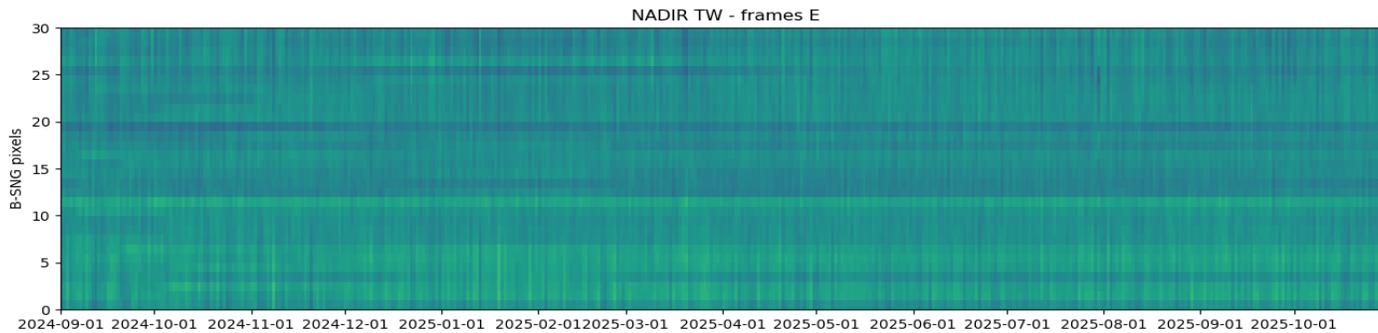
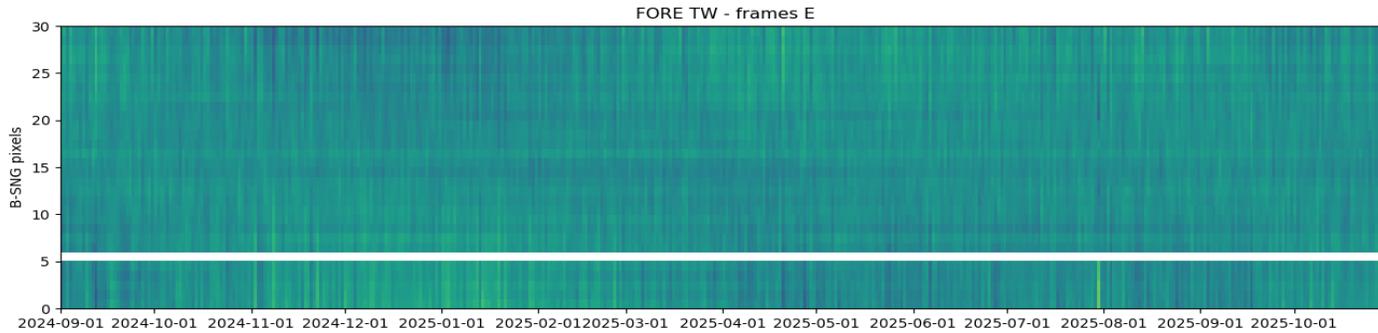


Bug in the stripping correction applied for the fore and nadir views → corrected the 5th June (frame 05793C onwards)

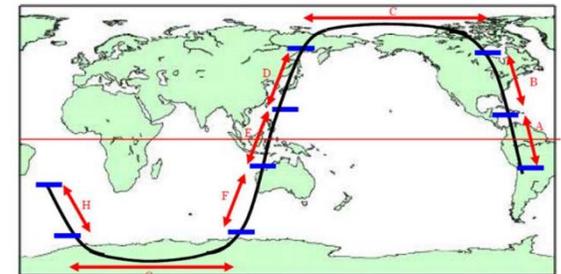
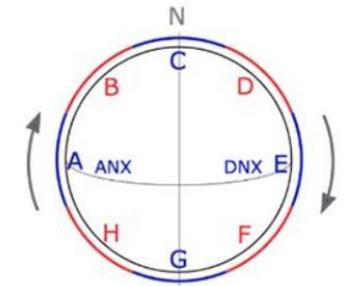


A, B, H: night
D, E, F: day
C, G: day or night depending on the season

TW Daytime Frames E

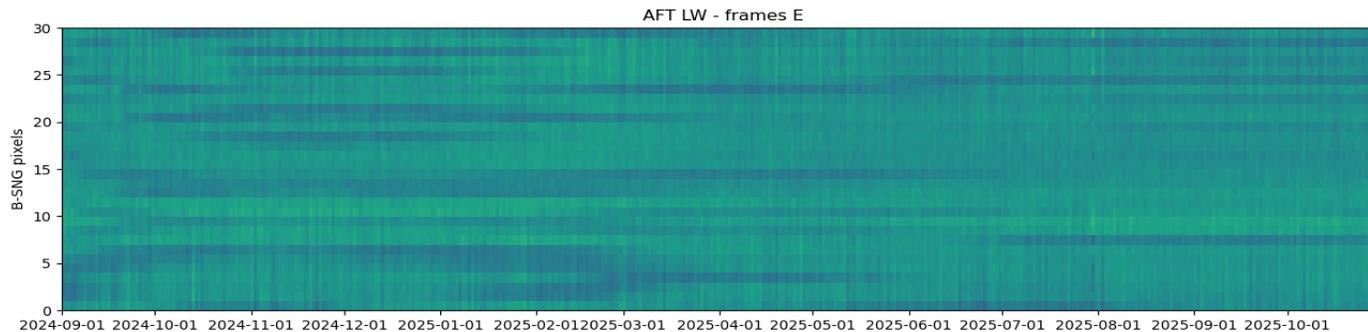
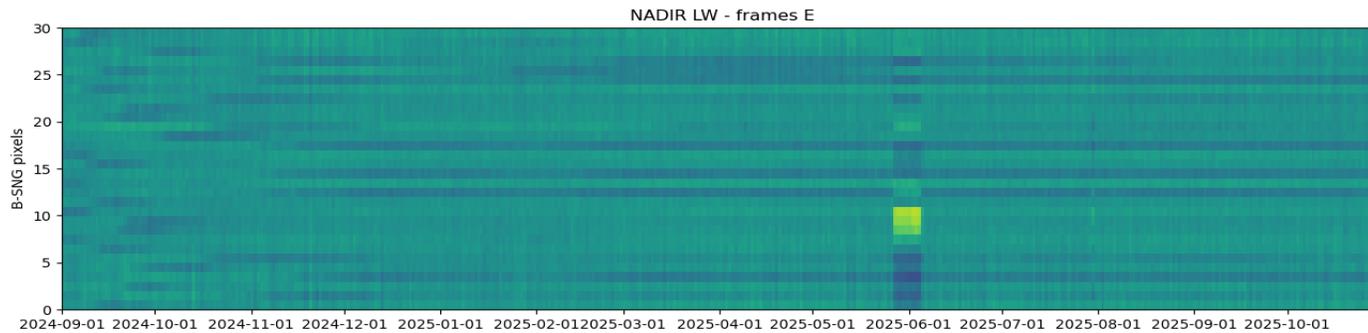
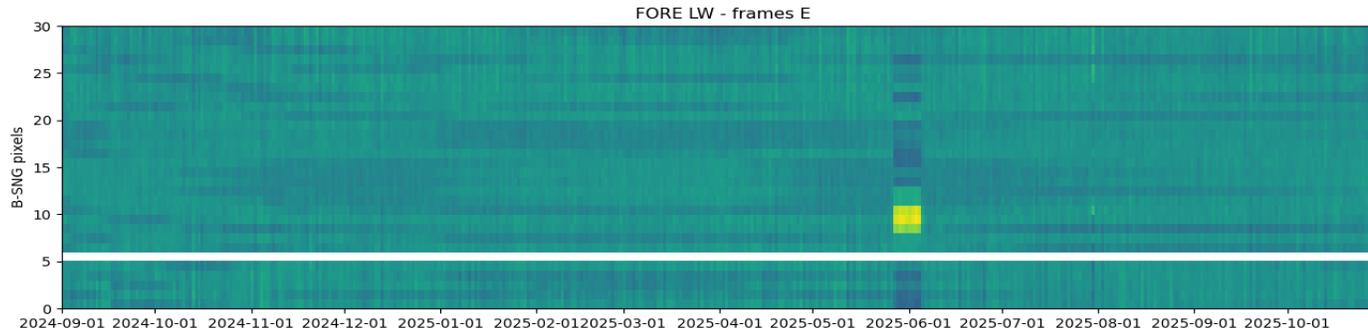


Bug in the stripping correction applied for the fore and nadir views → corrected the 5th June (frame 05793C onwards)

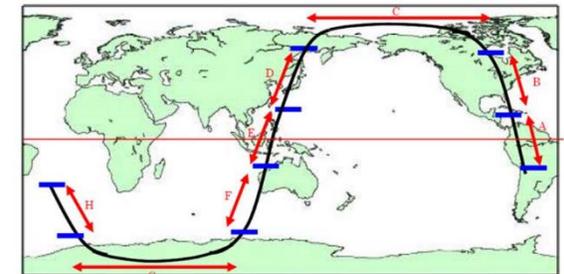
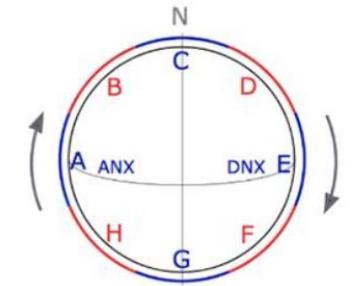


A, B, H: night
D, E, F: day
C, G: day or night depending on the season

LW
Daytime
Frames E

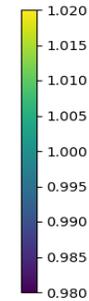
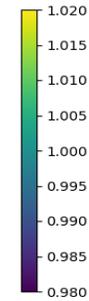
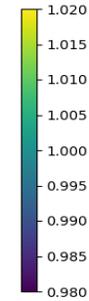
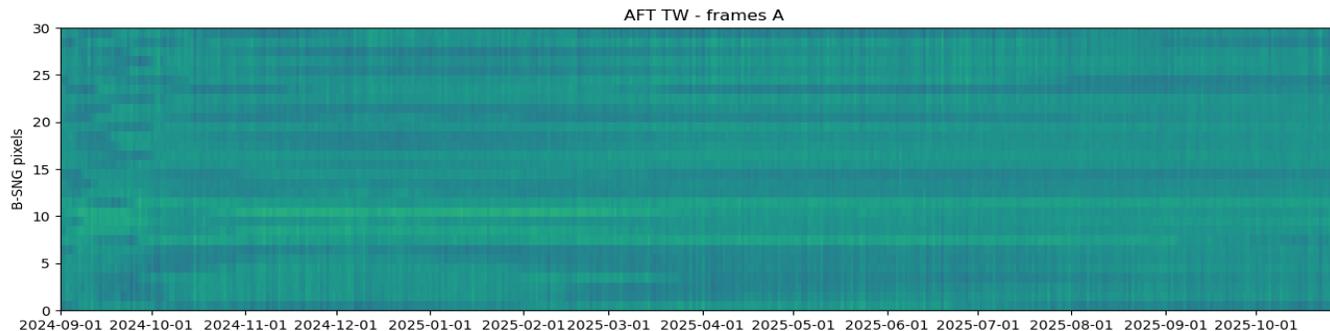
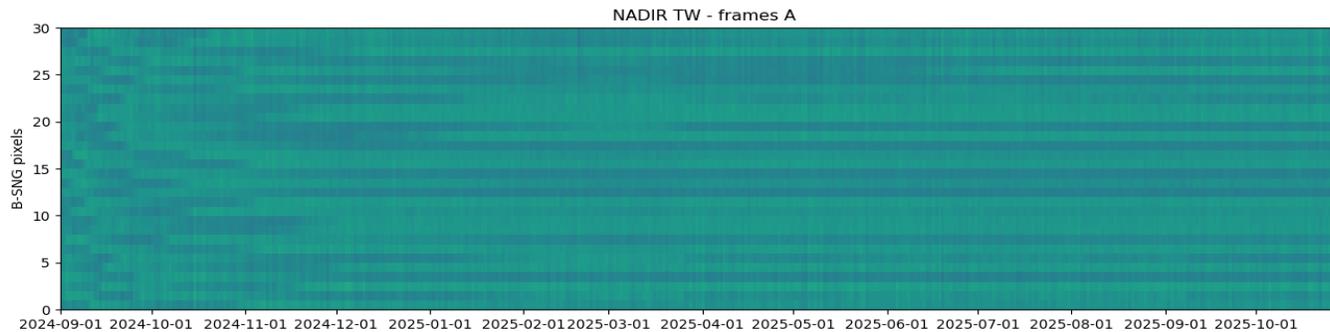
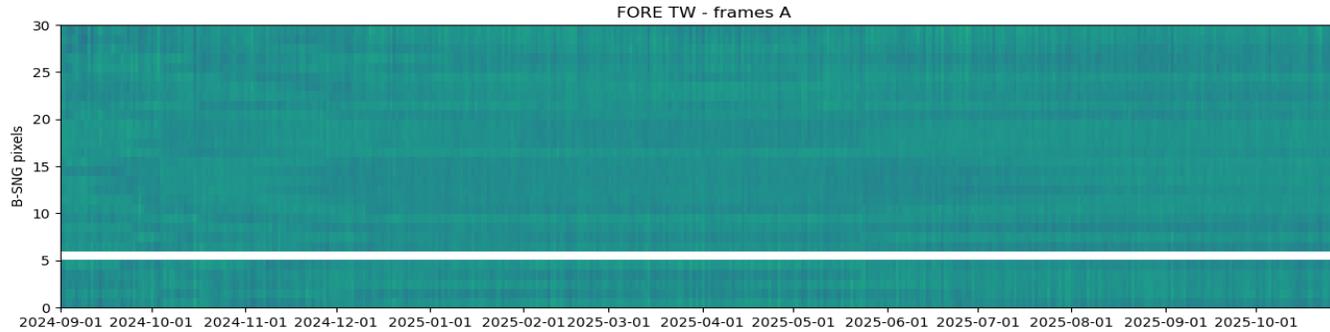


Bug in the stripping correction applied for the fore and nadir views → corrected the 5th June (frame 05793C onwards)

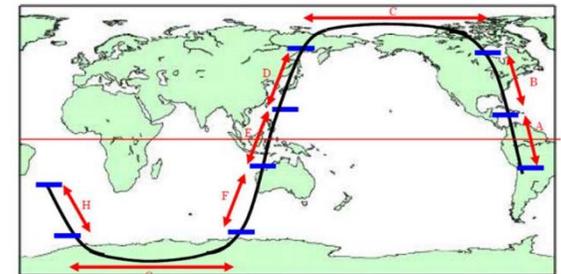
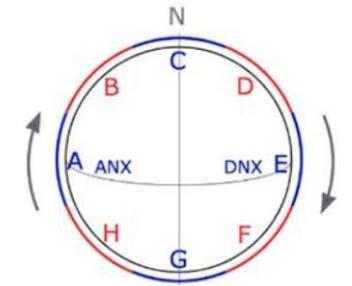


A, B, H: night
D, E, F: day
C, G: day or night depending on the season

TW Nighttime Frames A

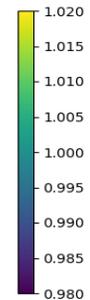
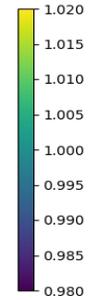
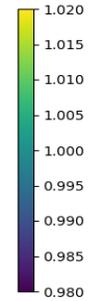
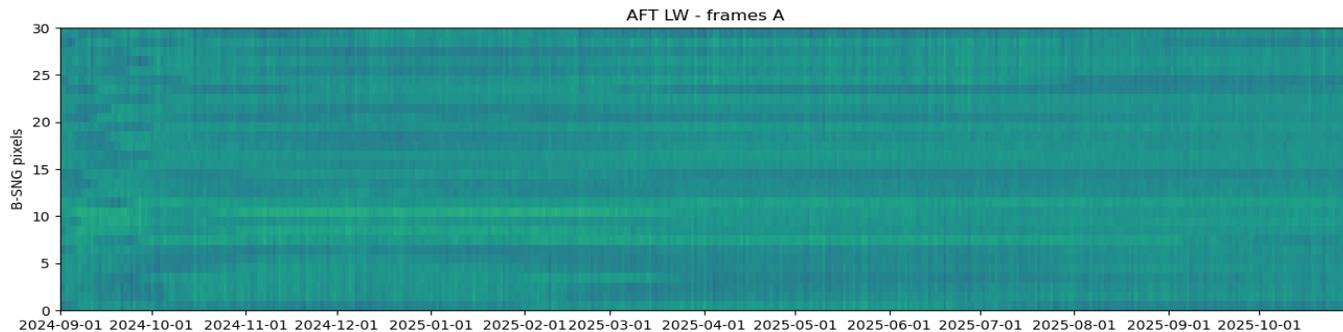
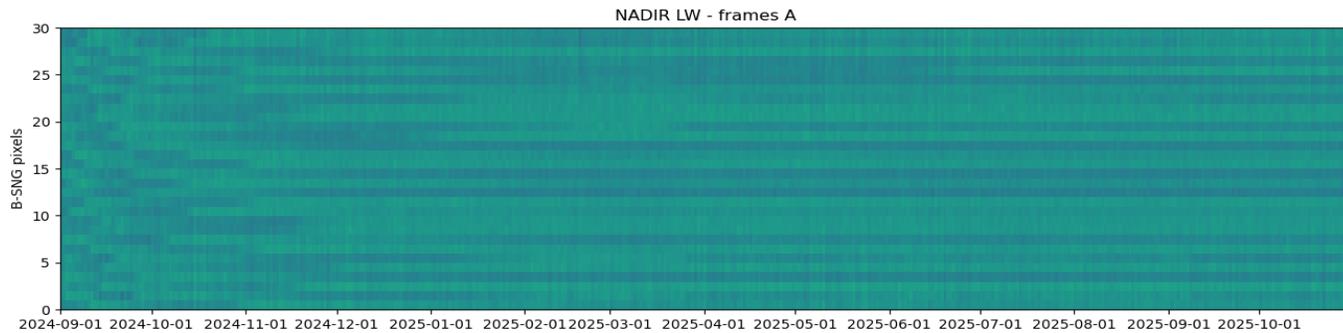
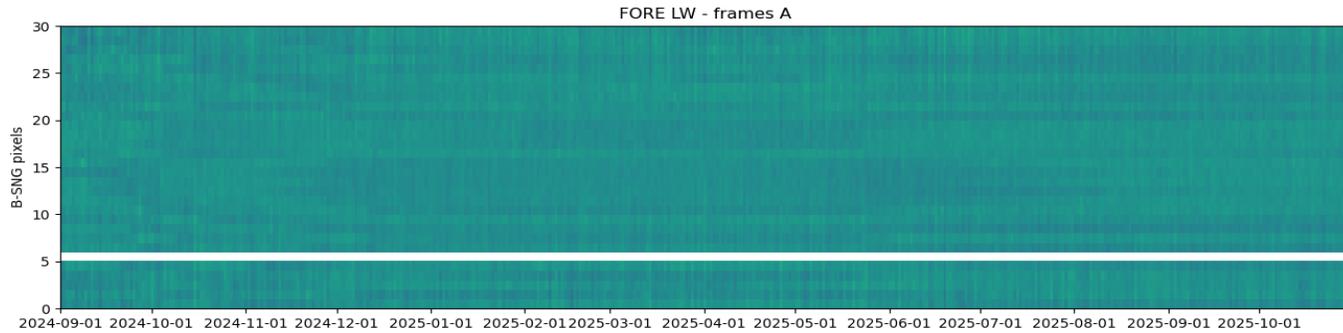


Bug in the stripping correction applied for the fore and nadir views → corrected the 5th June (frame 05793C onwards)

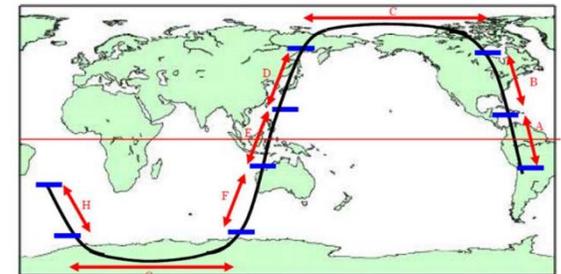
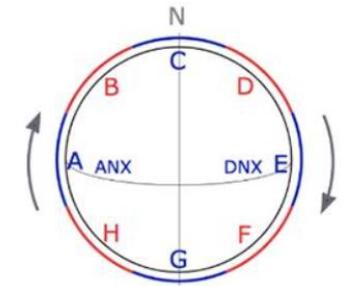


A, B, H: night
D, E, F: day
C, G: day or night depending on the season

LW Nighttime Frames A



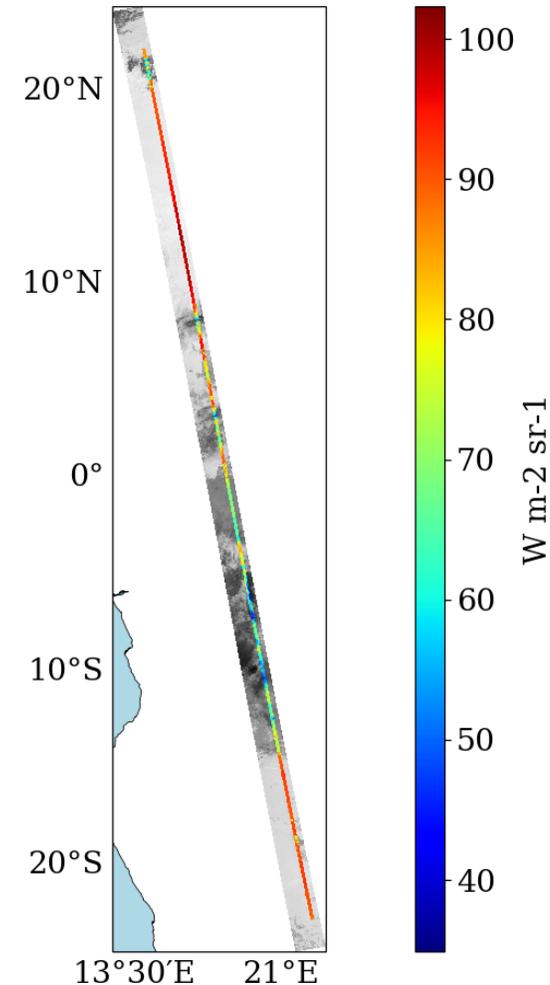
Bug in the stripping correction applied for the fore and nadir views → corrected the 5th June (frame 05793C onwards)



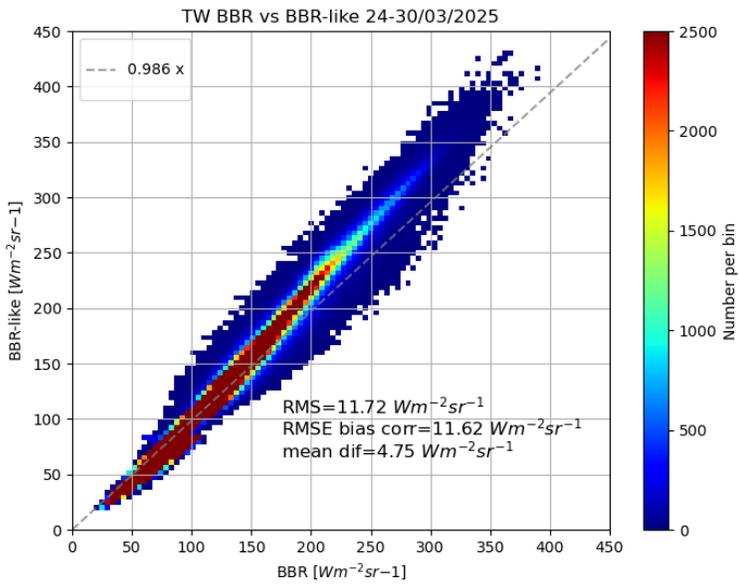
A, B, H: night
D, E, F: day
C, G: day or night depending on the season

- The BBR-like broadband product is calculated from narrowband MSI VNS reflectances and TIR radiances, by using theoretical regressions derived from Radiative Transfer Model calculations.
- The estimated broadband shortwave reflectances are converted into radiances taking into account the Sun-Earth distance at the mean frame time and shortwave/total-wave channel contamination.
- The estimated broadband radiances are then reprojected back into the grid implicitly defined by the BBR acquisitions, in order to provide data that are directly comparable to the BBR detectors.

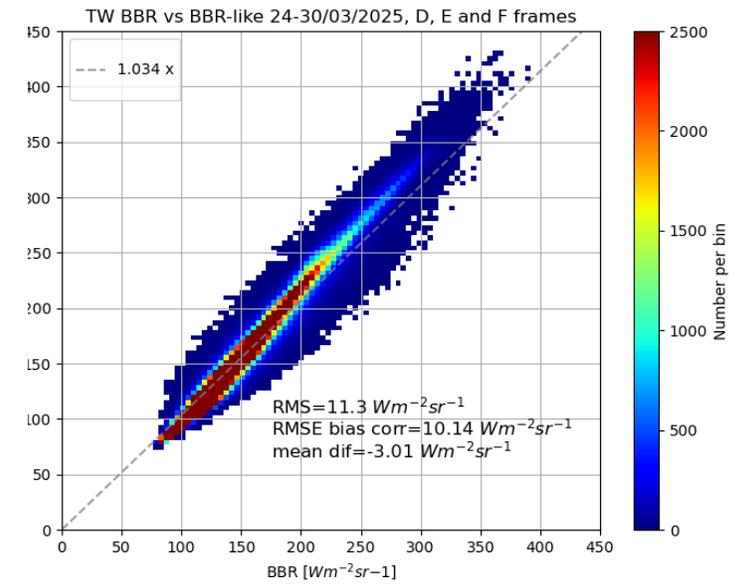
B-SNG and MSI TW radiances nadir view: 04747A



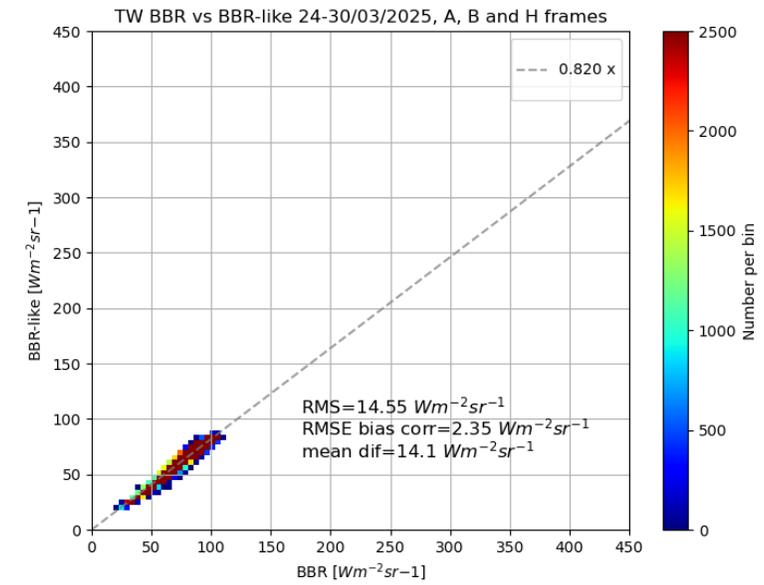
All-day



Daytime



Nighttime



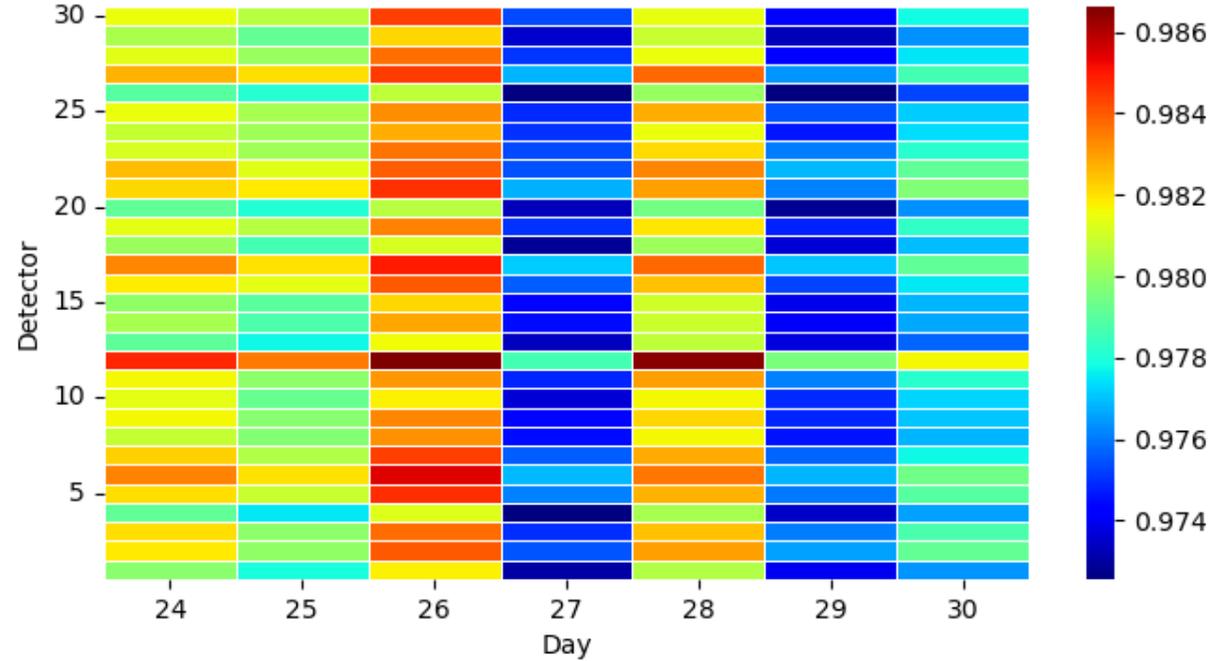


NB to BB: 24 – 30 March 2025, TW, Baseline BA

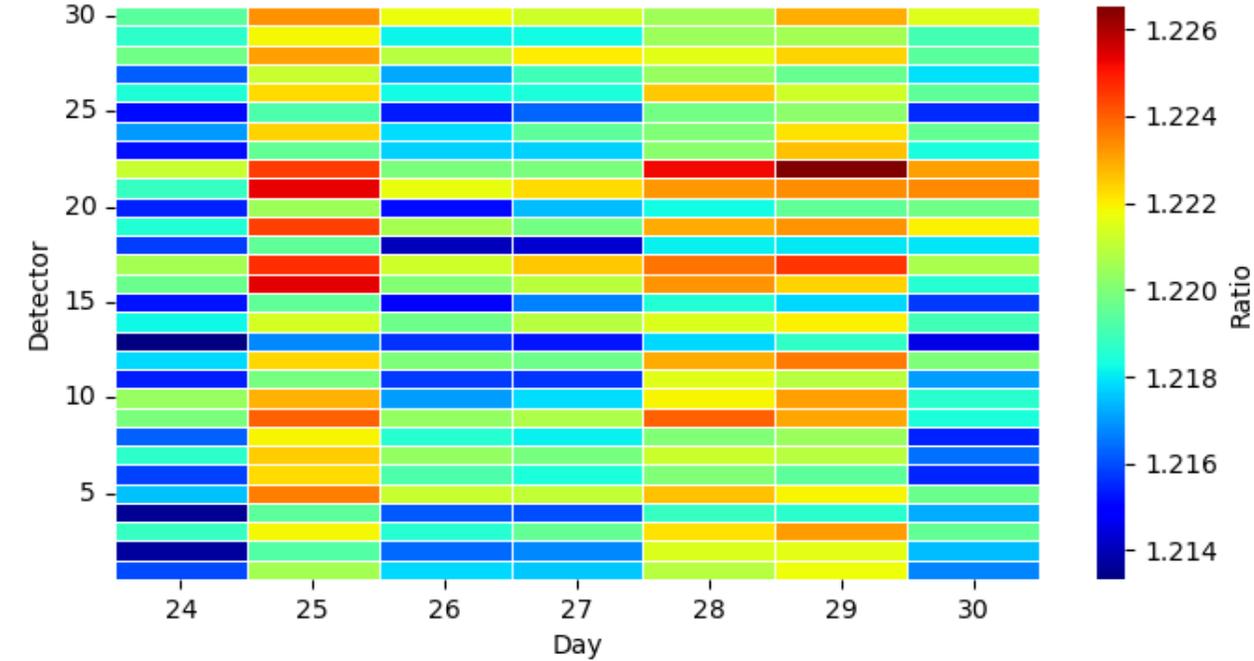
Daytime

Nighttime

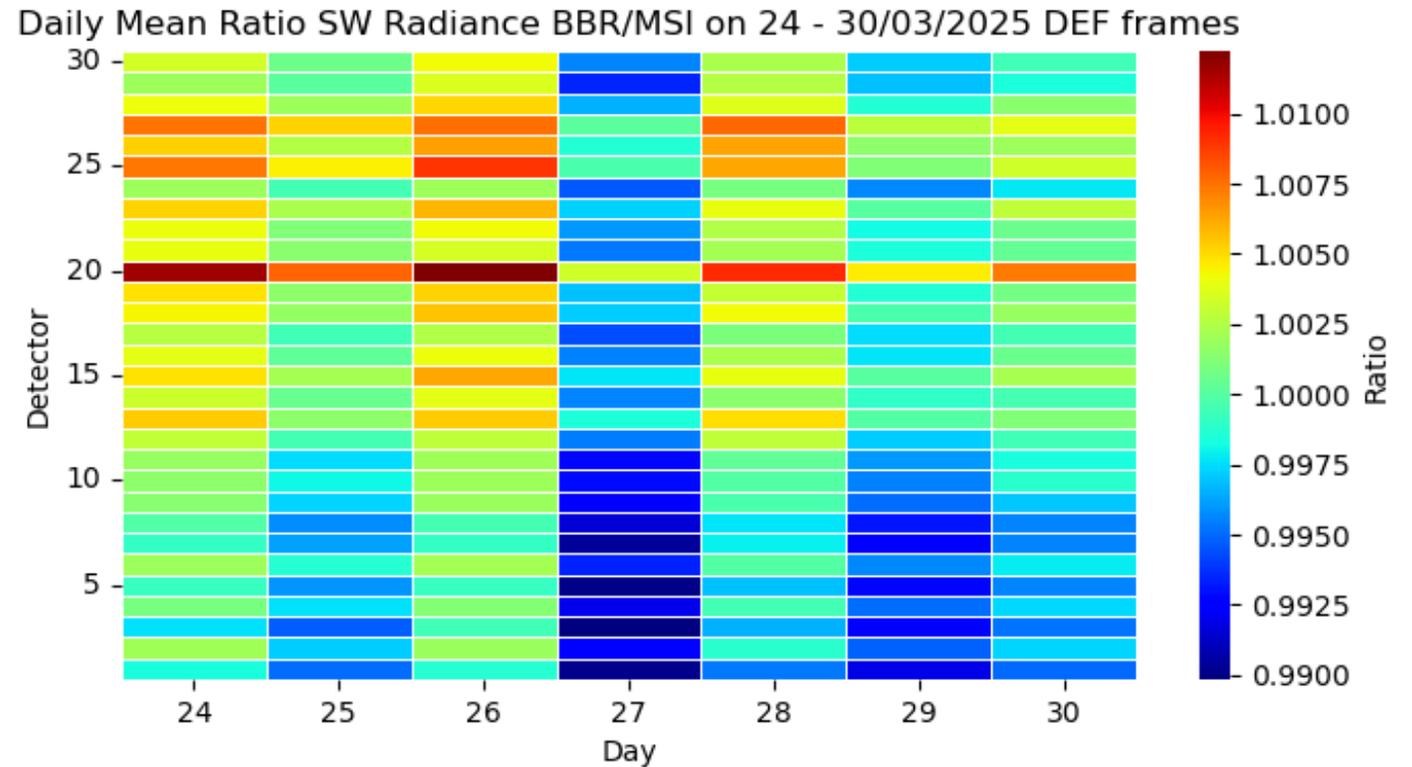
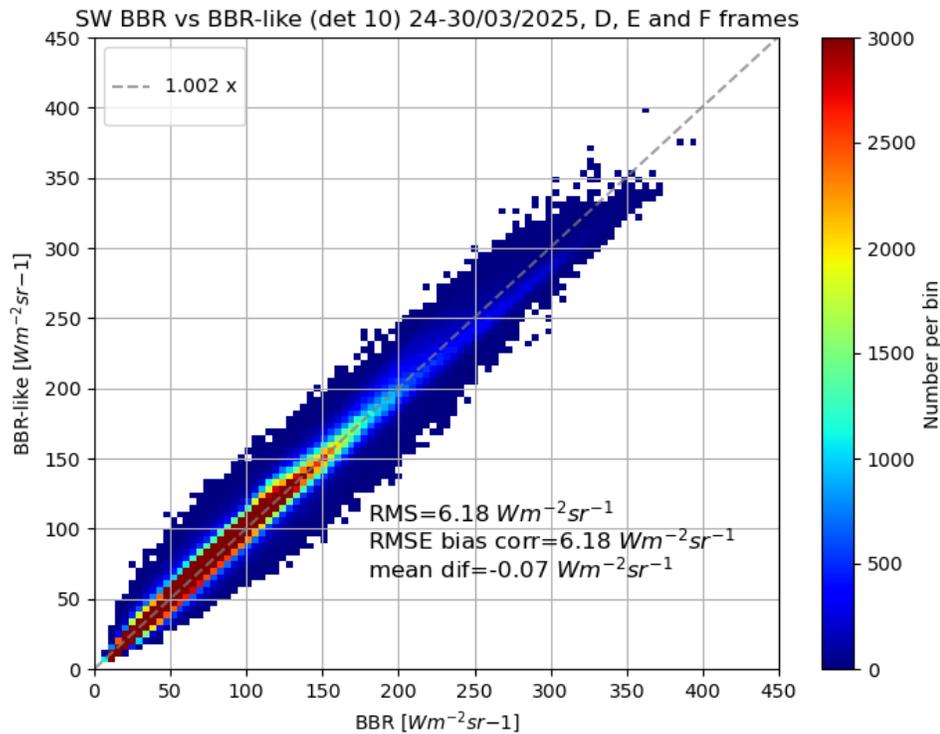
Daily Mean Ratio TW Radiance BBR/MSI on 24 - 30/03/2025 DEF frames



Daily Mean Ratio TW Radiance BBR/MSI on 24 - 30/03/2025 ABH frames



Daytime



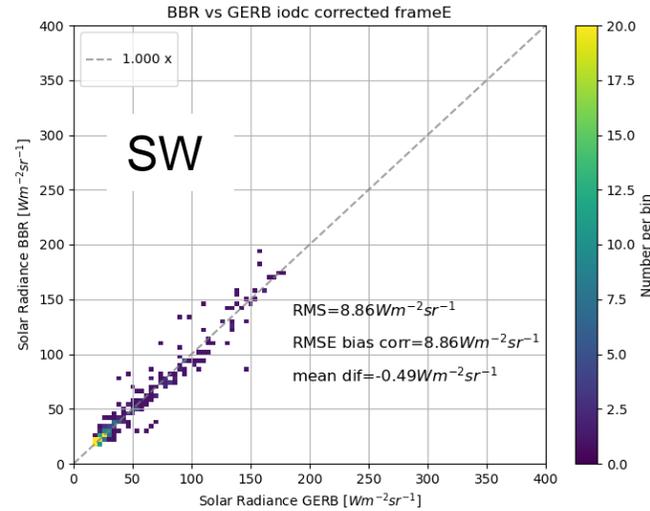


GERB-1 comparison: SW and LW Radiance, Baseline BA

- GERB-1 is over the Indian ocean.
- Data from 28 May 2025 to 5 August 2025.
- Only nadir comparisons.

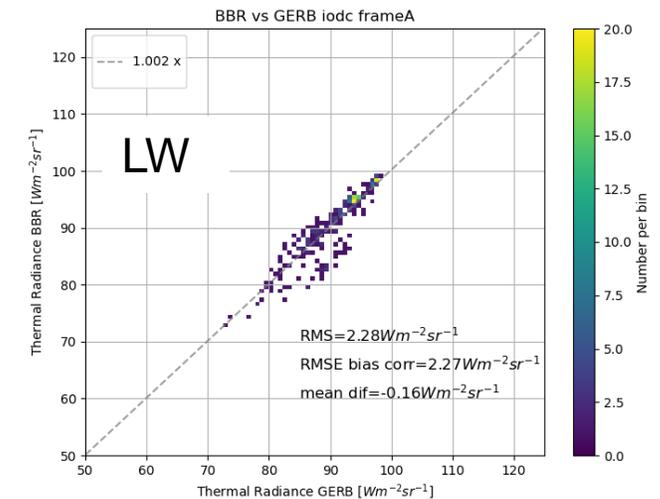
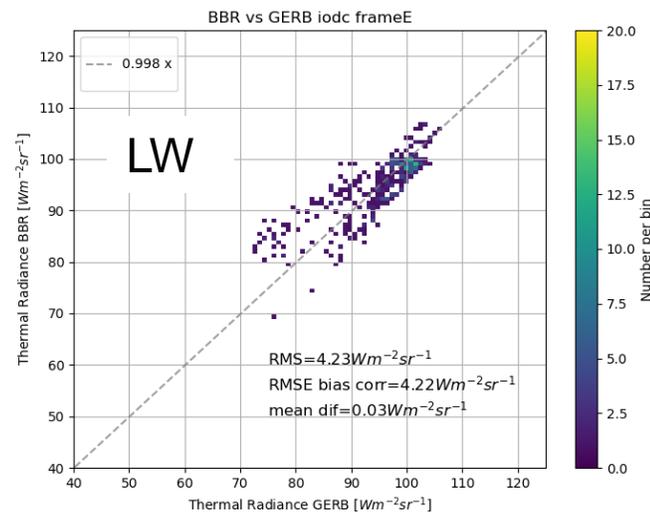
GERB VZA < 3 deg
 Δ dist < 3 km
 Δ time < 5 min

Daytime



Nighttime

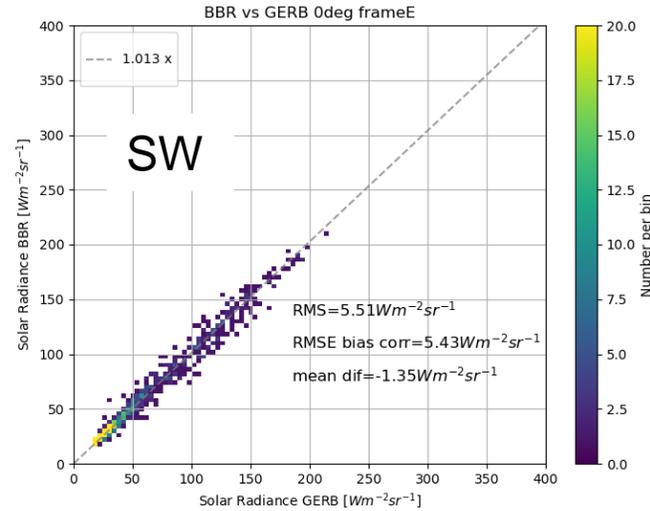
- GERB 1 user corrections applied.



- GERB-3 at 0deg
- Data from 28 May 2025 to 5 August 2025
- Only nadir comparisons

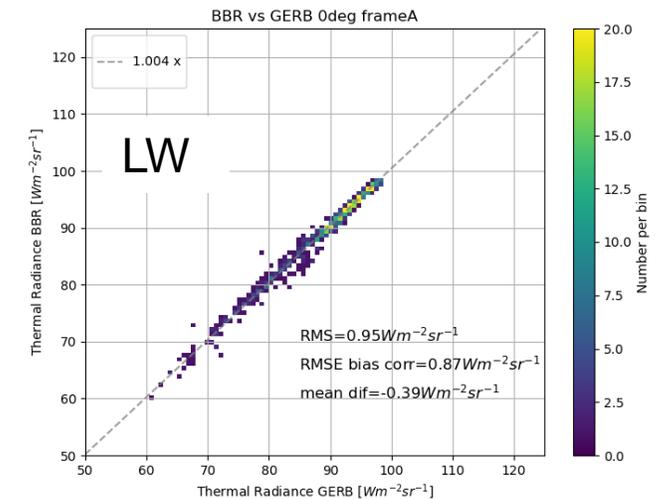
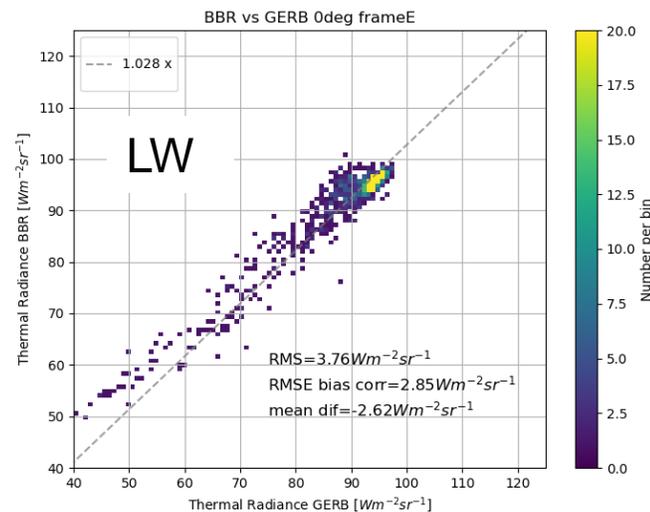
GERB VZA < 3 deg
 Δ dist < 3 km
 Δ time < 5 min

Daytime



Nighttime

- BBR solar radiances are slightly higher than GERB

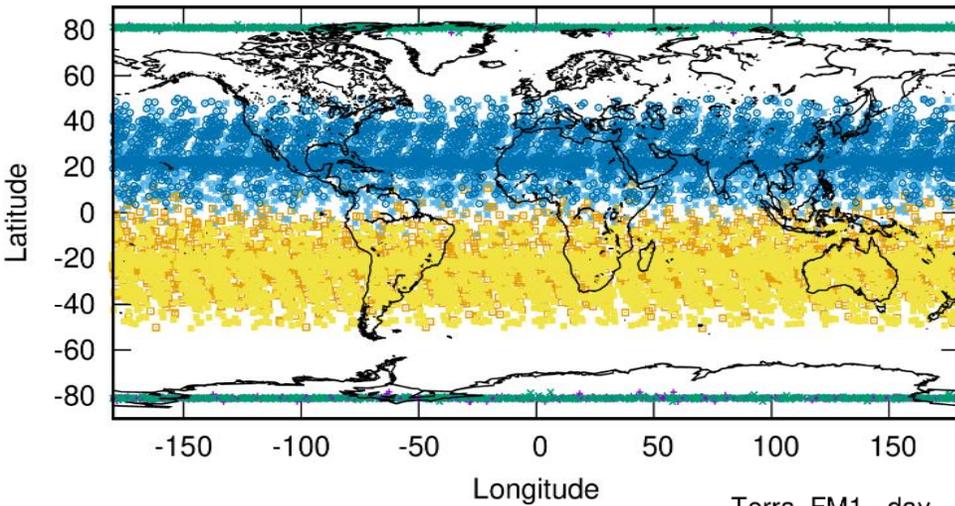




CERES SSF comparison: SW Flux, Baseline BA

10 August 2024 to
30 April 2025

CERES VZA < 50°
Δdist < 3 km
Δtime < 5 min



SW flux vs CERES SSF:

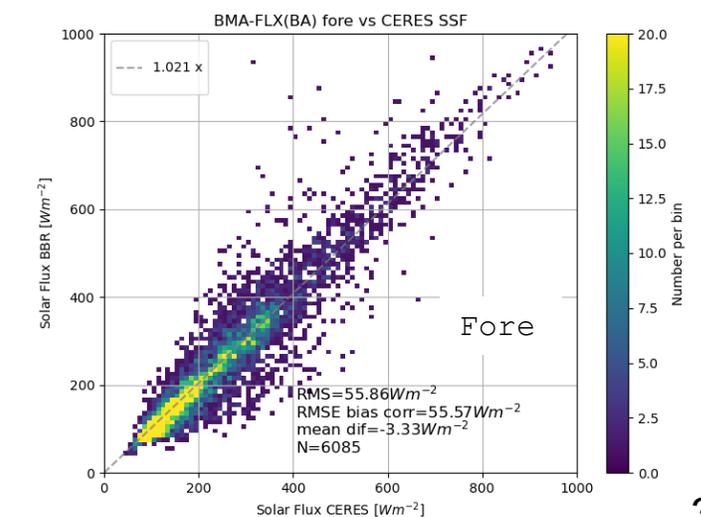
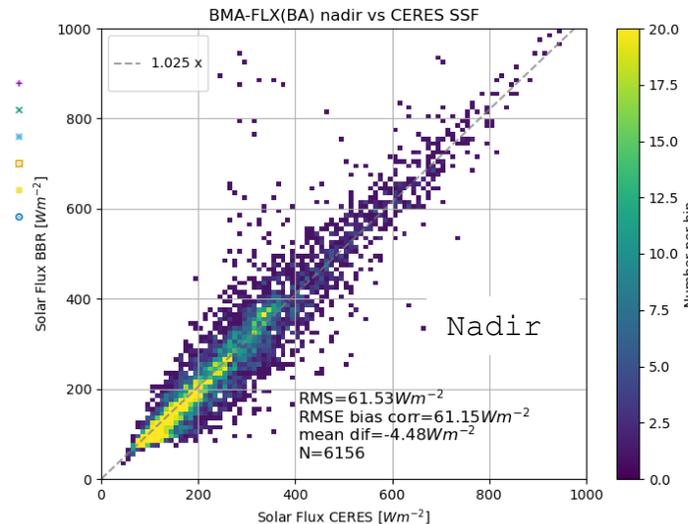
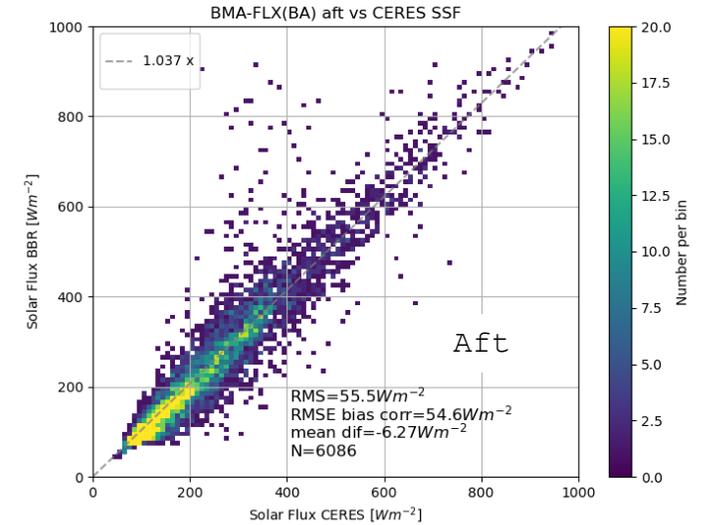
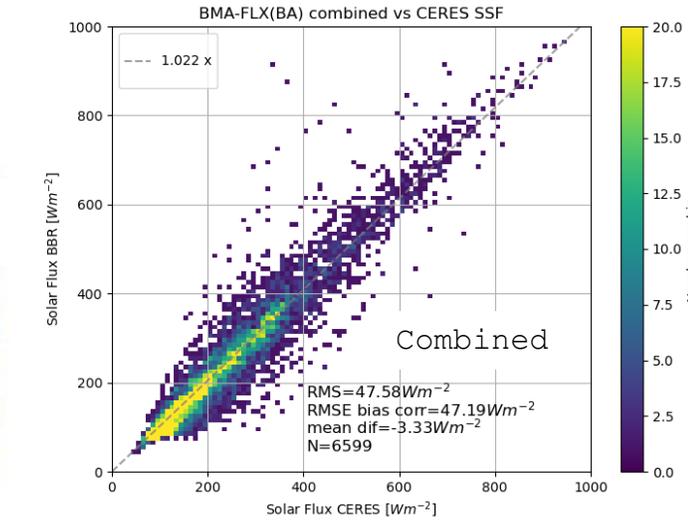
Aft : BBR = 1.037 CERES

Nadir: BBR = 1.025 CERES

Fore : BBR = 1.021 CERES

Combined: BBR = 1.022 CERES

Terra FM1 - day
 Terra FM1 - night
 Aqua FM3 - day
 Aqua FM3 - night
 NOAA20 FM6 - day
 NOAA20 FM6 - night

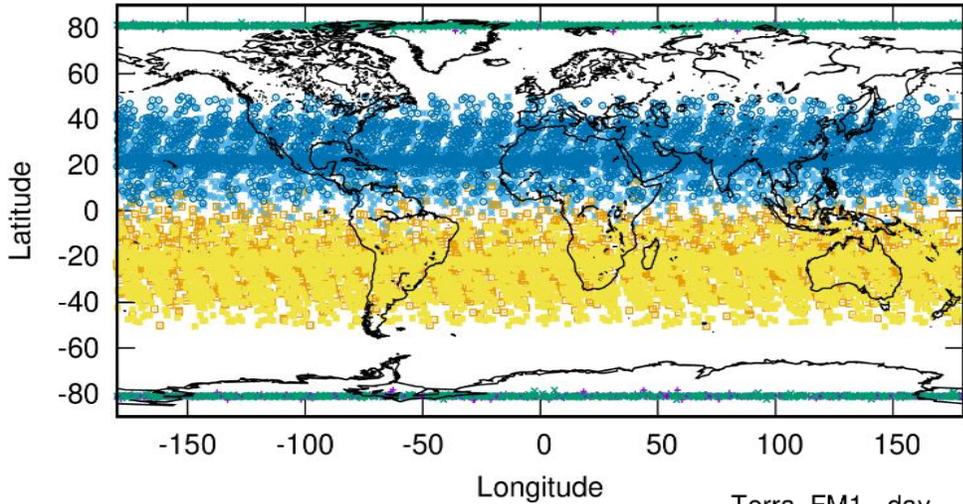




CERES SSF comparison: LW Flux, Baseline BA

10 August 2024 to
30 April 2025

CERES VZA < 50°
Δdist < 3 km
Δtime < 5 min



SW flux vs CERES SSF:

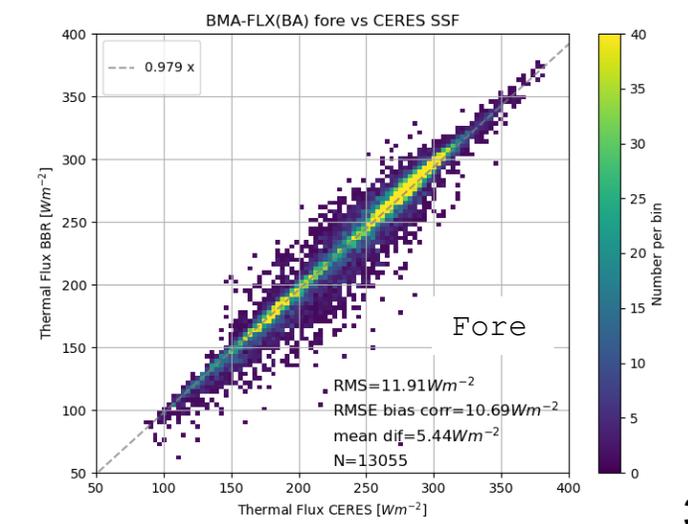
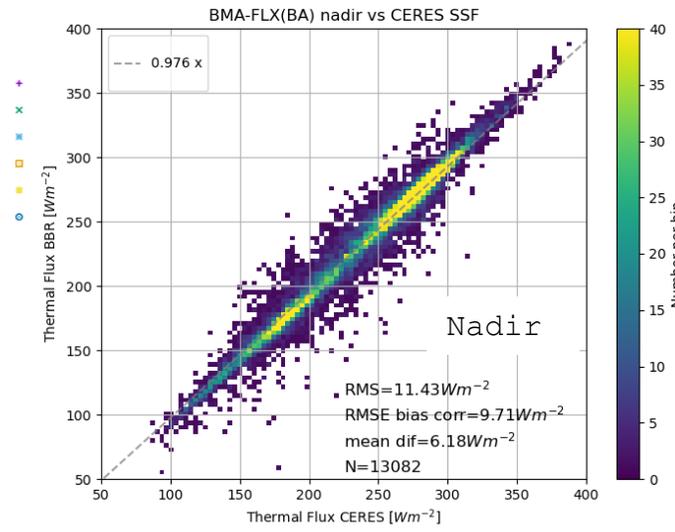
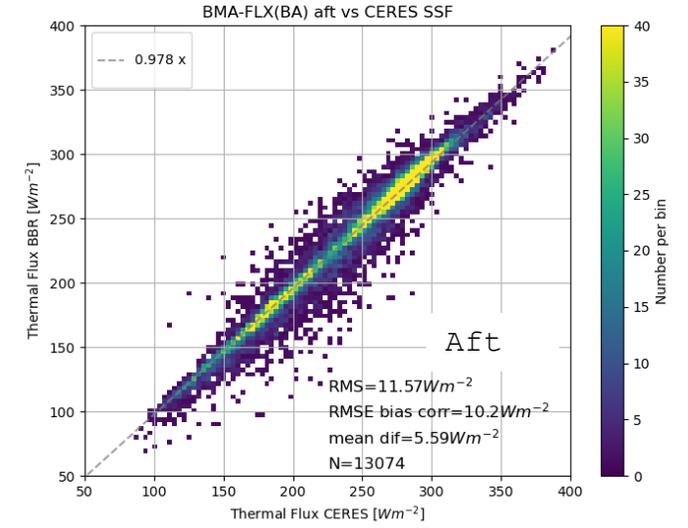
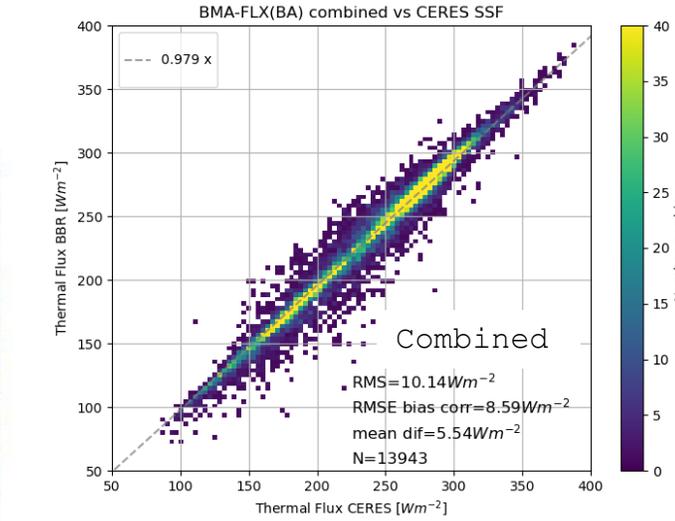
Aft : BBR = 0.978 CERES

Nadir: BBR = 0.976 CERES

Fore : BBR = 0.979 CERES

Combined: BBR = 0.979 CERES

Terra FM1 - day
 Terra FM1 - night
 Aqua FM3 - day
 Aqua FM3 - night
 NOAA20 FM6 - day
 NOAA20 FM6 - night



EarthCARE's broadband radiometer sees contrails over the Bay of Biscay

Contrails are elongated clouds that are formed by aeroplanes at high altitude. Under certain conditions of temperature and humidity, contrails can persist and evolve in aviation-induced cloudiness (AIC). The radiative effect of these clouds on Earth's climate, their climate *forcing*, is receiving more attention as it becomes evident that they are responsible for a non-negligible part of the climate impact of the aviation sector. Like natural clouds, AIC presents a cooling effect, due to reflection of incident solar radiation, and a strong greenhouse warming effect for terrestrial radiation. In some conditions (i.e., in daytime at low latitudes), the resulting net effect can be cooling, but in general the warming effect is predominant, in particular during the night or at high latitudes. Numerous international programmes are now addressing climate forcing due to contrails.

In this image, the Earth Cloud, Aerosol and Radiation Explorer (EarthCARE) satellite provides the perfect suite of instruments to detect contrails, characterise their optical properties, and quantify their radiative effects. The images show an overpass of a contrail over the Bay of Biscay on 30 April 2025 at 14:38 UTC. The characteristic shape of the contrails is visible in colour from the Broadband Radiometer (BBR) shortwave (SW) and in black and white from the Multi-Spectral Imager (MSI) thermal infrared (TIR-3) channel.

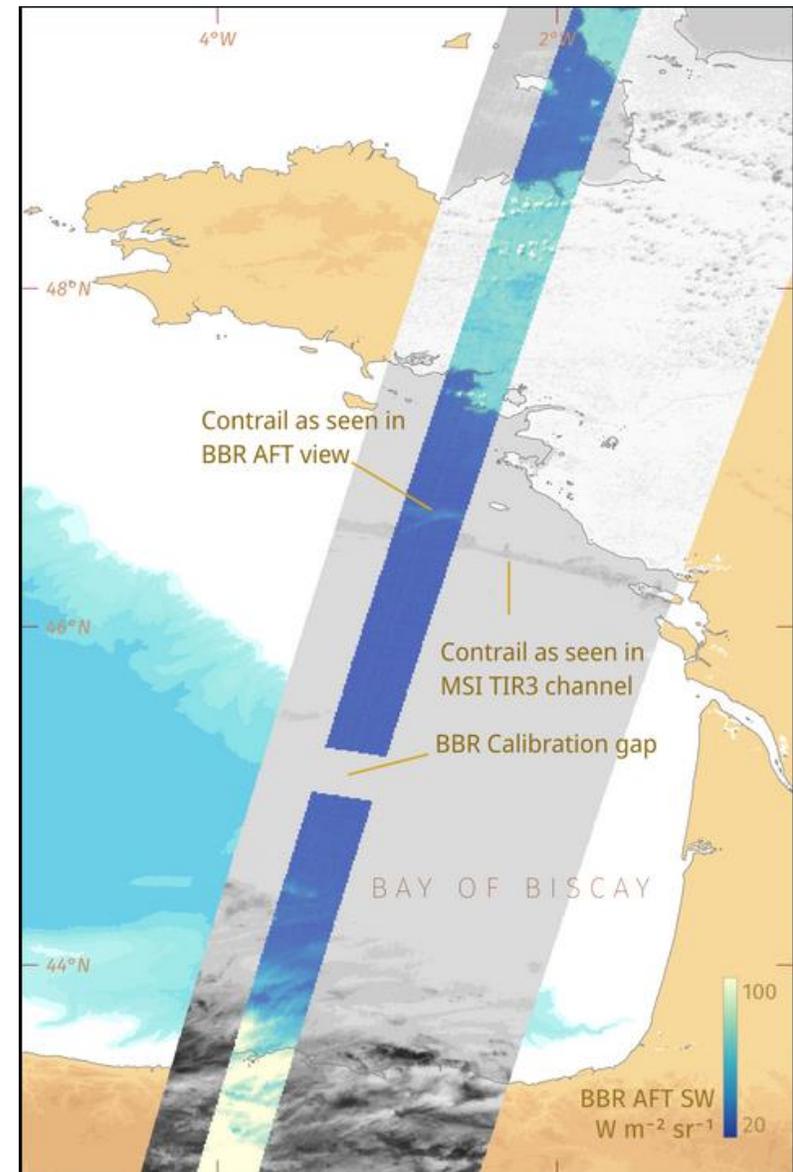
In the image, the BBR measurement from the *aft* view (at a viewing zenith angle of 55 degrees) is shown, thus the parallax with the MSI nadir measurement in the background. In addition, the Atmospheric Lidar (ATLID) instrument provides an accurate estimate of the contrail's altitude, which is the determinant for the warming effect. Outgoing radiance in the shortwave band, as measured by the BBR, is indicated by the key to the bottom right.

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Work Package number:	WP4
Work Package Title:	Quantitative evaluation of level 2 flux products, closure analysis
Responsible entity:	RMIB
WP responsible person	Aebi
Project phases (0,A,B,C,D,E):	E
Beginning and end dates of WP	01.01.2026 – 31.12.2026
Total FTE allocated to the WP	12 PM (1 FTE)
Objectives of the WP	Quantitative assessment of the BBR combined fluxes accuracy with respect to the scientific requirement of 10 W/m ² closure.
<p>Inputs:</p> <ul style="list-style-type: none"> • Tools from WP0. • L2 BMA-FLX data • CERES (SSF) and GERB (HR) data <p>Description of work and schedule:</p> <ul style="list-style-type: none"> • Qualitative evaluation of the BMA-FLX product: telescope specific fluxes, combined flux, reference level. Context from MSI color composite images and ATLID profiles. • Intercomparison with CERES and GERB fluxes using the collocated database from WP3. Analysis as function of scene type and homogeneity, solar zenith angle and observation conditions. • Verify closure with ACM-RT. The analysis will consider scenes for which simulated radiances match the 3 view observations. <p>Excluded tasks: validation at instrumented sites.</p> <p>Deliverables and dates:</p> <ul style="list-style-type: none"> • BBR L2b fluxes quantitative assessment report (30.06.2026). • Flux closure assessment report (31.12.2026). • Recommendation for BMA-FLX processor evolution. <p>Risks:</p> <ul style="list-style-type: none"> • Quality / maturity of ACM-RT product wrt the 10 W/m² requirement. 	

- Monitoring of various parameters in L1 and L2 (including new baseline-releases).
 - Stability checks
 - Checks for ageing.
- Continuation of the monitoring of potential issues/ageing of the instruments with the BBR-like product.
 - Improve the NB2BB for the TW.
 - Extend the analysis.
- Continuation of the analysis with GERB and CERES data.
- Find a way to handle all data gaps when the instrument is switched off.
- Potentially writing a scientific peer-reviewed publication.