



Koninklijk Meteorologisch Instituut België

Institut Royal Météorologique
Belgique

Königliches Meteorologisches
Institut Belgien

Royal Meteorological
Institute of Belgium

BRAVO

Progress Meeting (4) - WP3

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

24 April 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"> 3.1 • Basic, qualitative, evaluation of the BM-RAD product, including visualization (context from MSI images). 3.2 • Comparison unfiltered radiances with the Earth targets defined in WP1. 3.3 • Comparison with coangular co-incident observations from GERB and CERES to assess absolute level (calibration), and scene type consistency (spectral response/unfiltering). 3.4 • 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>	

Outlook from progress meeting on February 21, 2025

- Continuation of the monitoring of various parameters in L1 and L2 (including new baseline-releases).
- Continuation of the analysis of changes per month or even per day.
 - Will there be a reprocessing with the new baseline for all data (e.g. for B-NOM AD)?

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- Participation and poster presentation at the EarthCARE Validation Workshop in March 2025.
→ Title: EarthCARE BBR Validation Results within the BRAVO Project

EarthCARE BBR Validation Results within the BRAVO Project

Christine Aebi¹, Almudena Velazquez Blazquez¹, Edward Baudrez¹ and Nicolas Clerbaux¹
¹ Royal Meteorological Institute of Belgium (RMIB)



Introduction

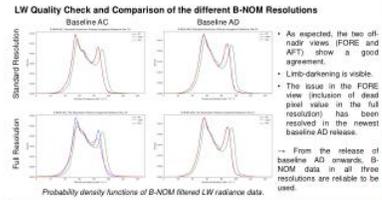
- The BroadBand Radiometer (BBR) on board the EarthCARE satellite is composed of three telescopes (NADIR, FORE and AFT), positioned along-track, with a fixed viewing angle each.
- The BBR is measuring the (filtered) shortwave (SW; 0.25 – 4.0 μm) and totalwave (TW; 0.25 – ~50 μm) radiance. The longwave (LW; 4.0 – ~50 μm) is thereafter calculated from the two aforementioned radiances.
- There are different BBR products provided as level-1 (B-SNG, B-NOM) and level-2 (BM-RAD and BMA-FLX).
- Within the Broadband Radiometer Verification (BRAVO) project, the BBR solar and thermal radiances and fluxes (level-1 and level-2) are validated and, among others, compared to data from various instruments, such as GERB or CERES.
- Shown here are first validation results of the B-NOM and the BM-RAD products. B-NOM is providing filtered radiances, whereas BM-RAD is providing unfiltered radiances.

Resolutions B-NOM and BM-RAD Products

Resolution	Along x Across Track	Product
Small	10 x 5 km ²	B-NOM, BM-RAD
Standard	10 x 10 km ²	B-NOM, BM-RAD
Full	10 x ~17 km ² (nadir) 10 x ~28 km ² (off-nadir)	B-NOM, BM-RAD
Assessment Domain	5 x 21 JSG	BM-RAD

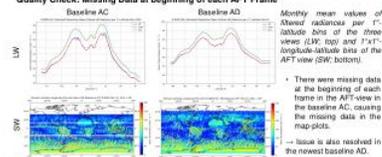
B-NOM: Quality Checks and Improvements with new Baseline

LW Quality Check and Comparison of the different B-NOM Resolutions



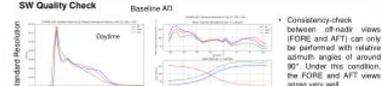
- As expected, the two off-nadir views (FORE and AFT) show a good agreement.
- Limb-darkening is visible.
- The issue in the FORE view (inclusion of dead pixel value in the full resolution) has been resolved in the newest baseline AD release.
- From the release of baseline AD onwards, B-NOM data in all three resolutions are reliable to be used.

Quality Check: Missing Data at beginning of each AFT Frame



- Monthly mean values of observed radiances per 1°-latitude bin of the three views (LW_top and 1°x1°-longitude/latitude bin of the AFT view SW_bottom).
- There were missing data at the beginning of each frame in the AFT-view in the baseline AC causing the missing data in the map-plot.
- Issue is also resolved in the newest baseline AD.

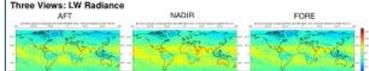
SW Quality Check



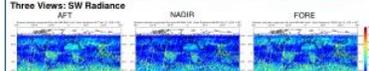
- Consistency check between off-nadir views (FORE and AFT) can only be performed with relative azimuth angles of around 90°. Under this condition, the FORE and AFT views agree very well.

BM-RAD Validation

Three Views: LW Radiance

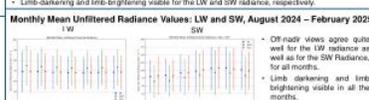


Three Views: SW Radiance



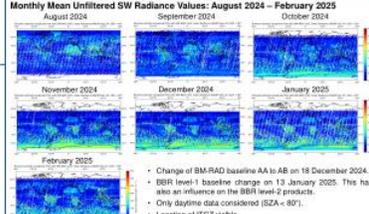
- Off-nadir views agree quite well for the LW radiance as well as for the SW Radiance.
- Limb-darkening and limb-brightening visible for the LW and SW radiance, respectively.

Monthly Mean Unfiltered Radiance Values: LW and SW, August 2024 – February 2025



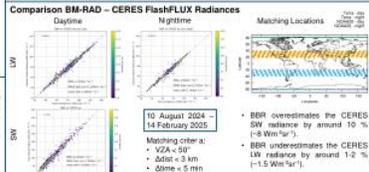
- Off-nadir views agree quite well for the LW radiance as well as for the SW Radiance, for all months.
- Limb-darkening and limb-brightening visible in all the months.

Monthly Mean Unfiltered SW Radiance Values: August 2024 – February 2025



- Change of BM-RAD baseline AA to AB on 18 December 2024.
- BBR level-1 baseline change on 13 January 2025. This has also an influence on the BBR level-2 products.
- Only daytime data considered (SZA < 80°).
- Location of ITCZ visible.

Comparison BM-RAD – CERES FlashFLUX Radiances



Matching Locations

10 August 2024 – 14 February 2025

Matching criteria:

- SZA < 80°
- Dist < 5 km
- Diff < 5 mW/m²

- BBR overestimates the CERES SW radiance by around 10% (= 8 W/m²).
- BBR underestimates the CERES LW radiance by around 1-2% (= 1.5 W/m²).

Summary and Outlook

- The BBR is operating stable and the first months of data look very promising.
- Several issues, that were present in older baselines, have been resolved in the newest baseline releases of B-NOM and BM-RAD.
- Comparisons with the more validated CERES SSF product will be performed as soon as those data are available.
- It is also planned to perform comparisons with data from the GERB instruments.

Acknowledgement

The BRAVO project (6809144334) is funded by the ESA Prodes programme. The CERES FlashFLUX data were obtained from the NASA Langley Research Center Atmospheric Sciences Data Center.

2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop
 17–20 March 2025 | ESA-ESRIN | Frascati (Rome), Italy



- Discussions and new potential collaborations (and support) with other teams:
 - A. Ehrlich (University of Leipzig): Validation of BBR TOA broadband irradiance (BMA_FLX_2B) by high altitude airborne observations during PERCUSION.
 - S. Kazadzis (PMOD/WRC): Measurement campaign in Greece, also using BBR data.
 - K. Kentaroh (JAXA), J. Cole (Env. Canada), C. Salas (GMV) and RMIB: Collaboration for the closure study.

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- Analysis of the ratio between BBR and MSI-based BBR-like data (open point from WP2).

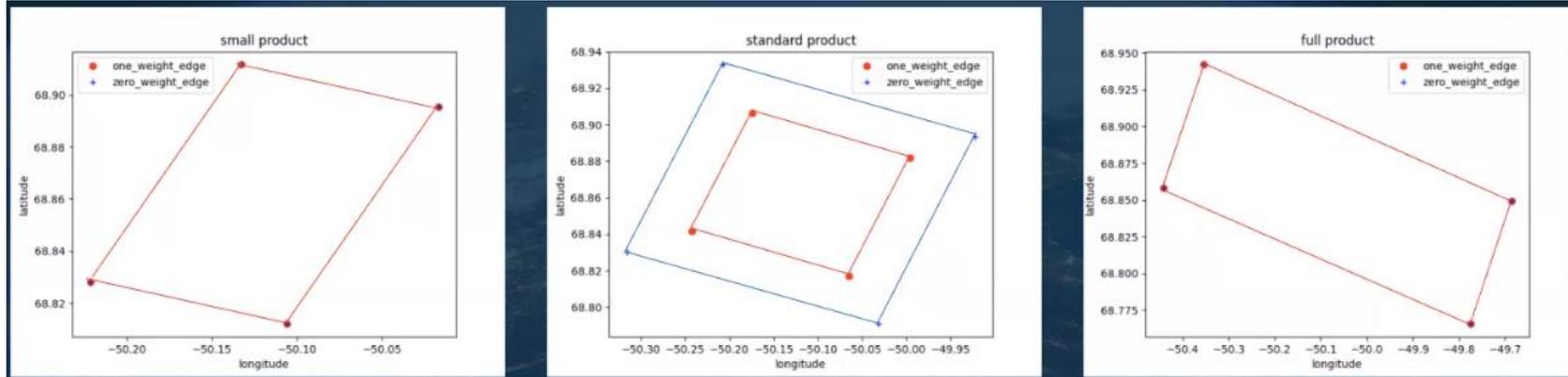
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- B-NOM

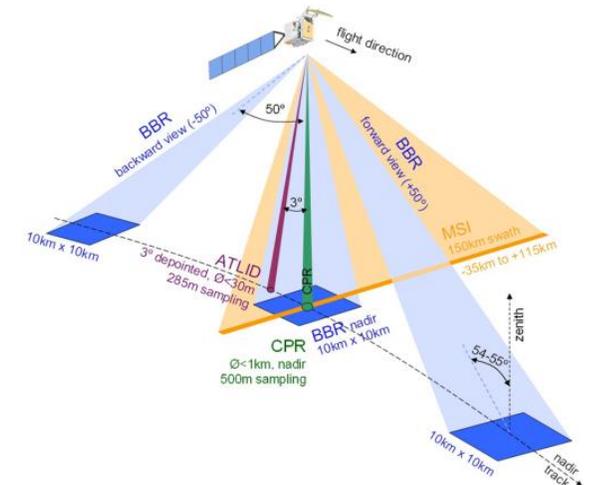
SW and **LW**
 filtered radiance
 integrated over
 three resolutions:

Resolution	along-track (km) x across-track (km)
Small	10 x 5 (configurable)
Standard	10 x 10
Full	Nadir: 10 x ~17 Off-nadir: 10 x ~ 28



- B-SNG

SW and **TW** filtered
 radiance at pixel level

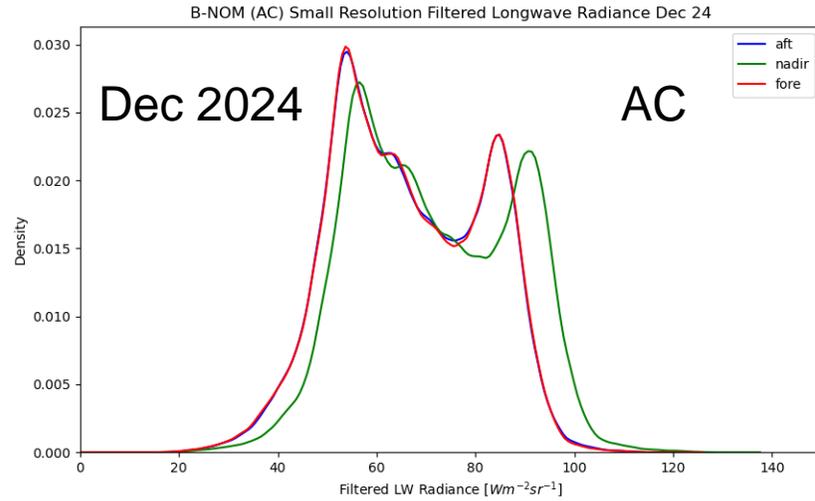


Filtered Radiances

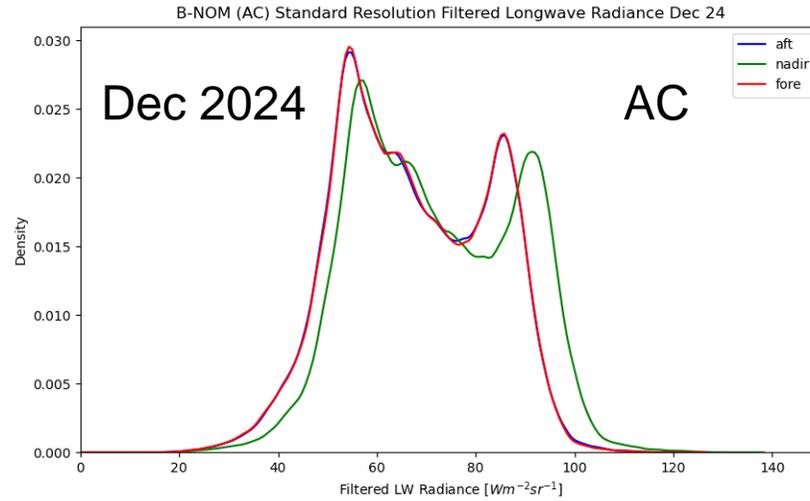


Comparison of different resolutions B-NOM product: LW Radiance

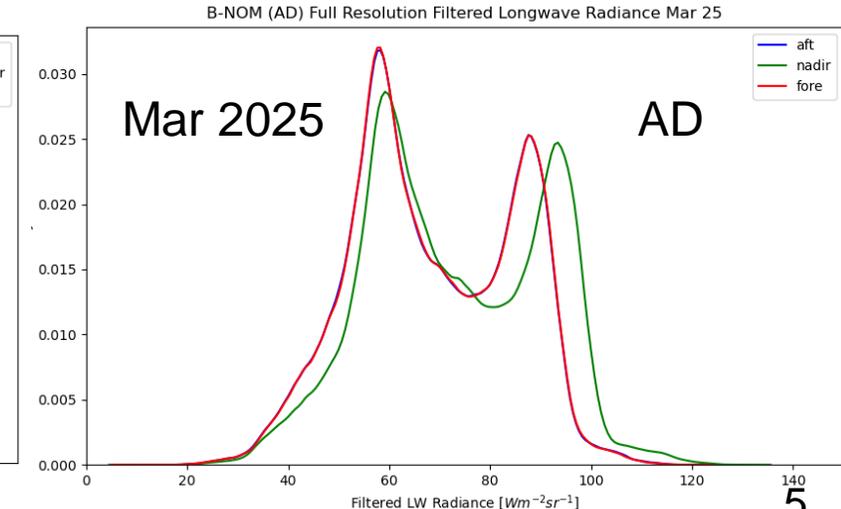
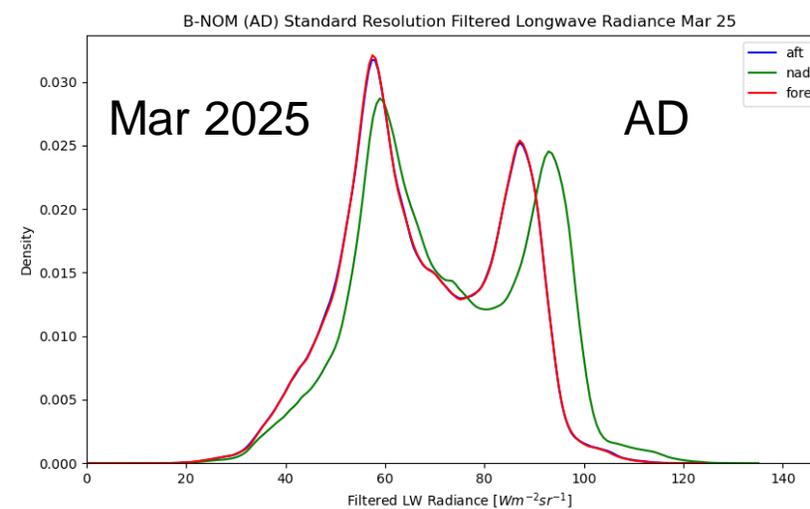
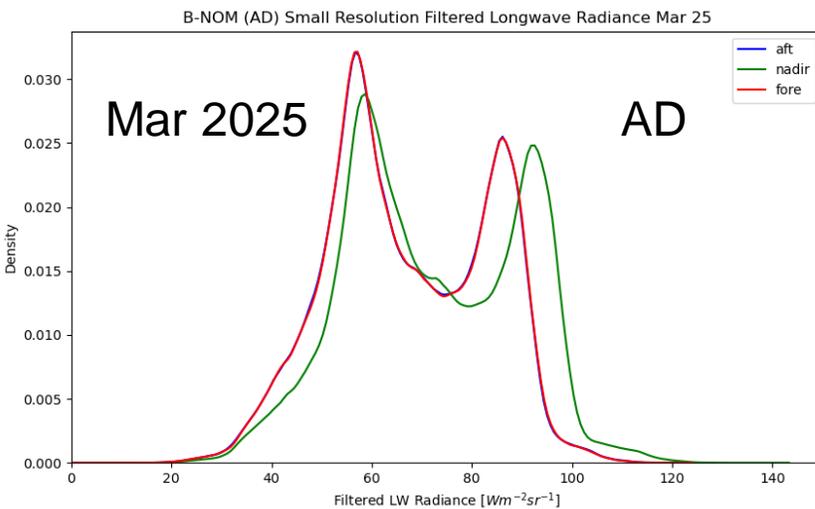
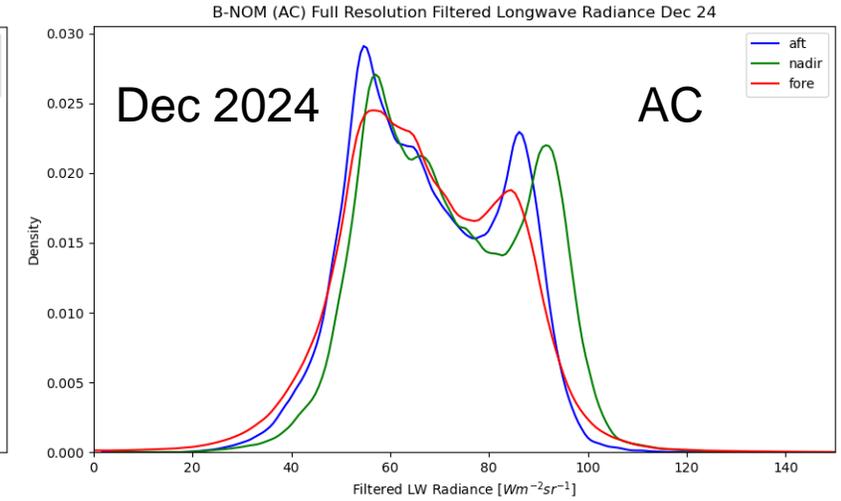
Small Resolution



Standard Resolution

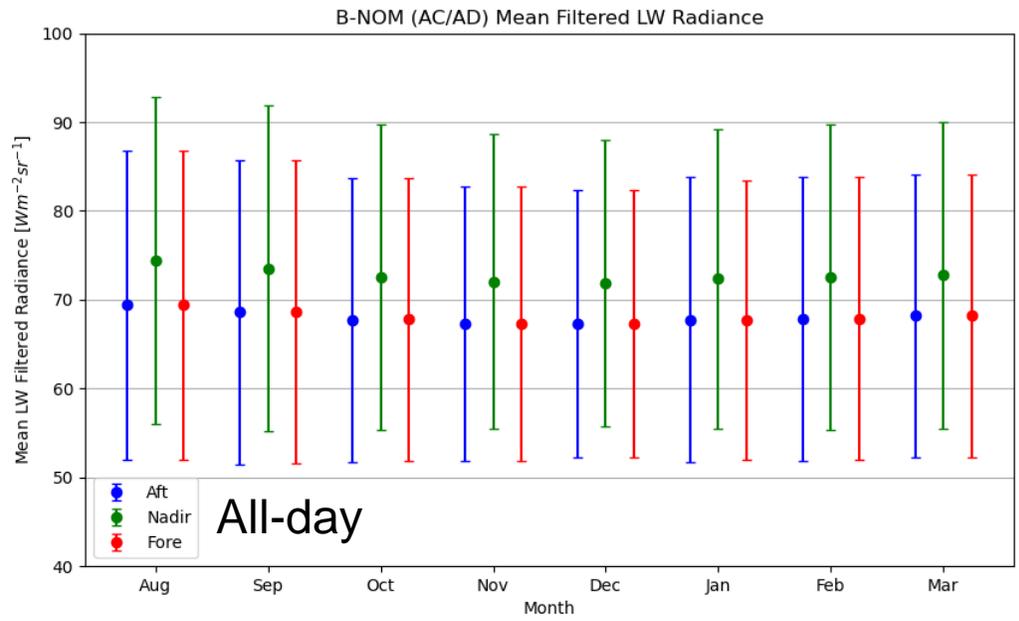


Full Resolution

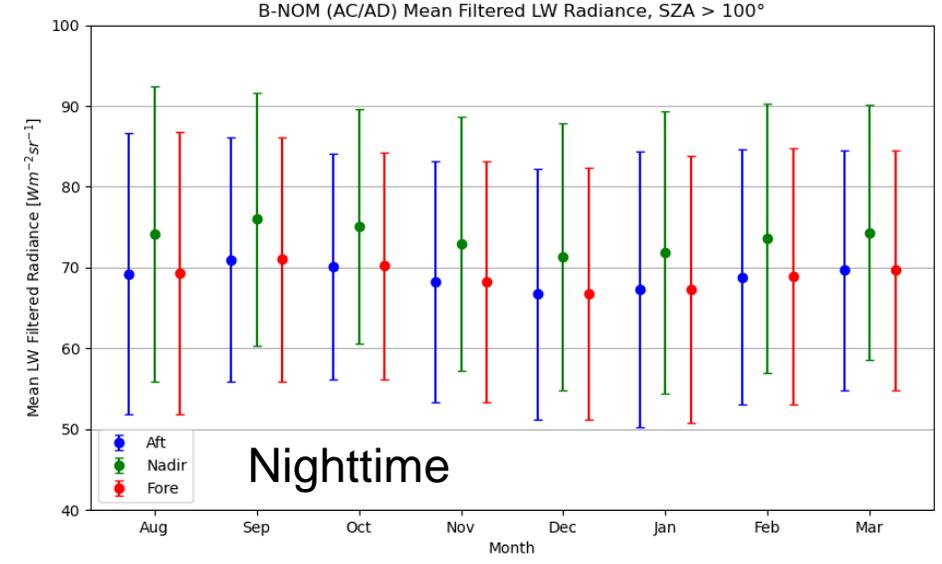
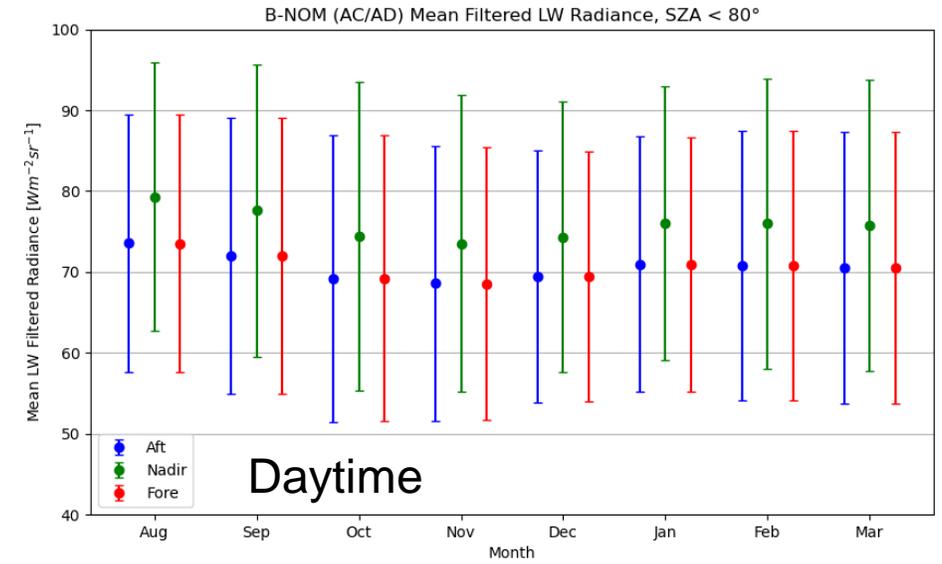




Mean Values of B-NOM Filtered LW Radiances per Month



Standard Resolution, Baseline AC and AD
(13 January 2025 onwards)



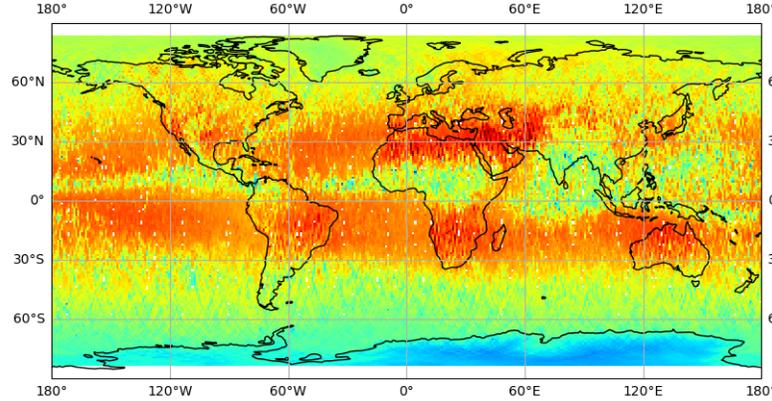


B-NOM Filt. LW Radiance per 1°x1° Lat.-Lon. Bin, Nadir, All-day

Aug 24

AC

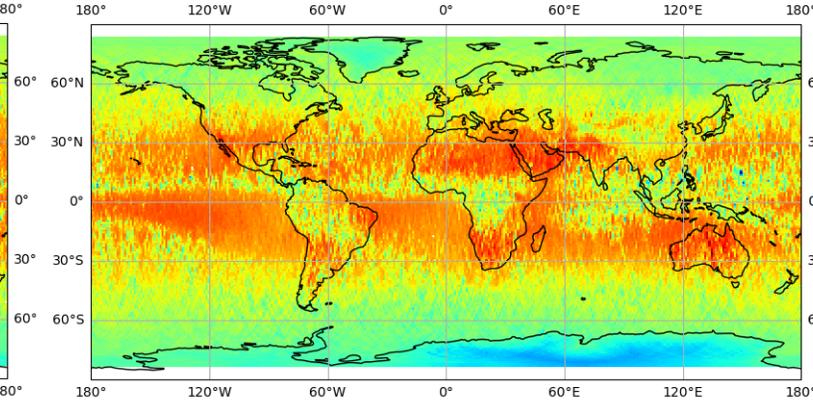
Binned Latitude-Longitude Plot with Mean LW Radiance NADIR B-NOM Aug 24



Oct 24

AC

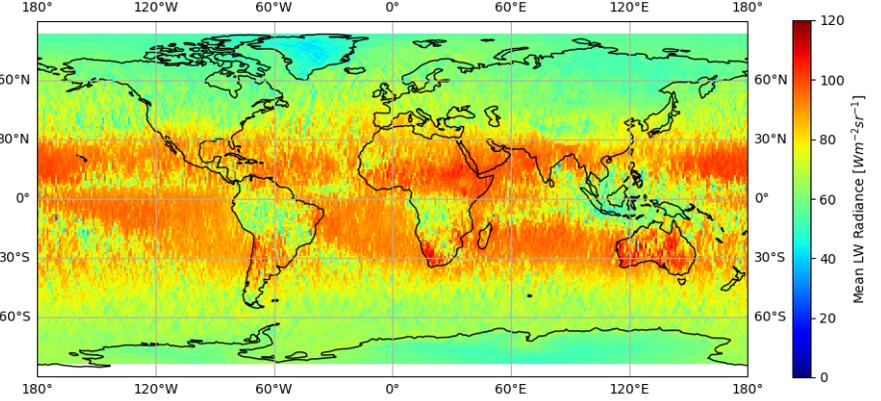
Binned Latitude-Longitude Plot with Mean LW Radiance NADIR B-NOM Oct 24



Dec 24

AC

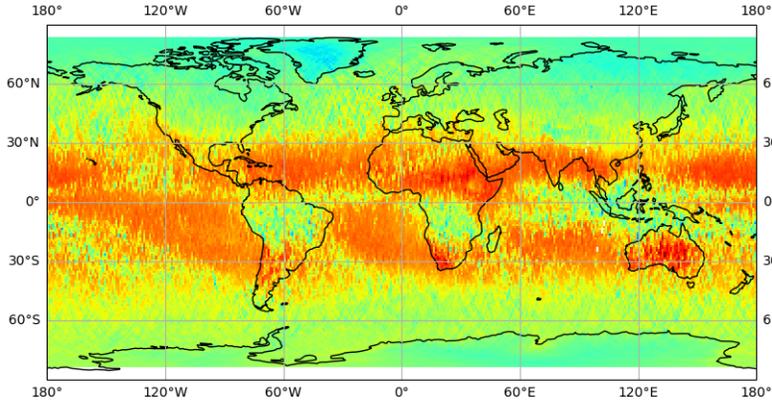
Binned Latitude-Longitude Plot with Mean LW Radiance NADIR B-NOM Dec 24



Jan 25

AC/AD

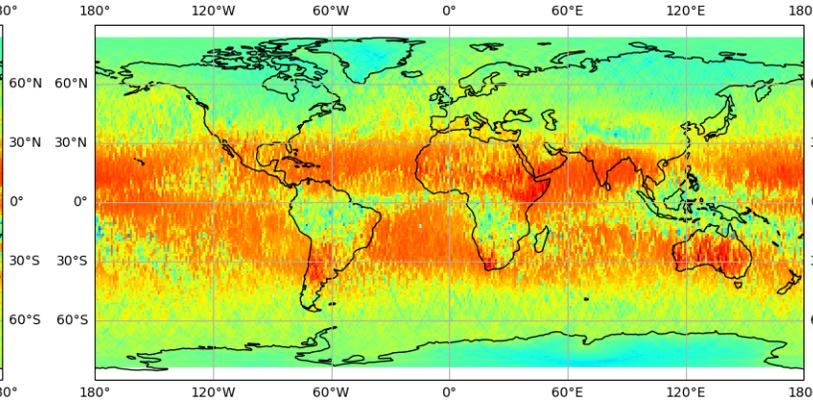
Binned Latitude-Longitude Plot with B-NOM Filt. LW Radiance NADIR Jan 25



Feb 25

AD

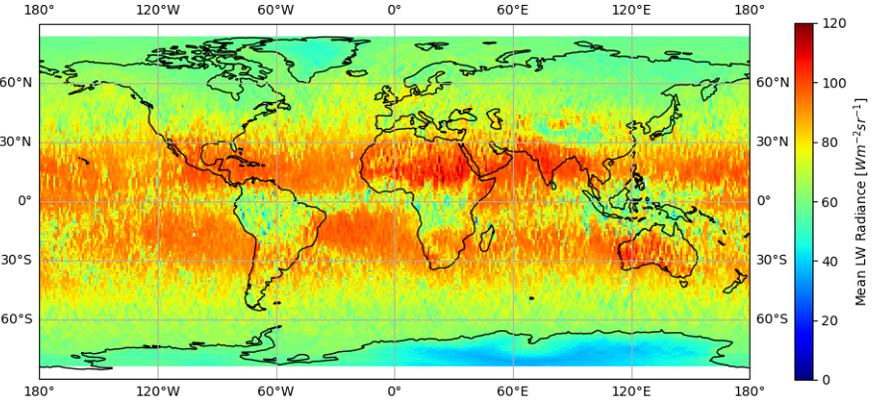
Binned Latitude-Longitude Plot with B-NOM Filt. LW Radiance NADIR Feb 25



Mar 25

AD

Binned Latitude-Longitude Plot with B-NOM Filt. LW Radiance NADIR Mar 25





B-NOM Filt. LW Radiance per 1°x1° Lat.-Lon. Bin, Aft, Daytime

Aug 24

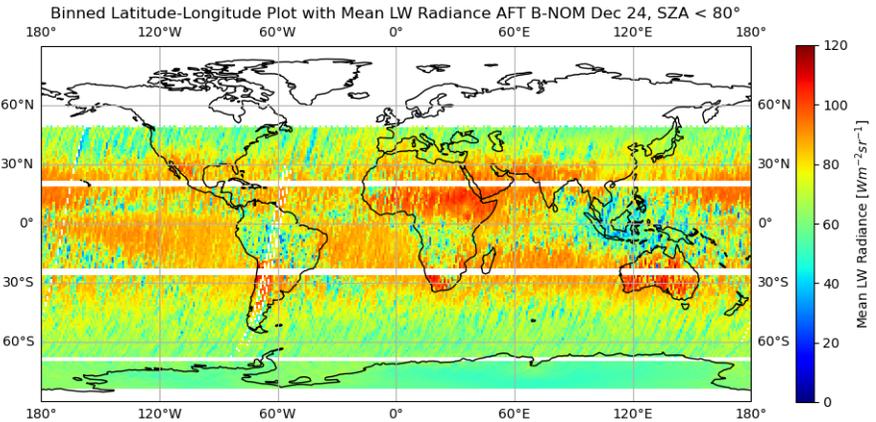
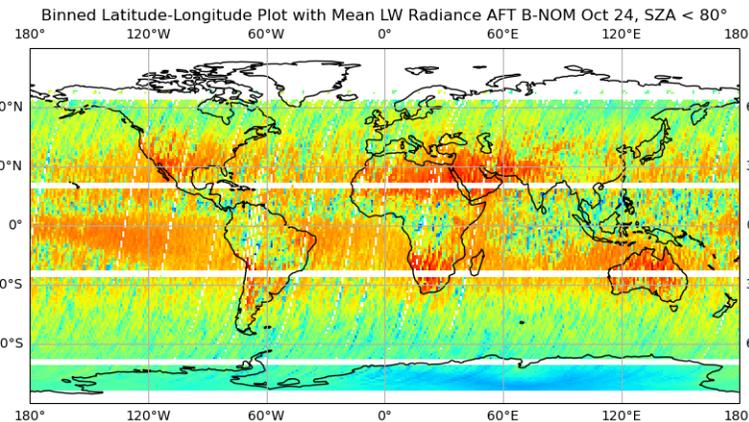
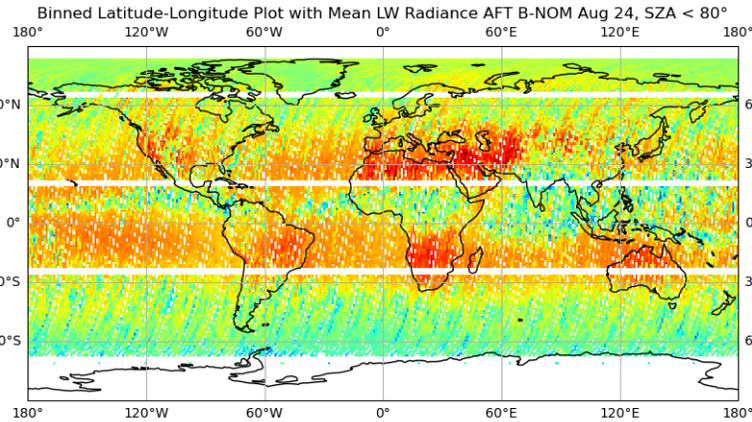
AC

Oct 24

AC

Dec 24

AC



Jan 25

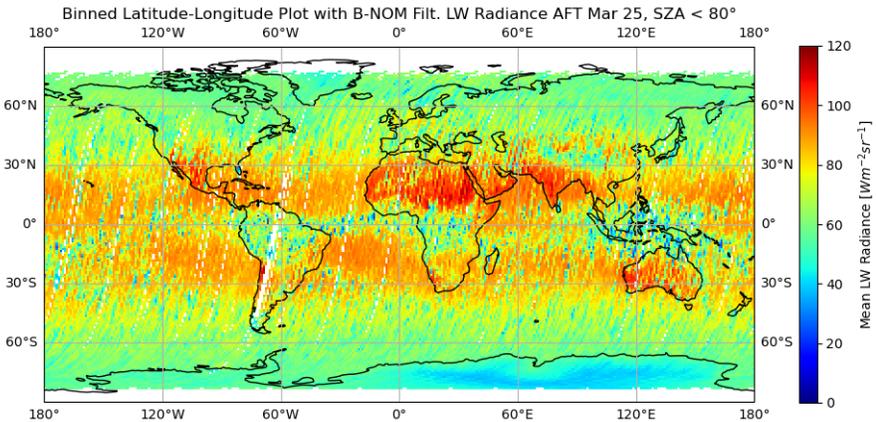
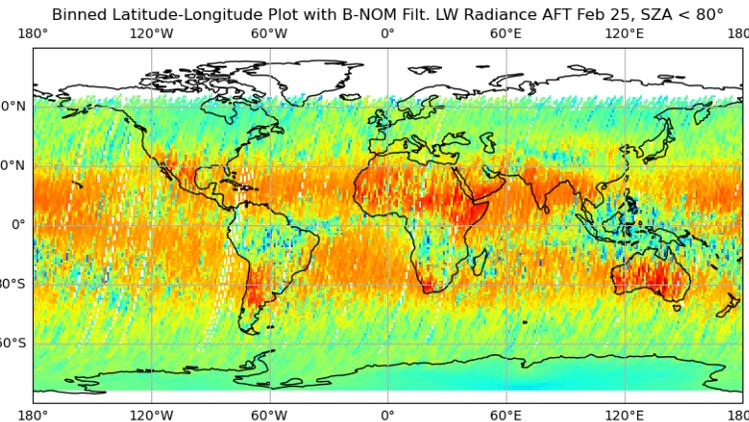
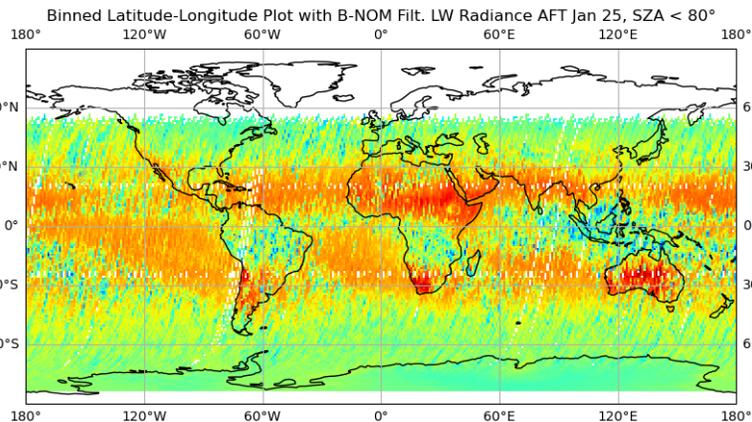
AC/AD

Feb 25

AD

Mar 25

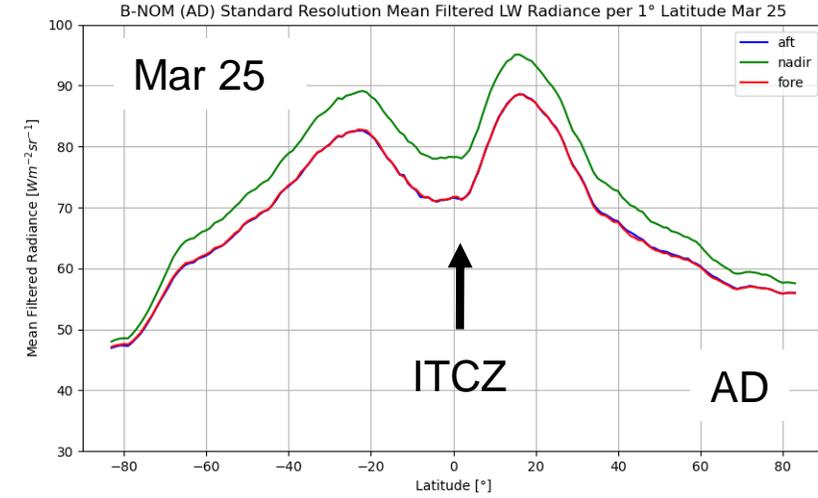
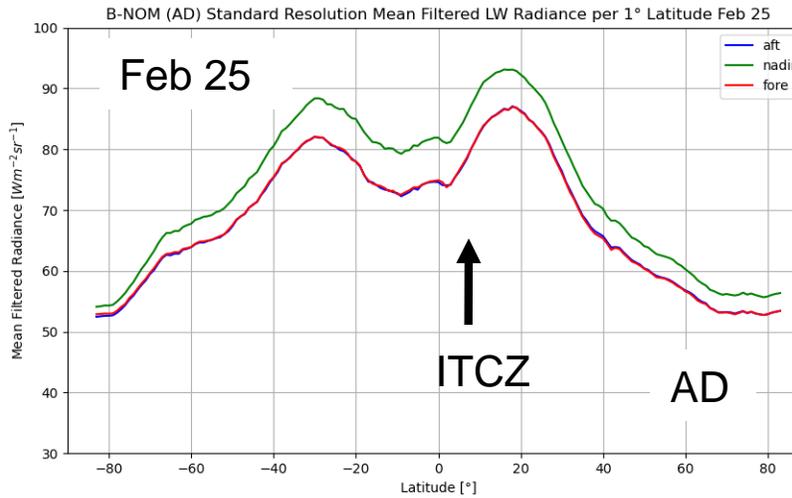
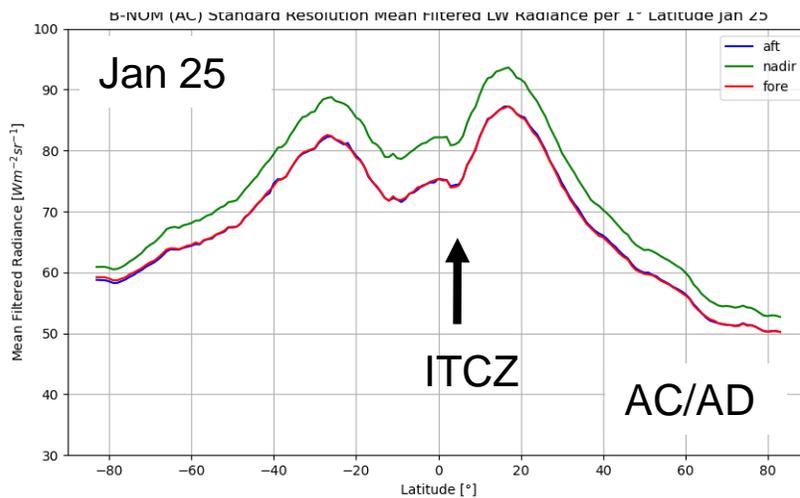
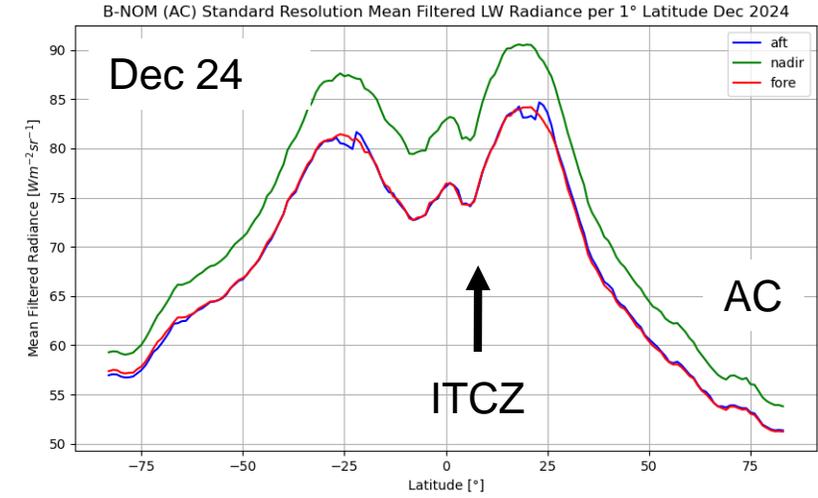
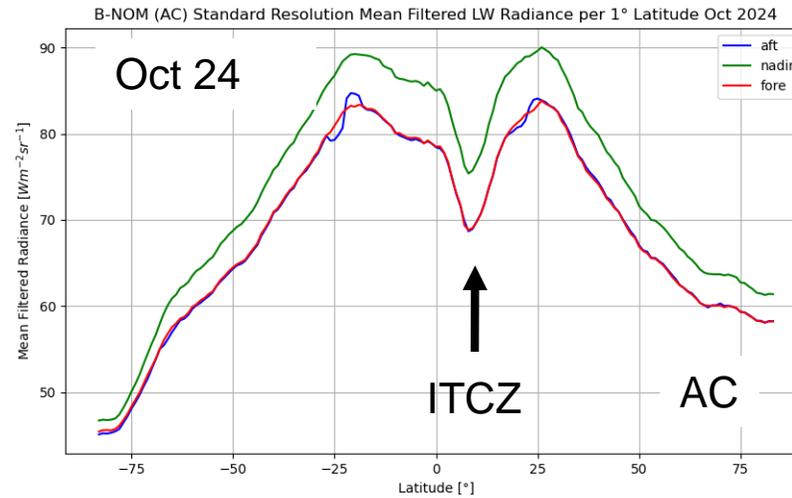
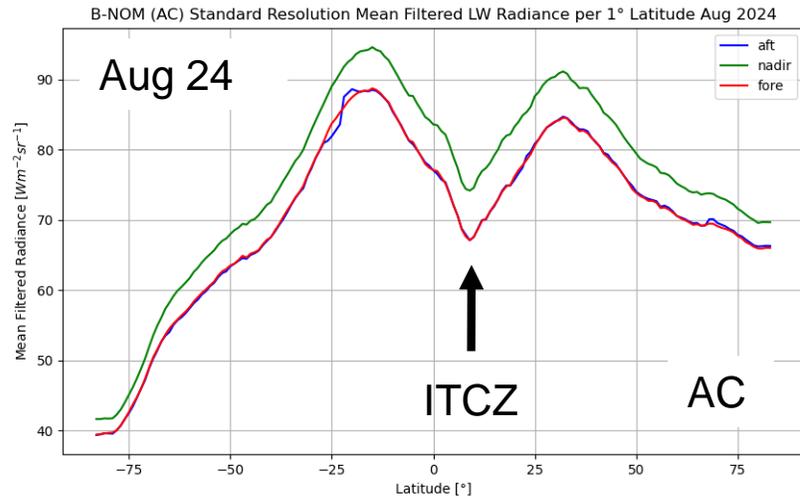
AD



- Gaps in the AFT view at the beginning of each frame – corrected in baseline AD (13 January onwards).



B-NOM Filt. LW Radiance per 1° Lat. Bin, Aug 24 to Mar 25



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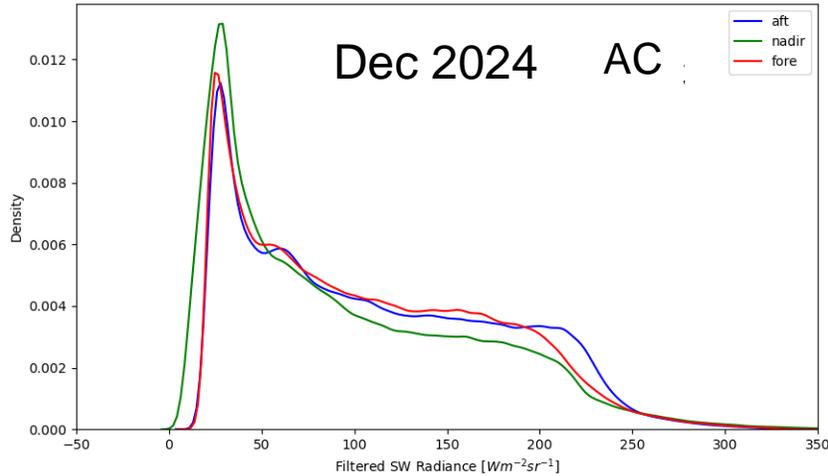
Comparison of different resolutions B-NOM product: SW Radiance

Small Resolution

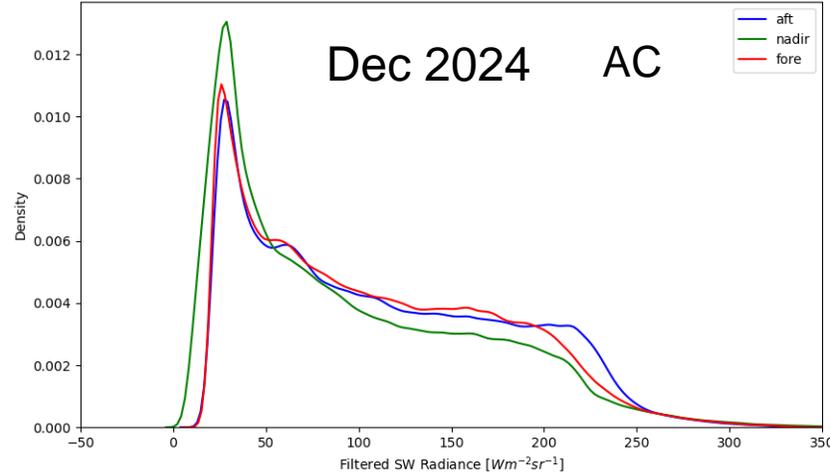
Standard Resolution

Full Resolution

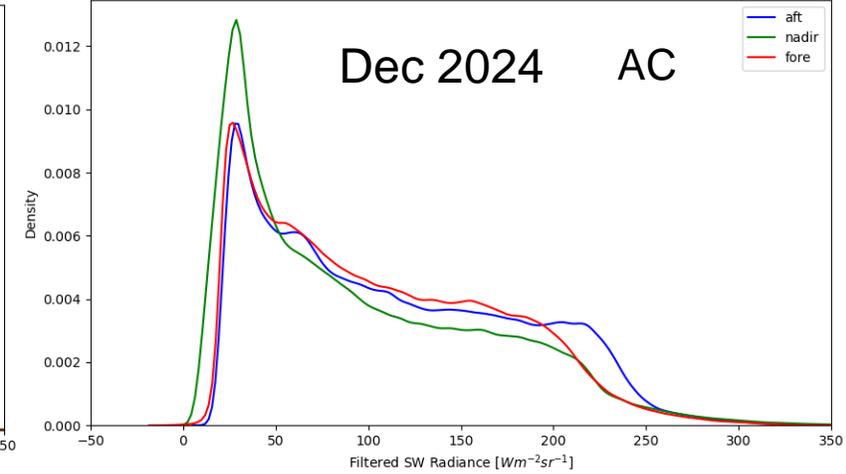
B-NOM (AC) Small Resolution Filtered Shortwave Radiance Dec 24 with SZA < 80°



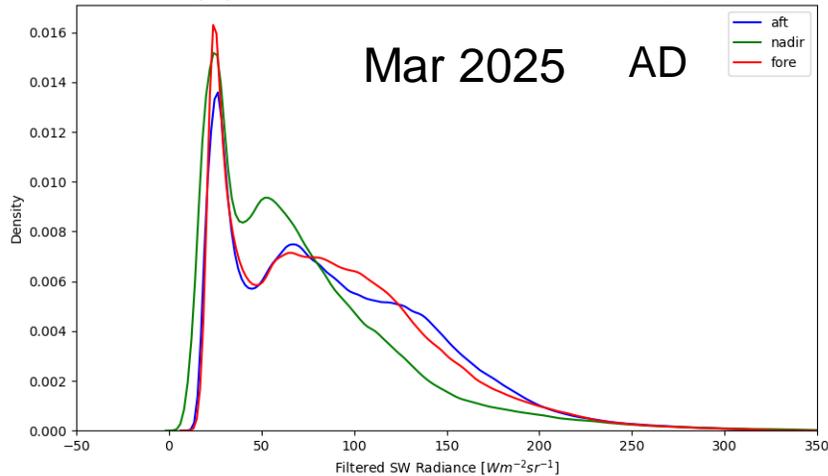
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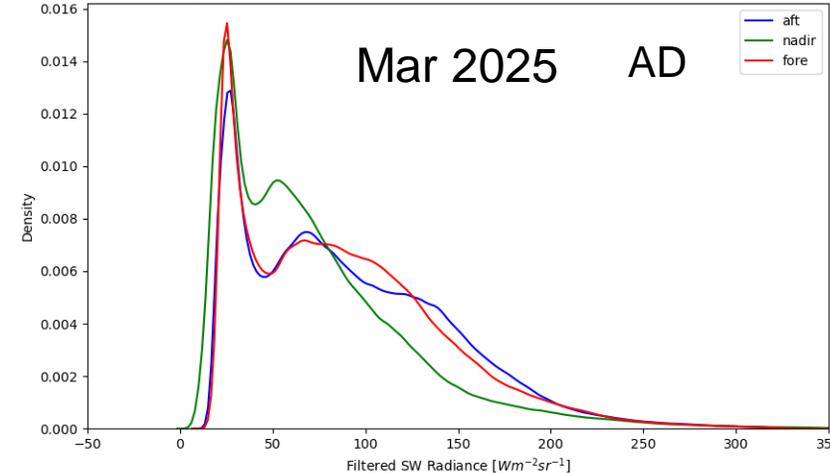
B-NOM (AC) Full Resolution Filtered Shortwave Radiance Dec 24 with SZA < 80°



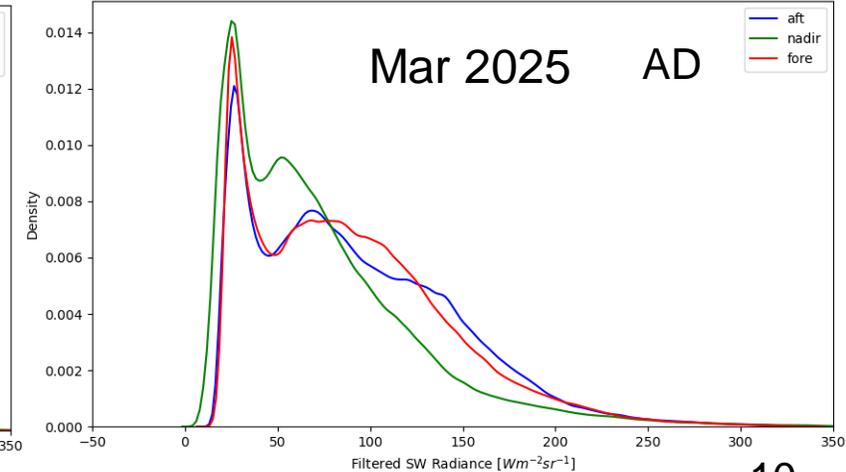
B-NOM (AD) Small Resolution Filtered Shortwave Radiance Mar 25, SZA < 80°



B-NOM (AD) Standard Resolution Filtered Shortwave Radiance Mar 25, SZA < 80°



B-NOM (AD) Full Resolution Filtered Shortwave Radiance Mar 25, SZA < 80°

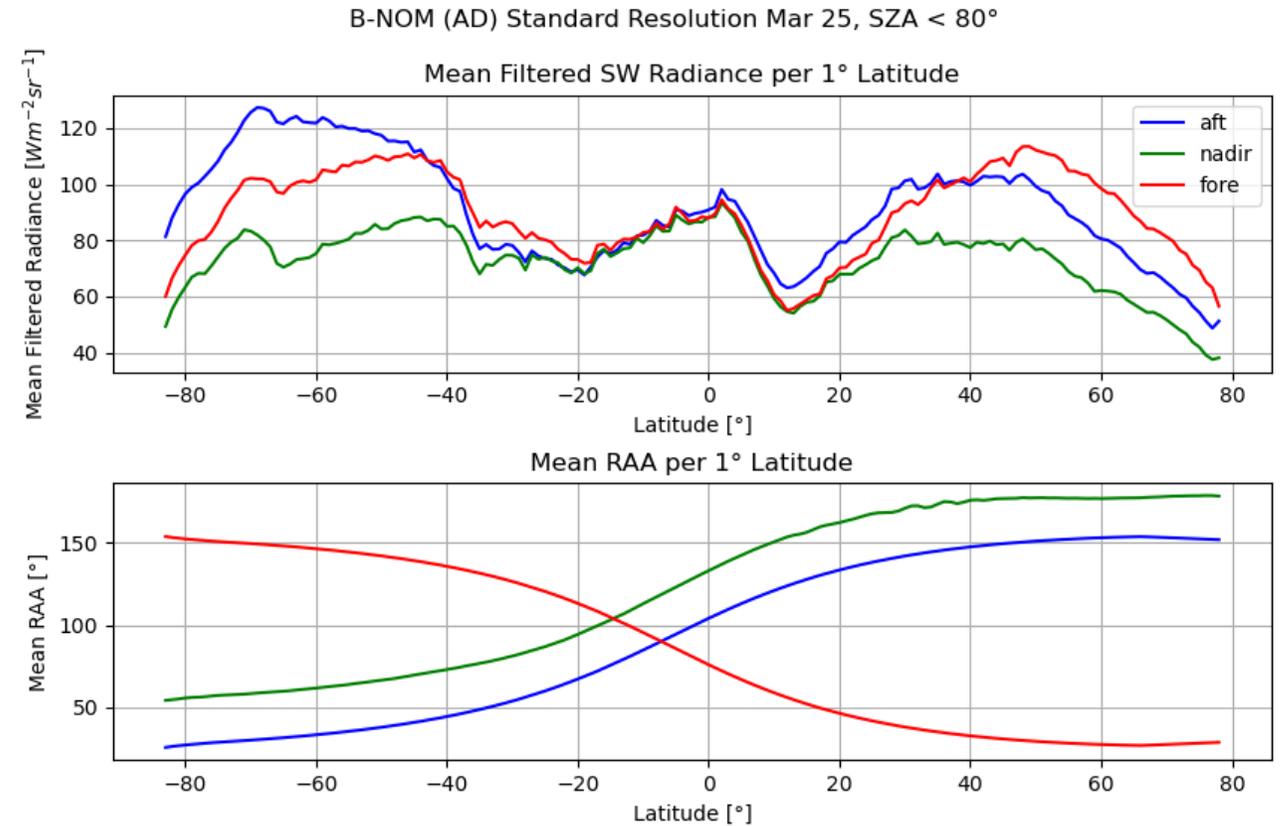
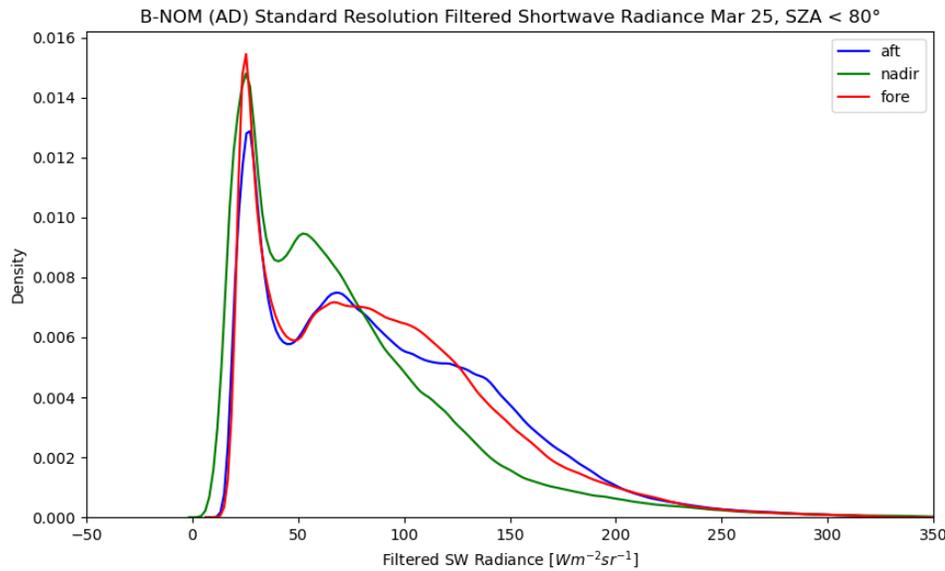




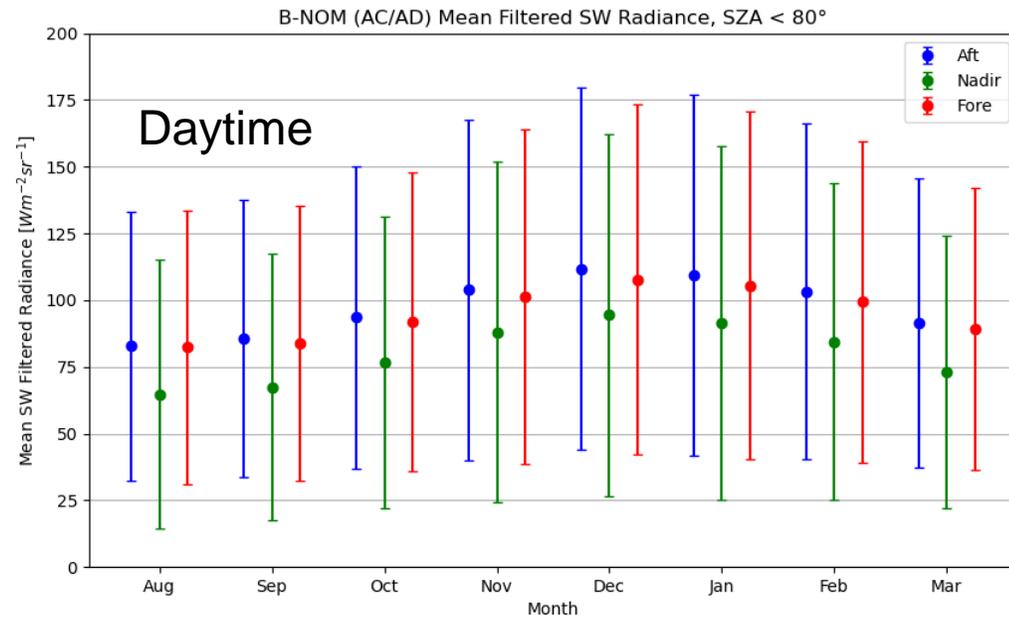
Quality Check: B-NOM SW Radiance

Standard Resolution

March 25, Baseline AD



Mean Values of Filtered SW Radiances per Month - Daytime





B-NOM Filt. SW Radiance per 1°x1° Lat.-Lon. Bin, Nadir, Daytime

Aug 24

AC

Oct 24

AC

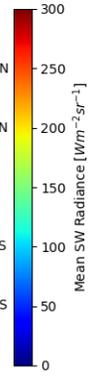
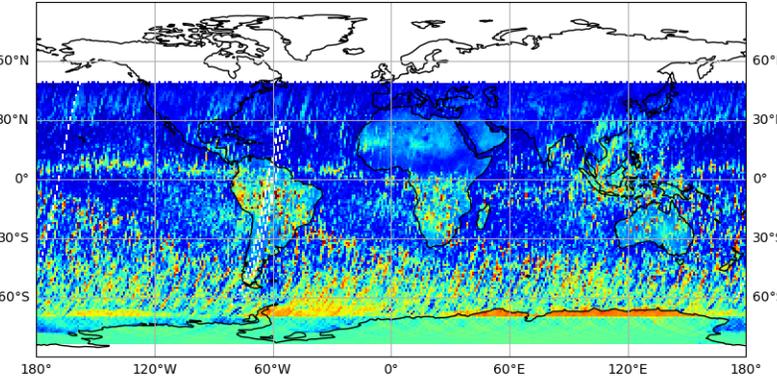
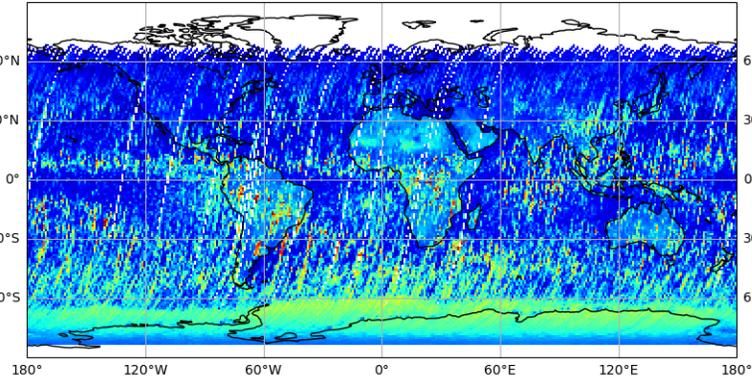
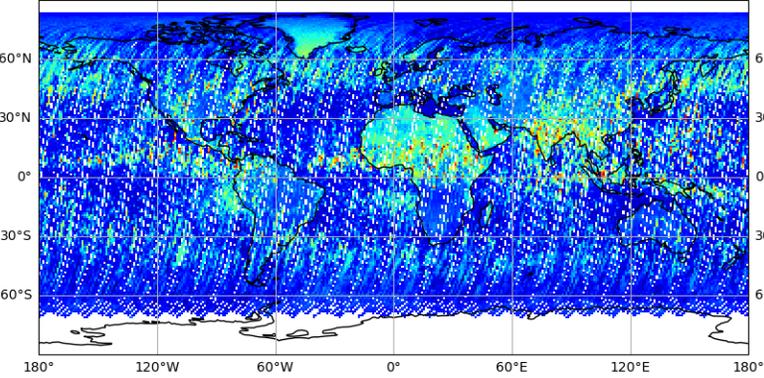
Dec 24

AC

Binned Latitude-Longitude Plot with Mean SW Radiance NADIR B-NOM Aug 24, SZA < 80°

Binned Latitude-Longitude Plot with Mean SW Radiance NADIR B-NOM Oct 24, SZA < 80°

Binned Latitude-Longitude Plot with Mean SW Radiance NADIR B-NOM Dec 24, SZA < 80°



Jan 25

AC/AD

Feb 25

AD

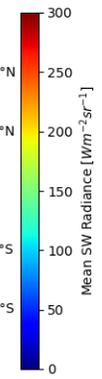
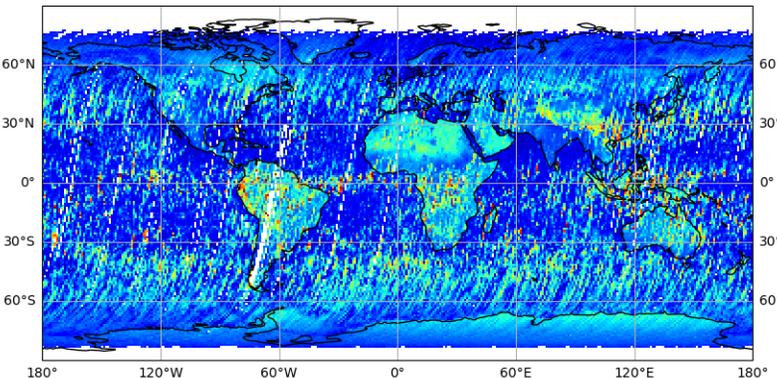
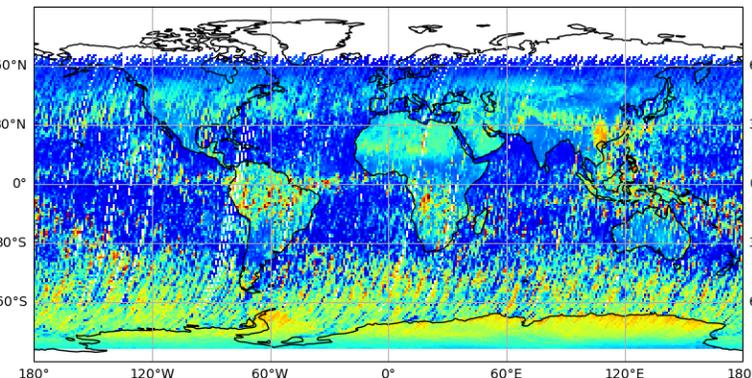
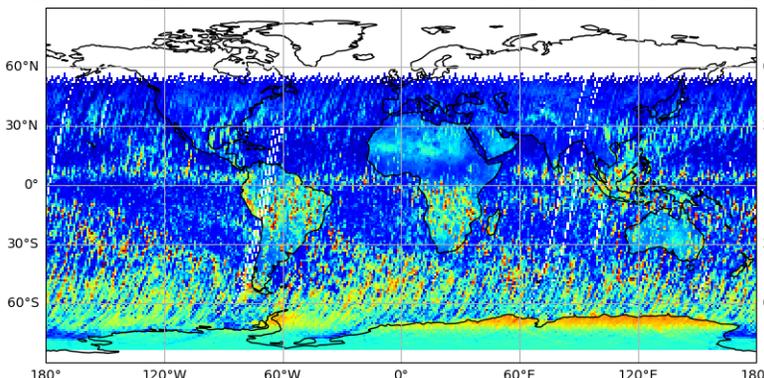
Mar 25

AD

Binned Latitude-Longitude Plot with B-NOM Filt. SW Radiance NADIR Jan 25, SZA < 80°

Binned Latitude-Longitude Plot with B-NOM Filt. SW Radiance AFT Feb 25, SZA < 80°

Binned Latitude-Longitude Plot with B-NOM Filt. SW Radiance NADIR Mar 25, SZA < 80°



- 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 – today
- Remark: Baseline change of L1 products on 13/01/2025, which is also influencing the L2 products



BM-RAD Product Resolutions

L1 PSF	Size (across x along track)	Reference grid	L1 filtered radiances	BM-RAD unfiltered radiances	BMA-FLX fluxes	BMA-FLX combined flux
Standard	10x10 km2	BBR	B-NOM	✓	✓	✓
Small	5x10 km2	BBR	B-NOM	✓	✓	✓
Full	17x10 km2 (nadir) 28x10 km2	BBR	B-NOM	✓	✓	
Assessment domain	5x21 JSG (configurable)	JSG	B-SNG	✓	✓	✓
JSG*	1x1 JSG (or 3x3 JSG)	JSG	B-SNG	✓		



Different resolutions BM-RAD product: TH Unfiltered Radiance

Small Resolution

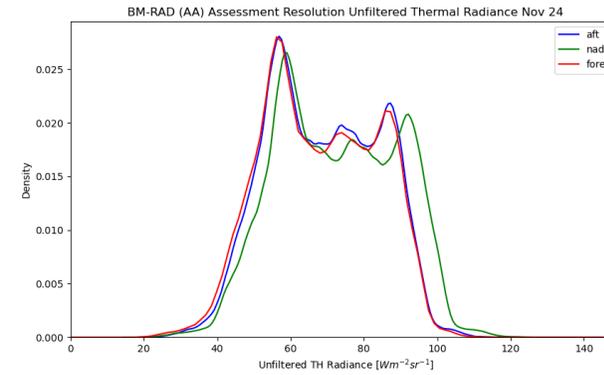
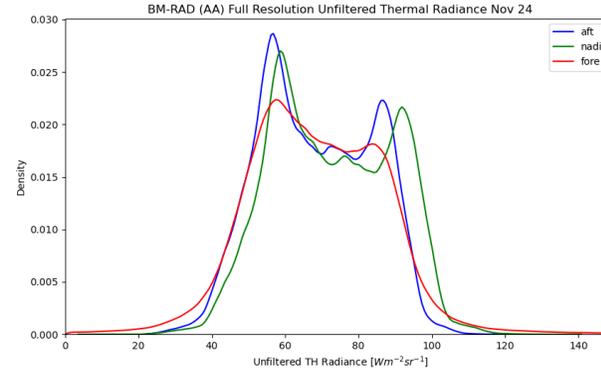
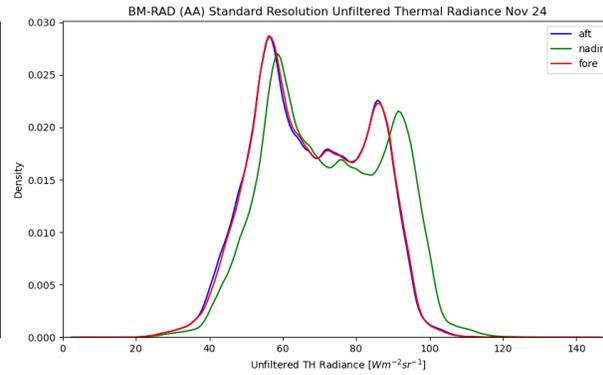
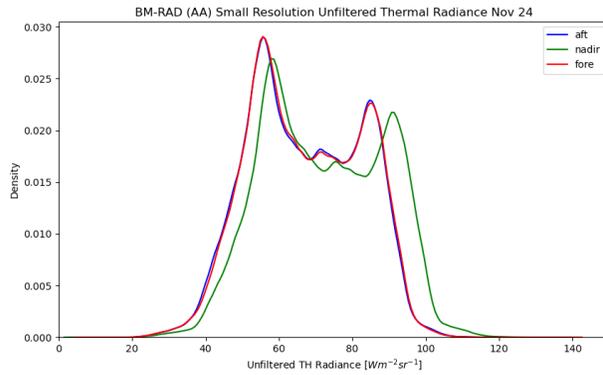
Standard Resolution

Full Resolution

Assessment Domain

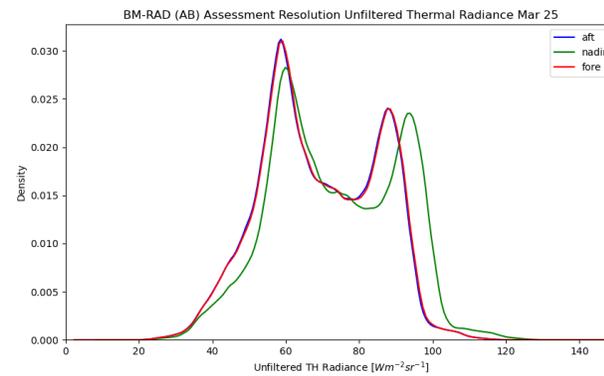
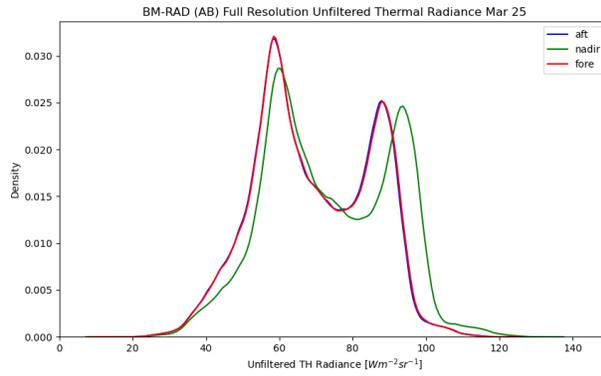
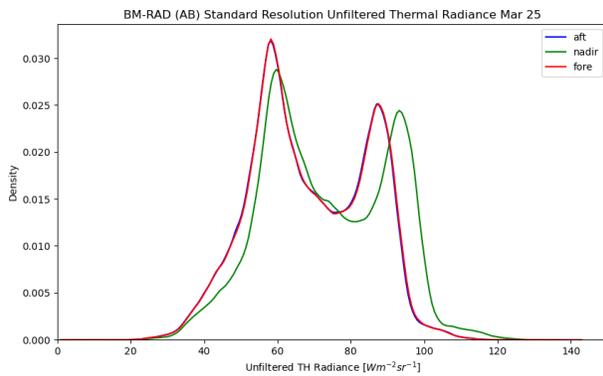
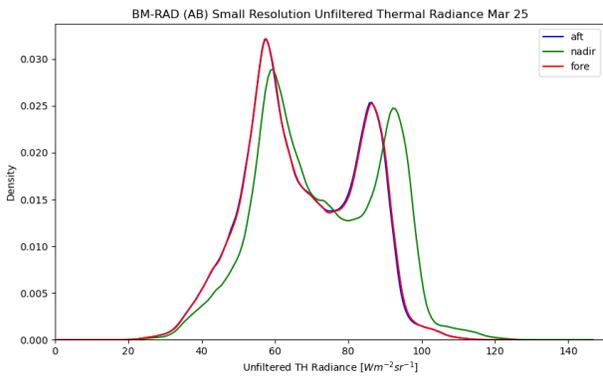
Nov 2024

AA



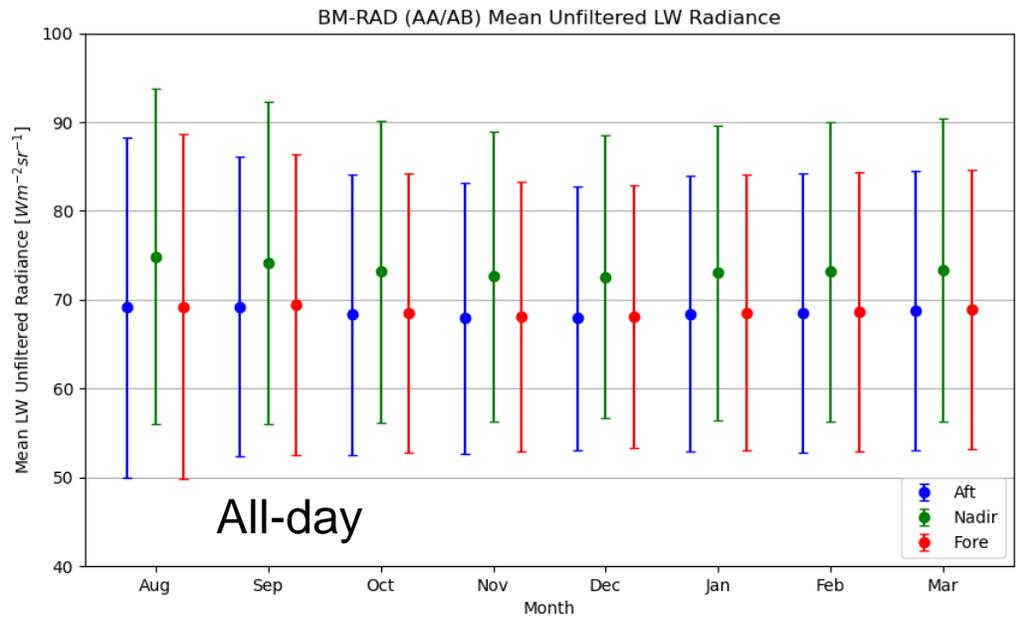
Mar 2025

AB

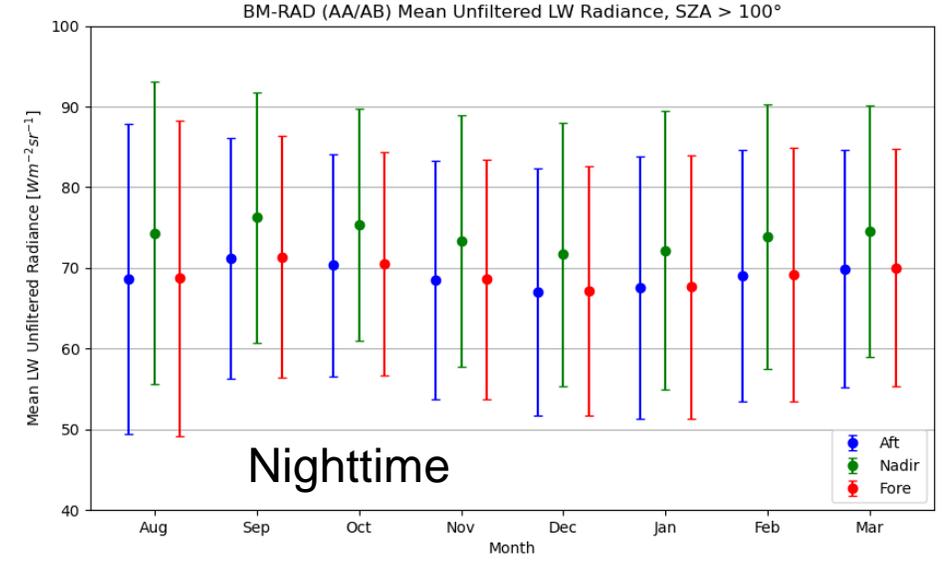
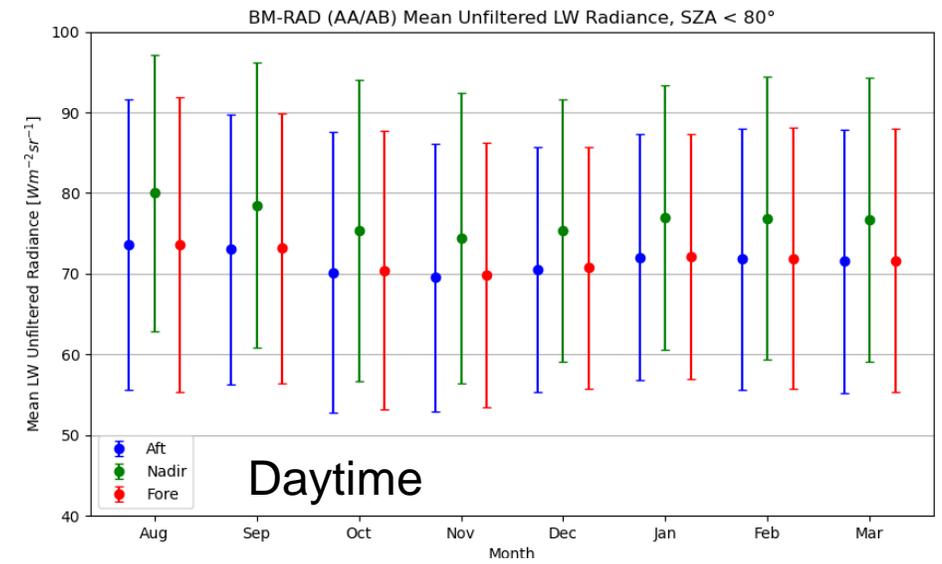




Mean Values of BM-RAD Unfiltered TH Radiances per Month



Standard Resolution, Baseline AA and AB (from 18 December onwards)





BM-RAD Unfilt. TH Radiance per 1°x1° Lat.-Lon. Bin, Nadir

Aug 24

AA

Oct 24

AA

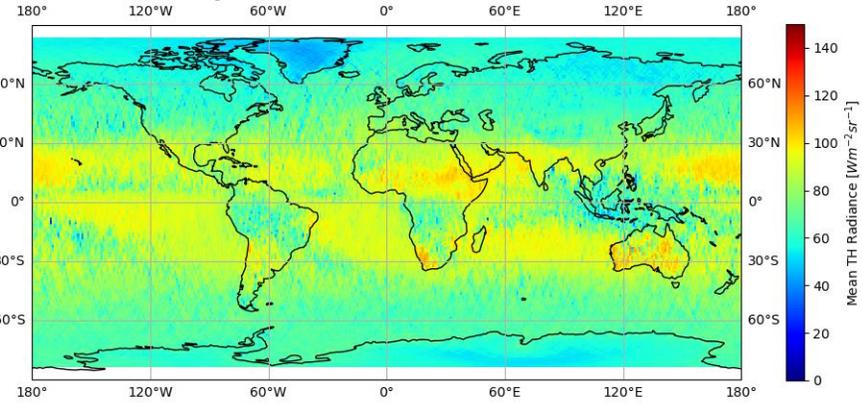
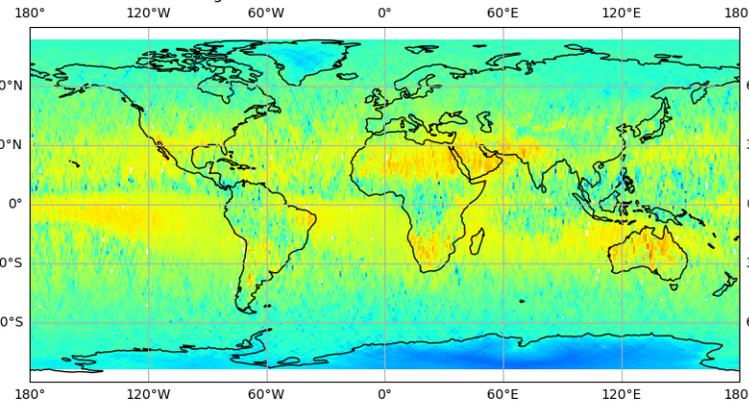
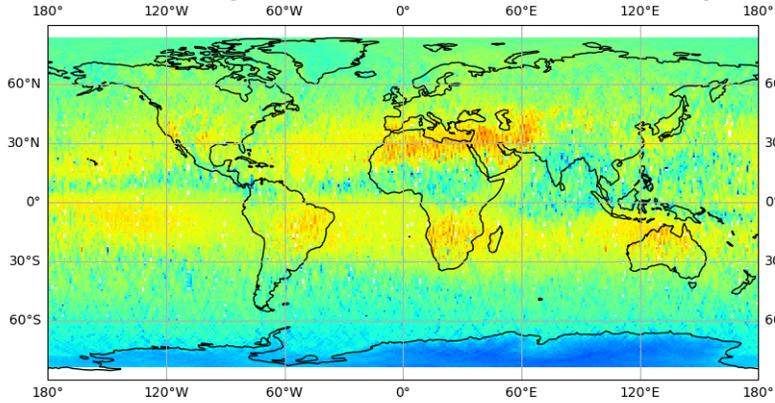
Dec 24

AA/AB

Binned Latitude-Longitude Plot with BM-RAD Unfil. Thermal Radiance NADIR Aug 24

Binned Latitude-Longitude Plot with BM-RAD Unfil. Thermal Radiance NADIR Oct 24

Binned Latitude-Longitude Plot with BM-RAD Unfil. Thermal Radiance NADIR Dec 24



Jan 25

AB

Feb 25

AB

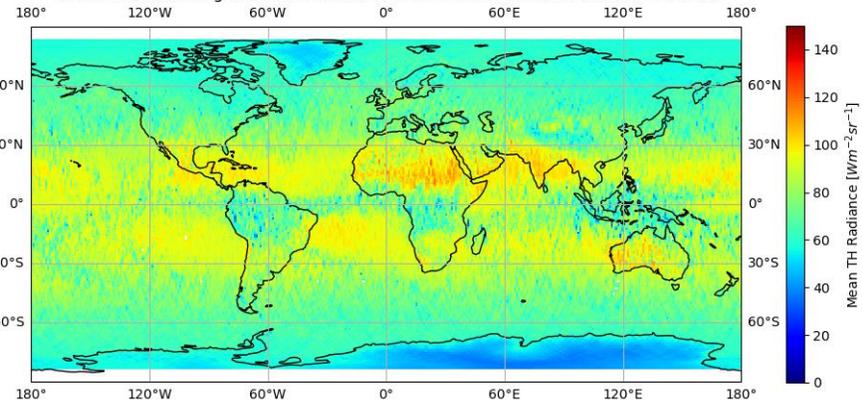
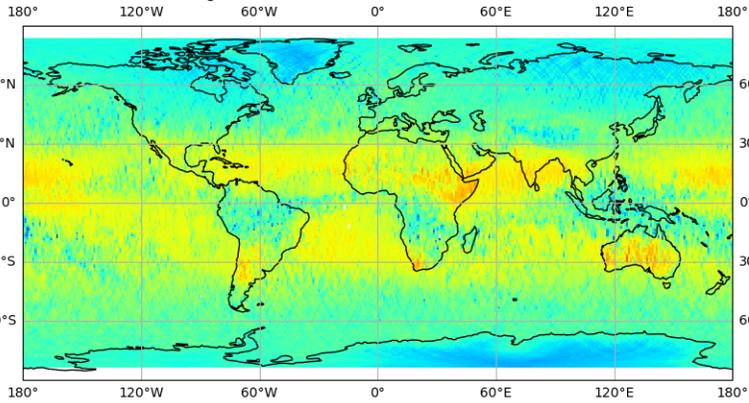
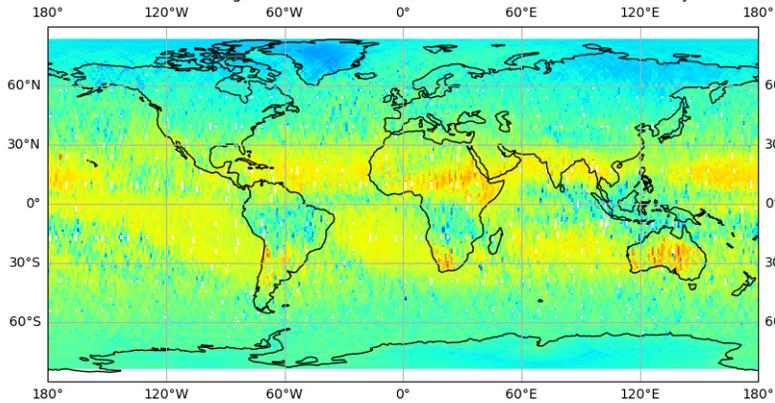
Mar 25

AB

Binned Latitude-Longitude Plot with BM-RAD Unfil. Thermal Radiance NADIR Jan 25

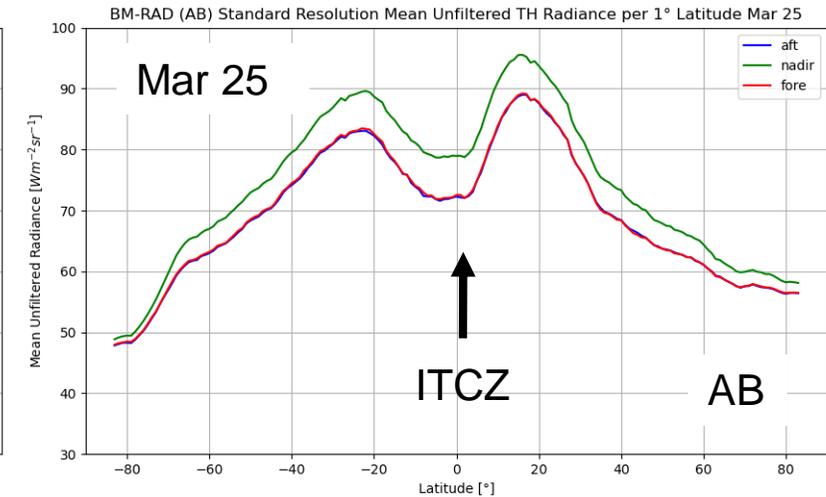
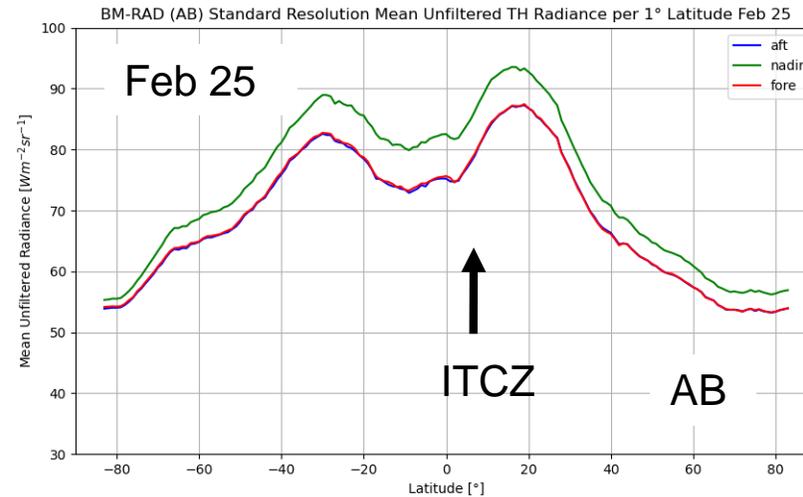
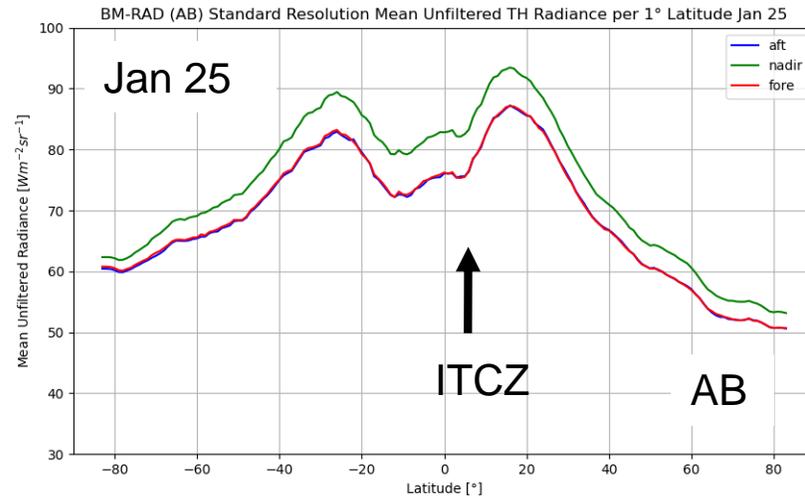
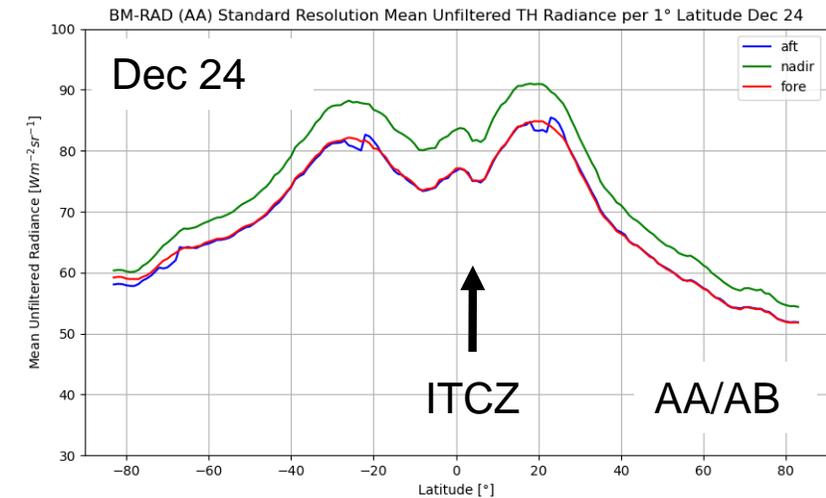
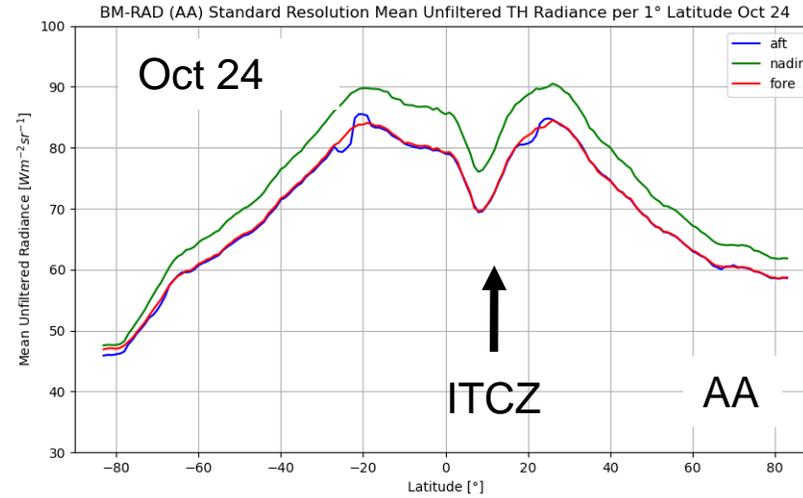
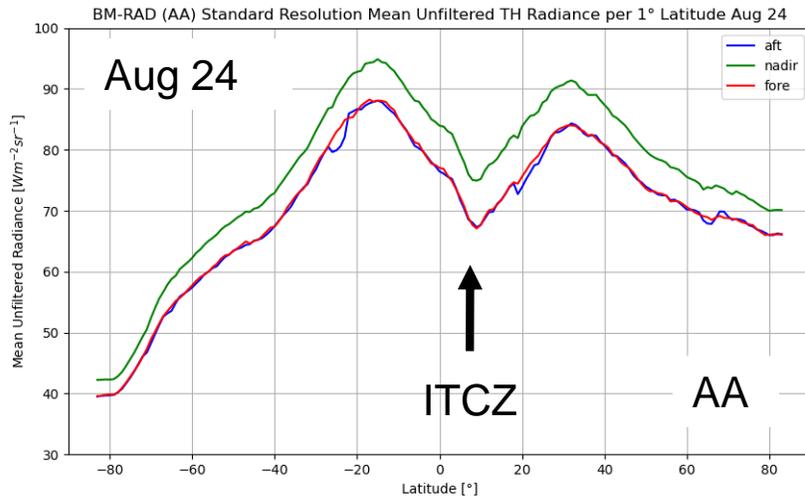
Binned Latitude-Longitude Plot with BM-RAD Unfil. Thermal Radiance NADIR Feb 25

Binned Latitude-Longitude Plot with BM-RAD Unfil. Thermal Radiance NADIR Mar 25





BM-RAD Unfilt. LW Radiance per 1° Lat. Bin, Aug 24 to Mar 25



- Gaps in the AFT view at the beginning of each frame – corrected in baseline AD (13 January onwards).



Different resolutions BM-RAD product: SOL Unfiltered Radiance

Small Resolution

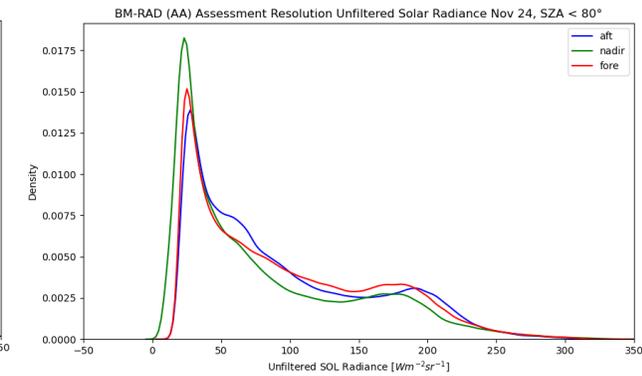
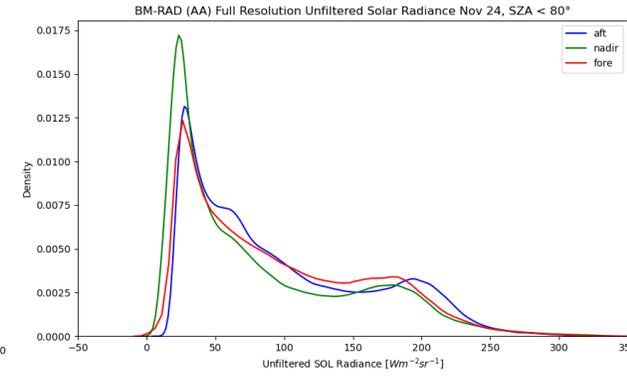
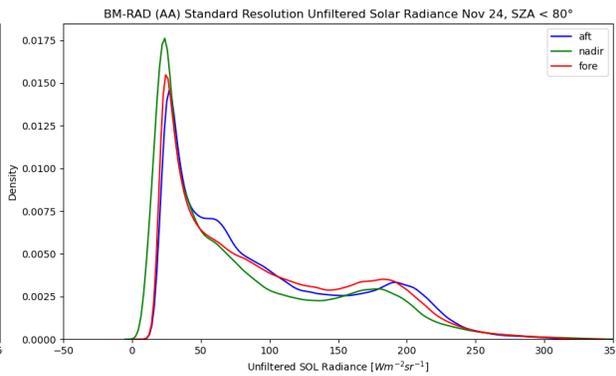
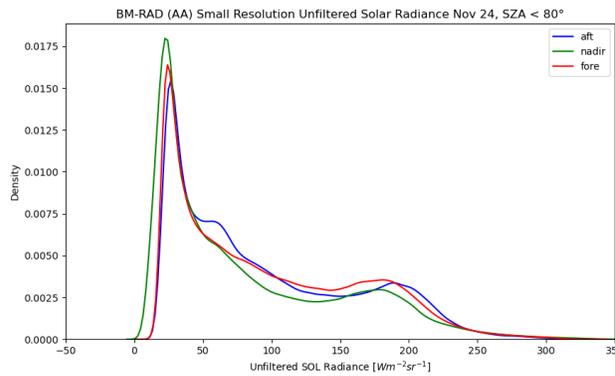
Standard Resolution

Full Resolution

Assessment Domain

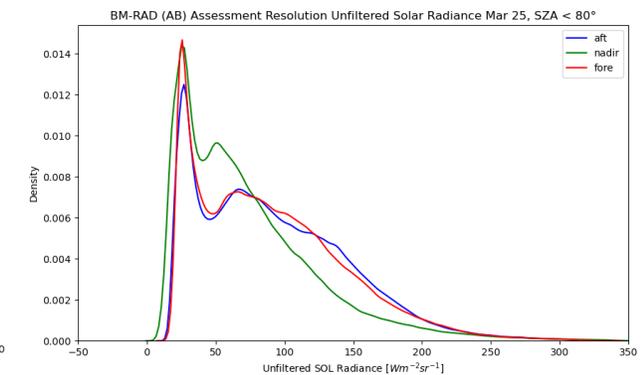
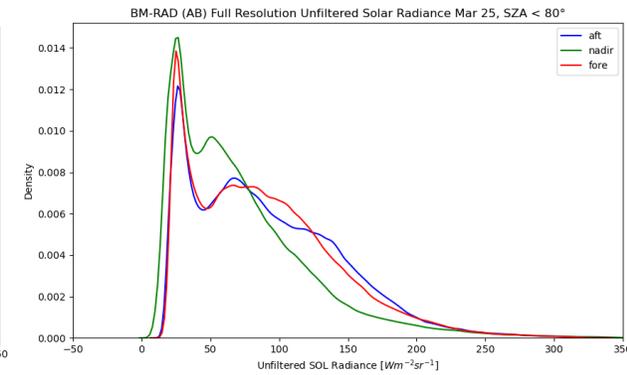
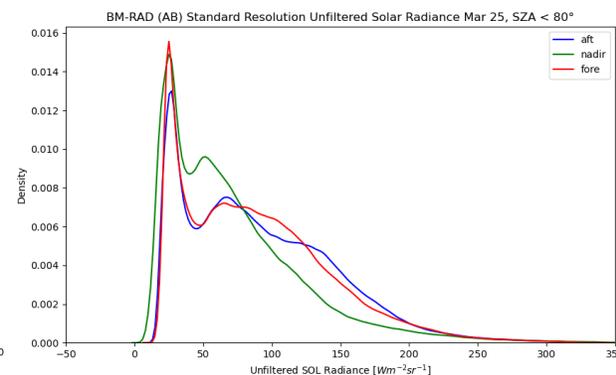
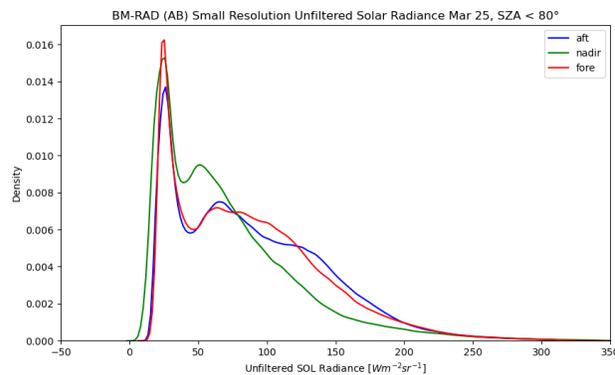
Nov 2024

AA

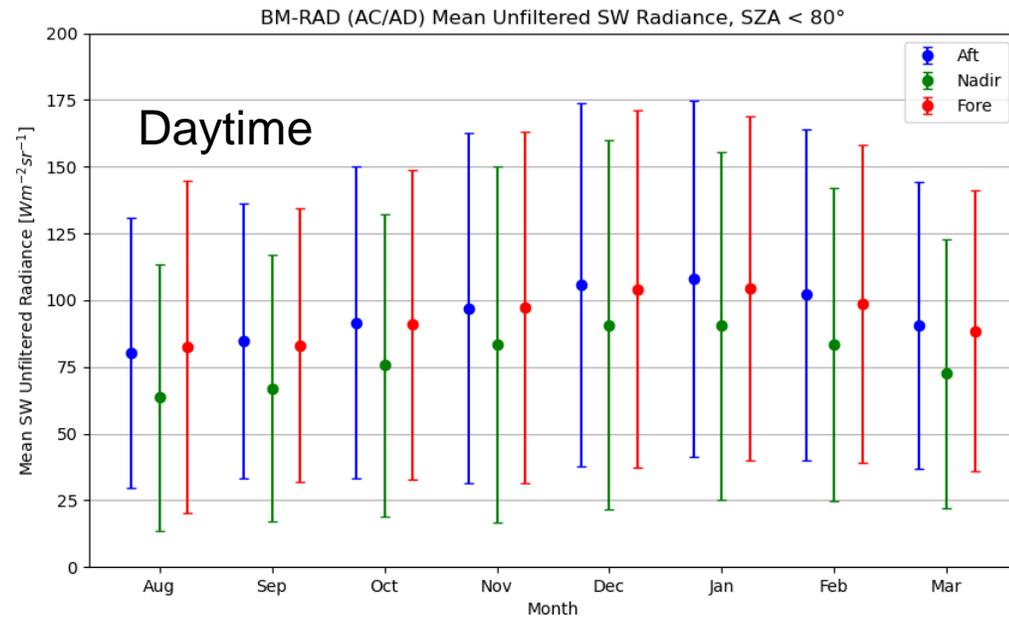


Mar 2025

AB



Mean Values of Unfiltered SOL Radiances per Month - Daytime



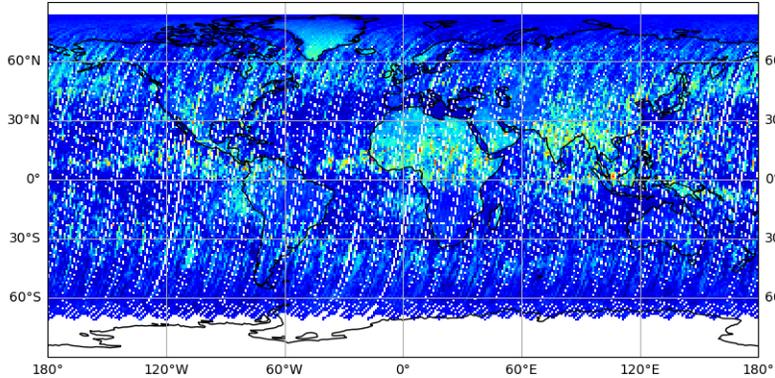


BM-RAD Unfilt. SOL Radiance per 1°x1° Lat.-Lon. Bin, Nadir

Aug 24

AA

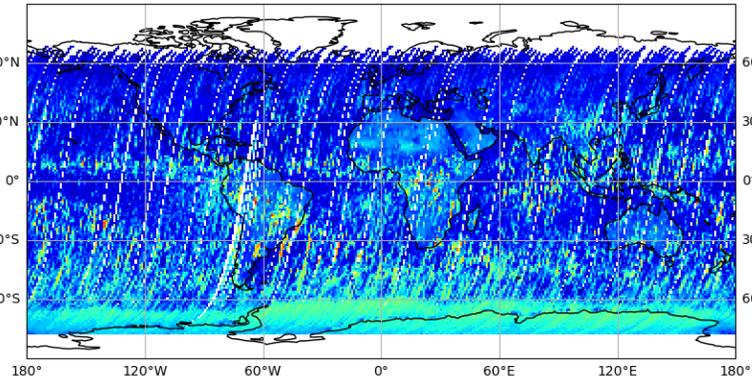
Binned Latitude-Longitude Plot with BM-RAD Unfil. Solar Radiance NADIR Aug 24, SZA < 80°



Oct 24

AA

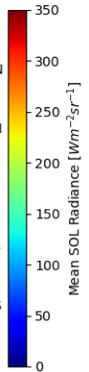
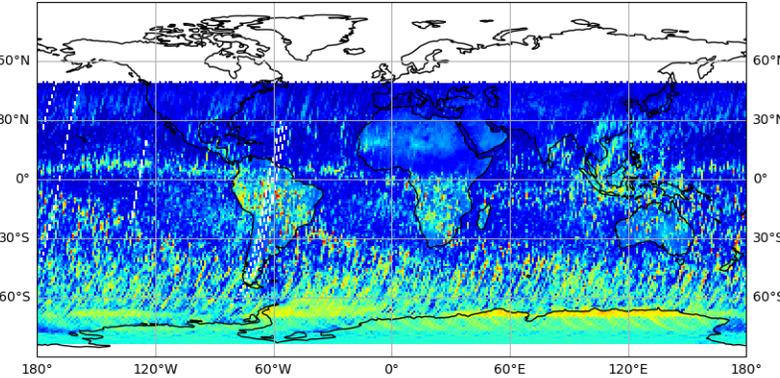
Binned Latitude-Longitude Plot with BM-RAD Unfil. Solar Radiance NADIR Oct 24, SZA < 80°



Dec 24

AA/AB

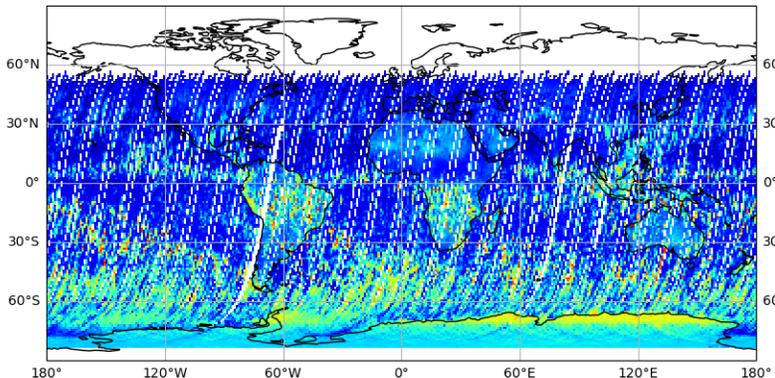
Binned Latitude-Longitude Plot with BM-RAD Unfil. Solar Radiance NADIR Dec 24, SZA < 80°



Jan 25

AB

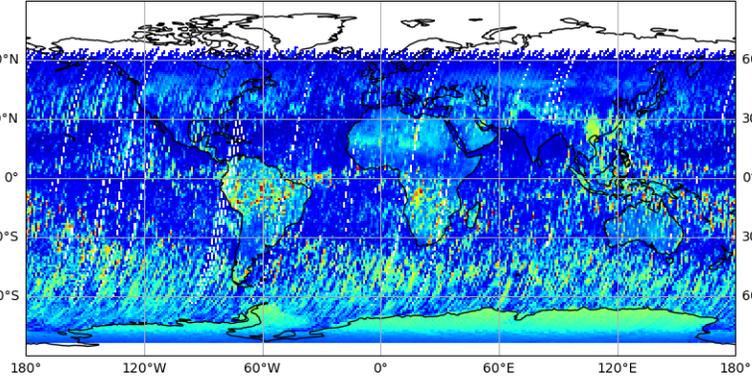
Binned Latitude-Longitude Plot with BM-RAD Unfil. Solar Radiance NADIR Jan 25, SZA < 80°



Feb 25

AB

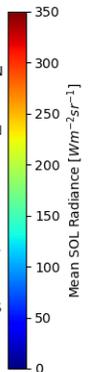
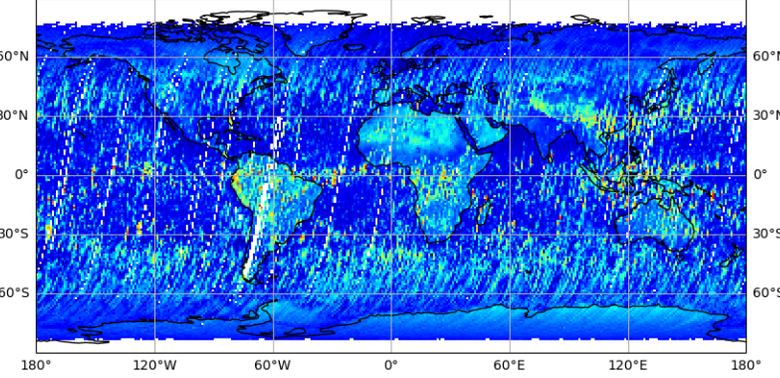
Binned Latitude-Longitude Plot with BM-RAD Unfil. Solar Radiance NADIR Feb 25, SZA < 80°



Mar 25

AB

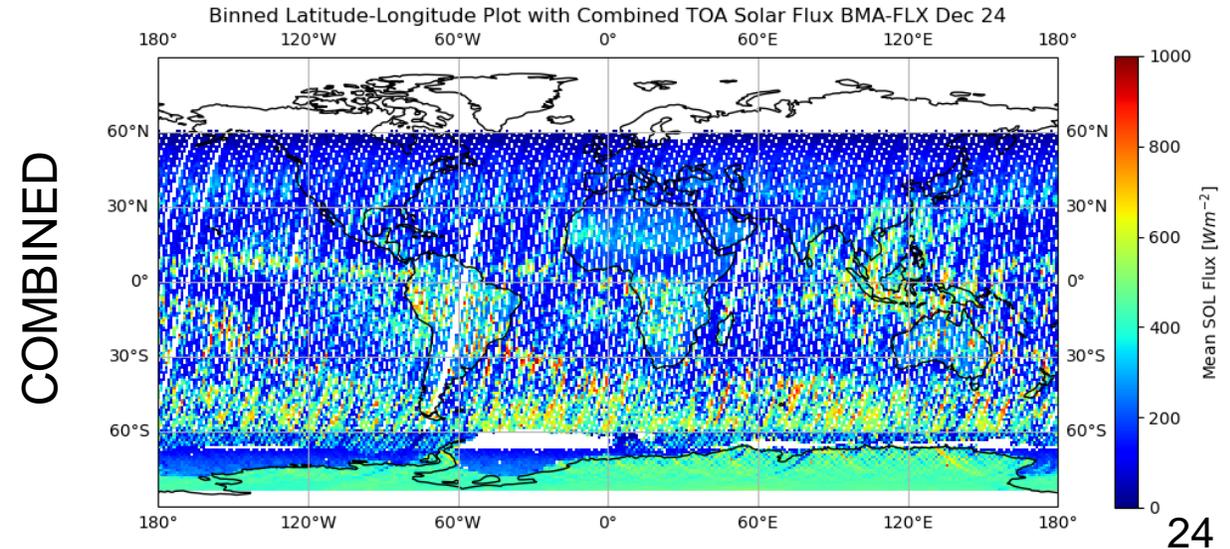
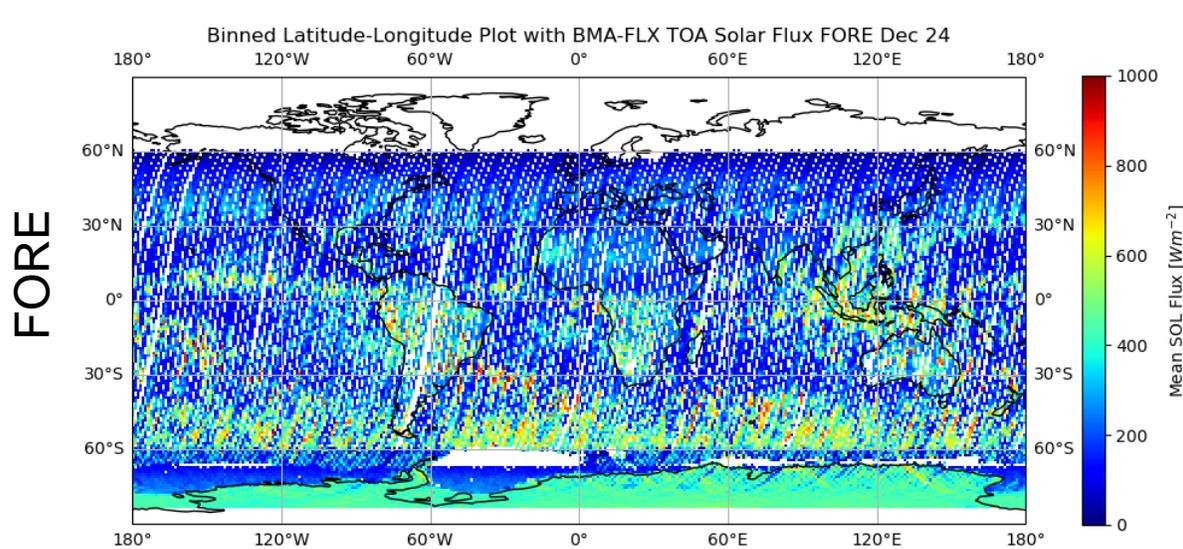
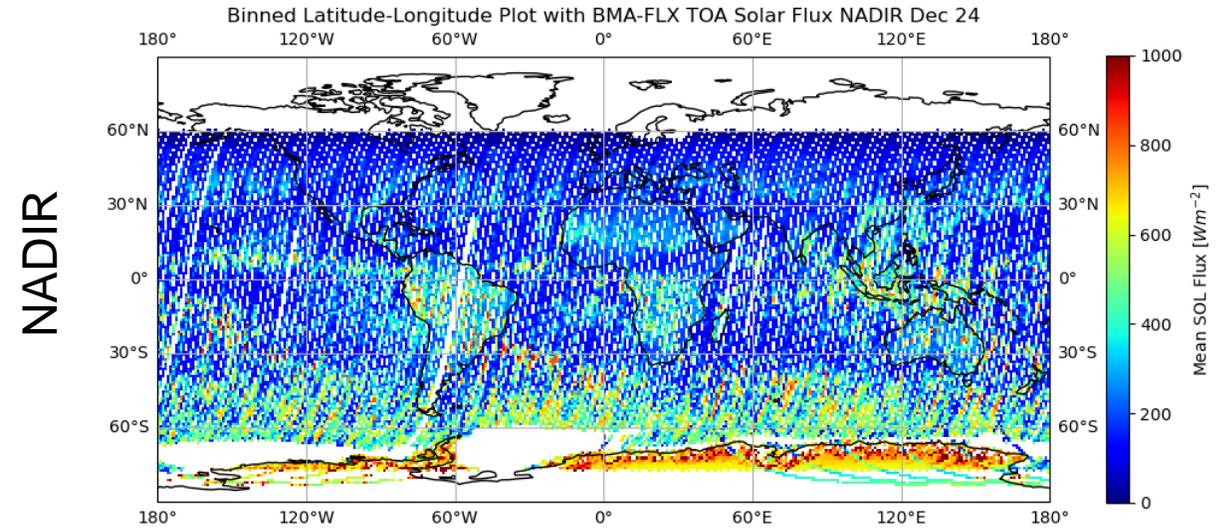
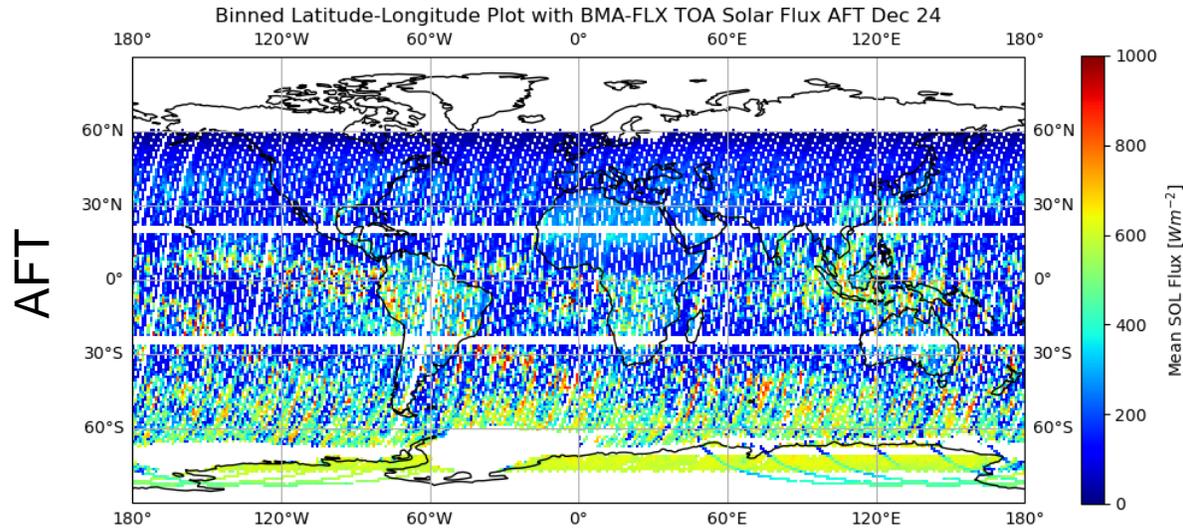
Binned Latitude-Longitude Plot with BM-RAD Unfil. Solar Radiance NADIR Mar 25, SZA < 80°



- 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 – today
- Remark: Although no change in the baseline, there have been many changes done until today.

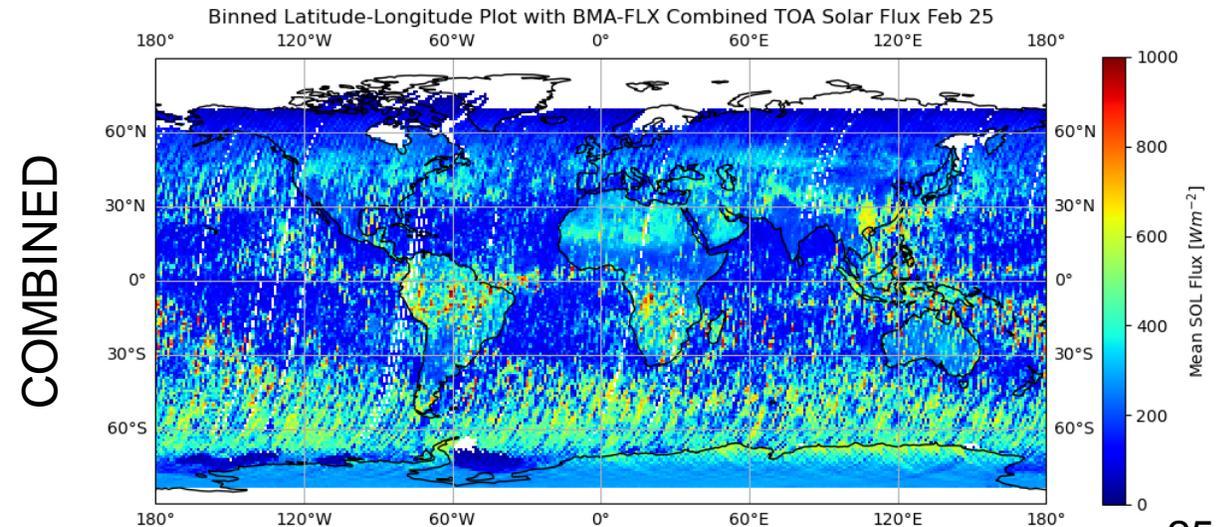
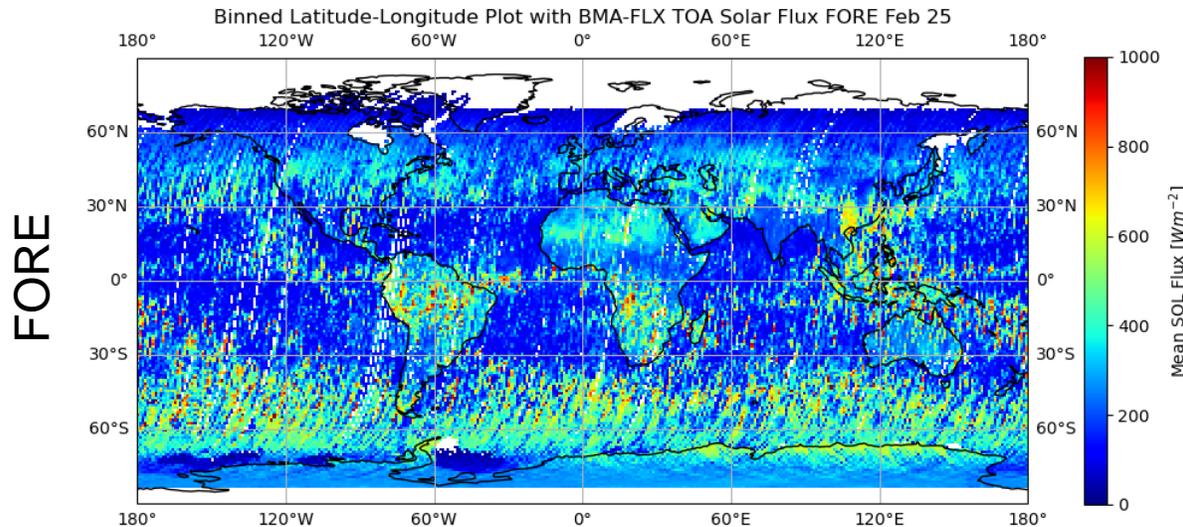
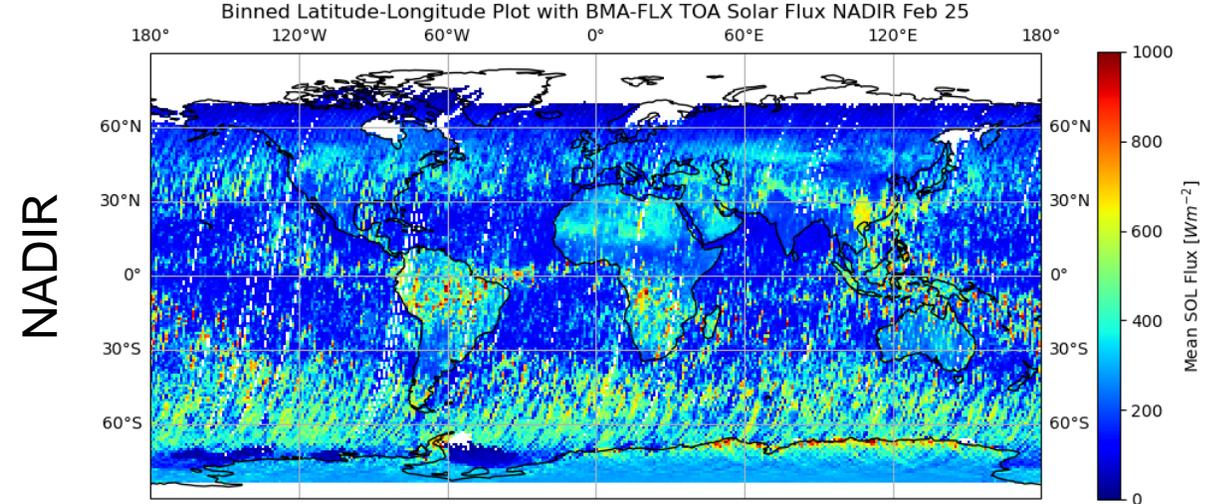
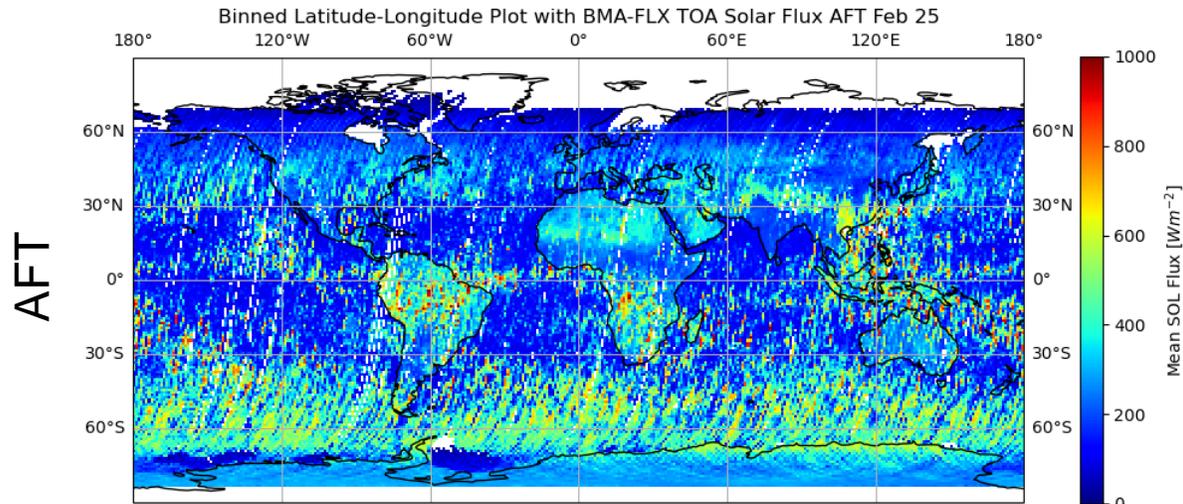


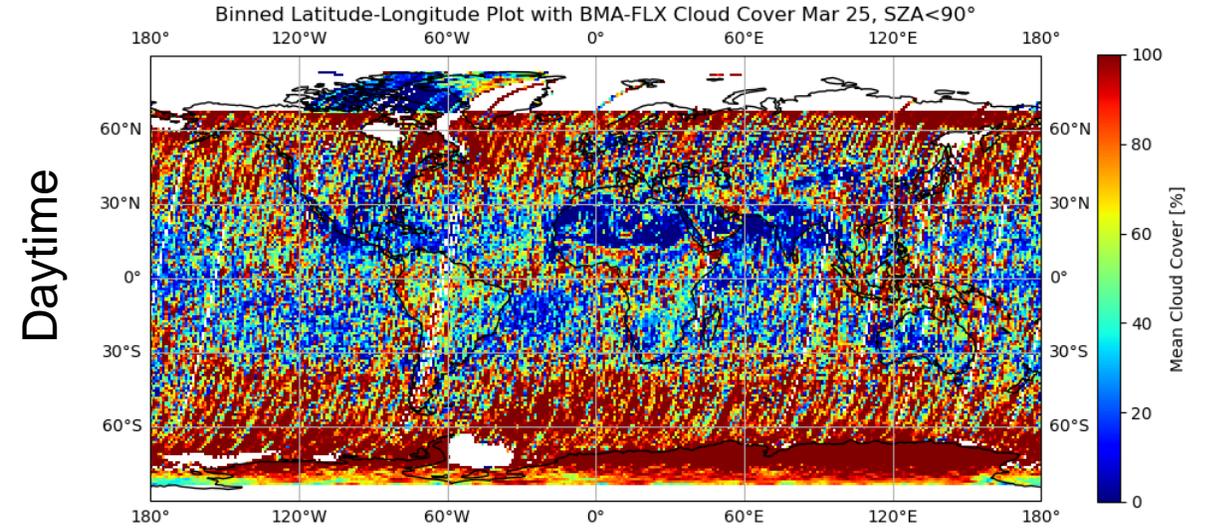
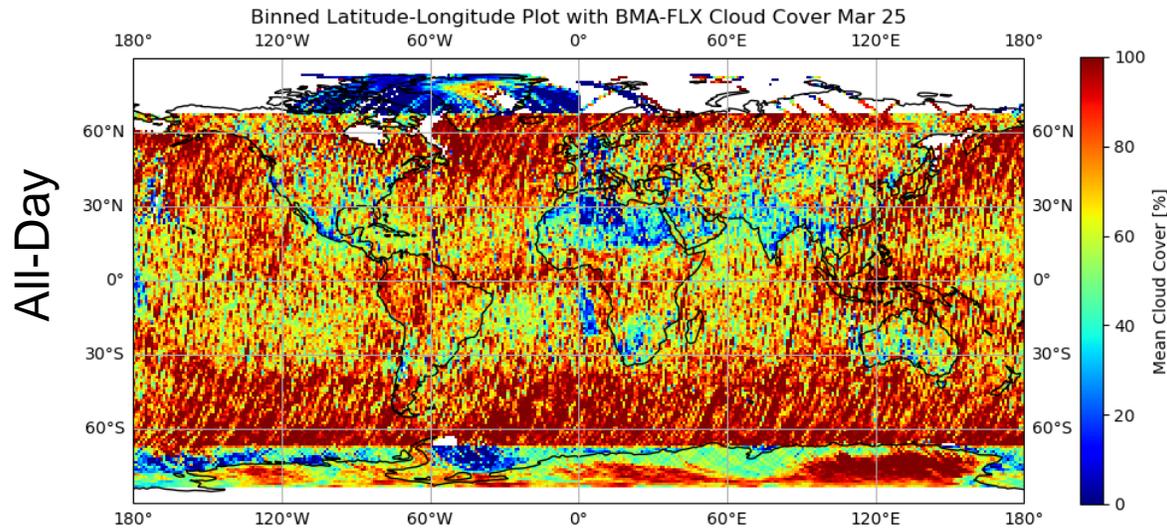
BMA-FLX SOL Flux per 1°x1° Lat.-Lon. Bin, 1 – 18 Dec 2024



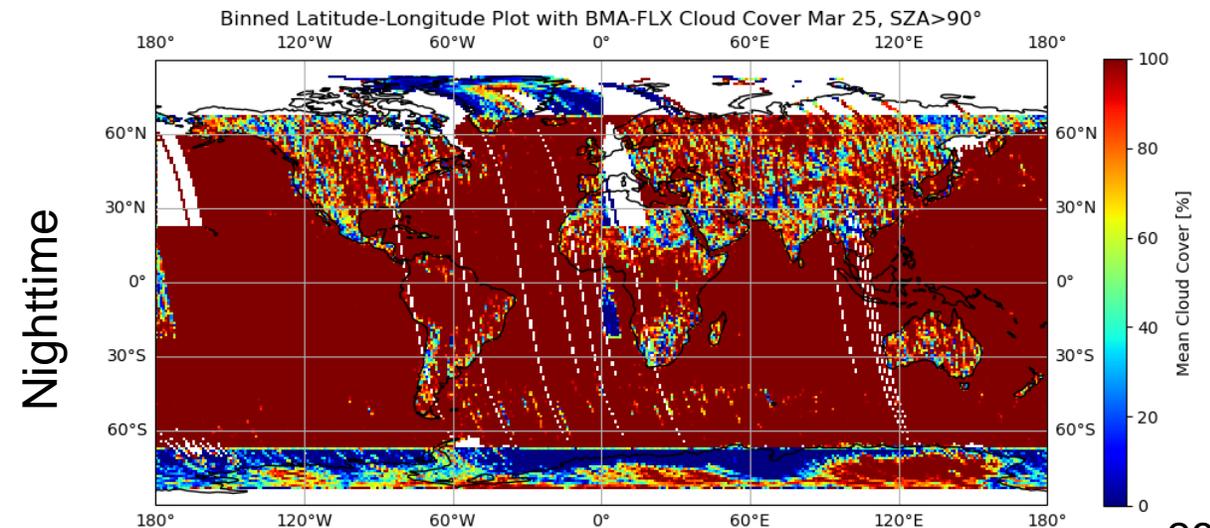


BMA-FLX SOL Flux per 1°x1° Lat.-Lon. Bin, Feb 25





- There is an issue with the cloud-mask.
- At nighttime there are almost only overcast cases detected.



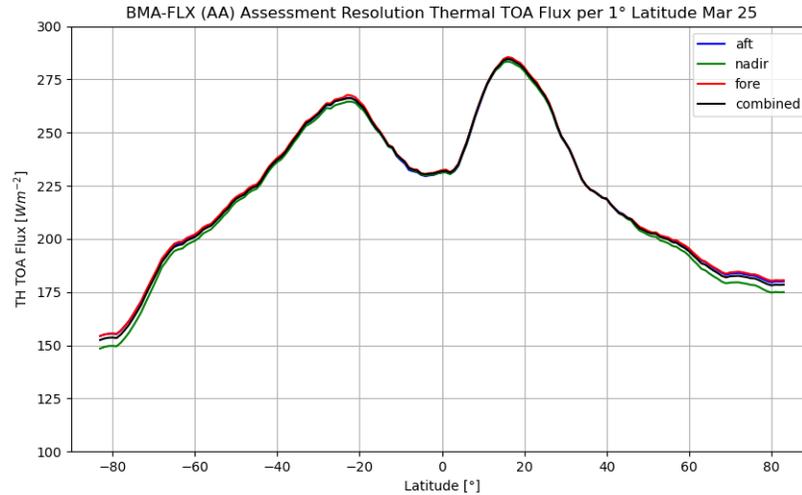


BMA-FLX: Comparisons including and excluding margins

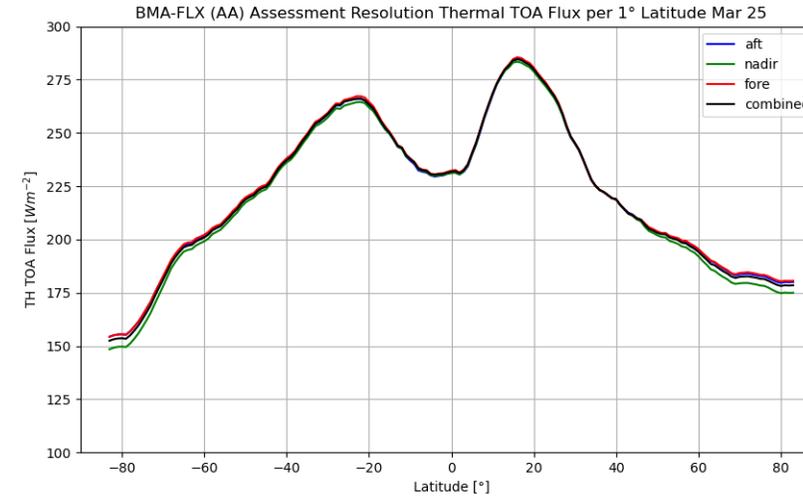
Assessment Domain

TH TOA Flux

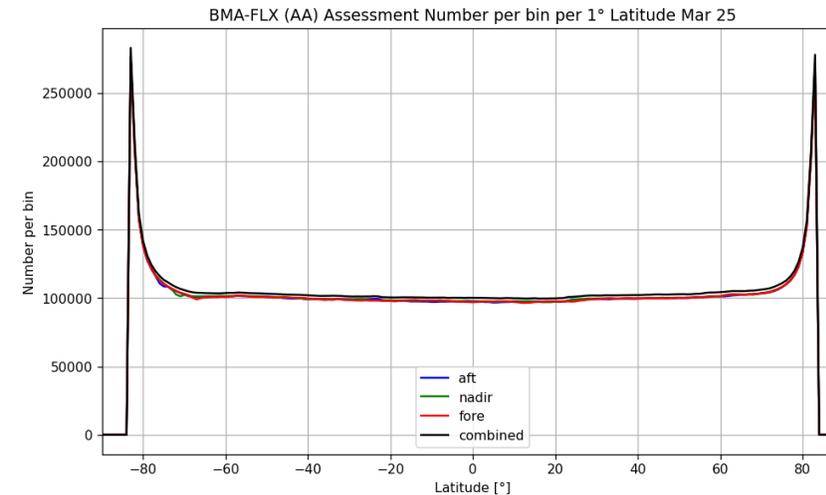
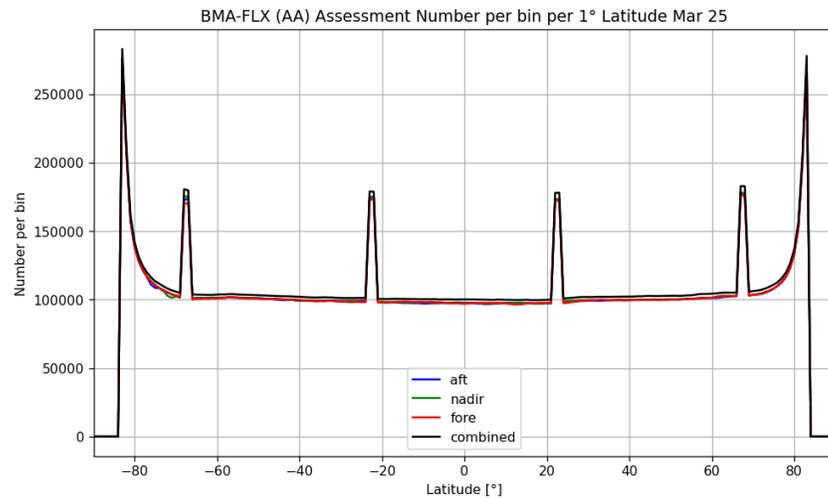
Including Margins



Excluding Margins



Counts per Bin



- Margins have been introduced with the change of the L1 baseline to AD.



BMA-FLX: Comparisons including and excluding margins

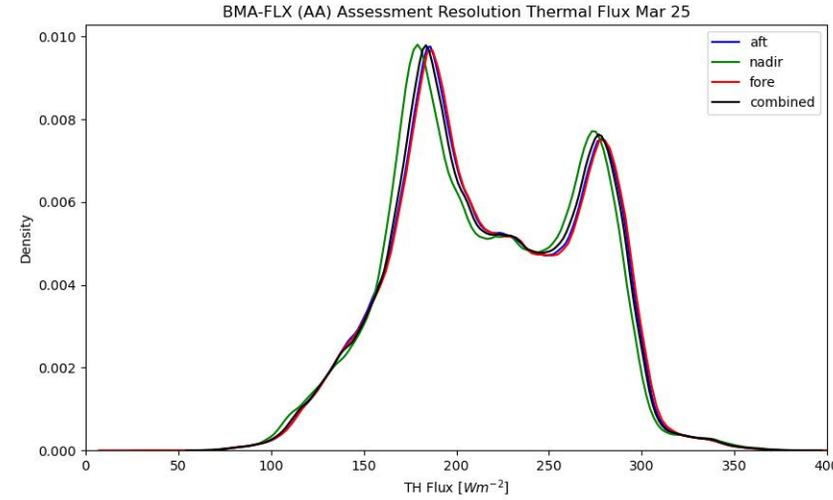
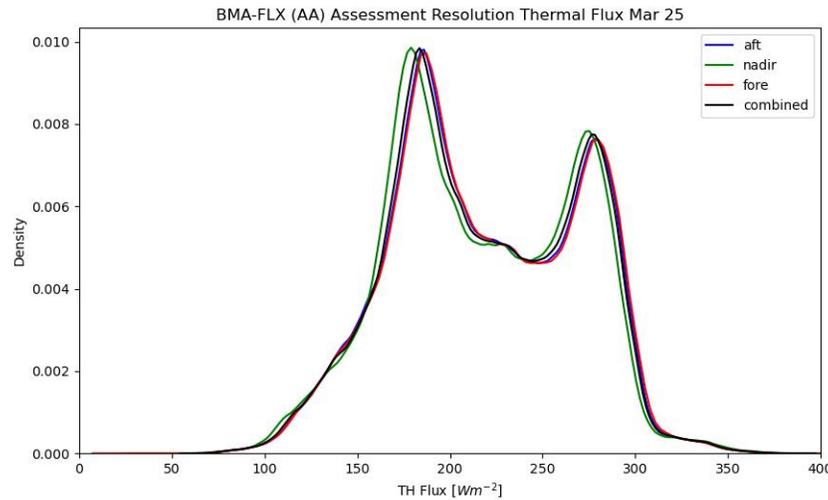
Including Margins

Excluding Margins

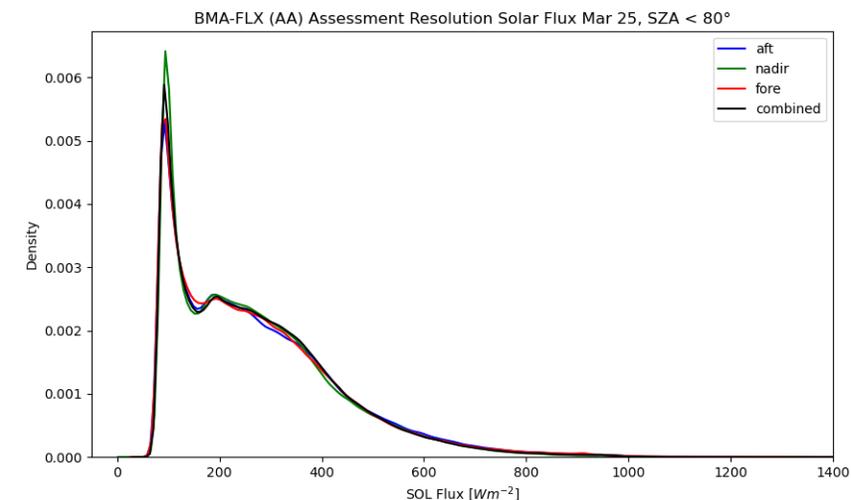
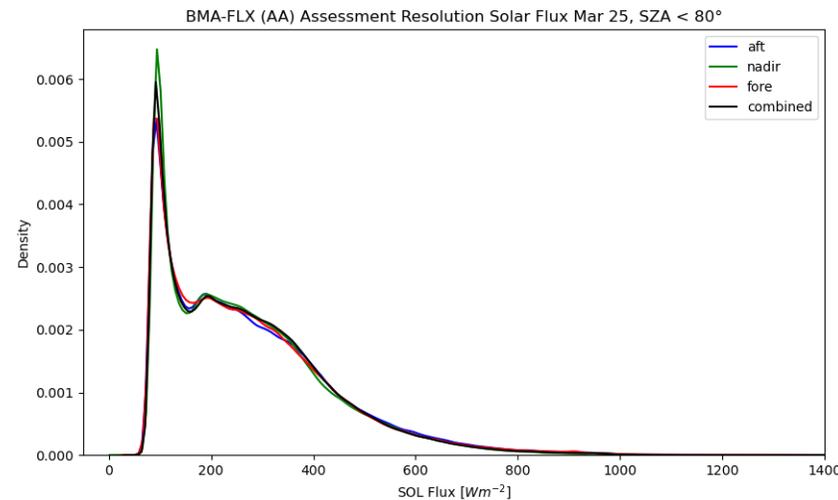
Assessment Domain

All-day

TH TOA Flux



Counts per Bin



Daytime

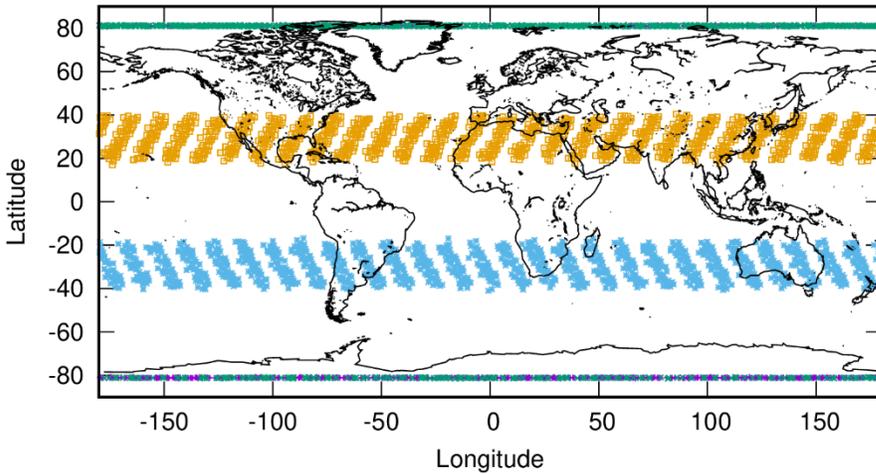
- Margins have been introduced with the change of the L1 baseline to AD.



CERES SSF comparison: SW and LW Radiance

10 August 2024 to
28 February 2025

Terra - day +
 Terra - night x
 NOAA20 - day *
 NOAA20 - night □

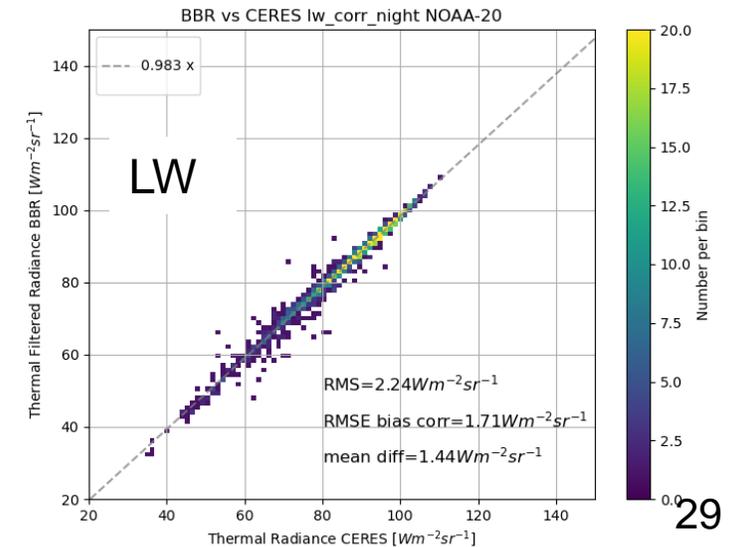
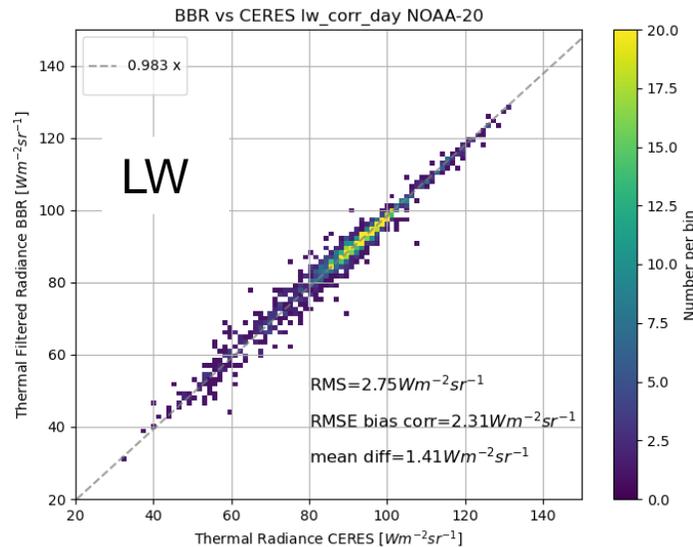
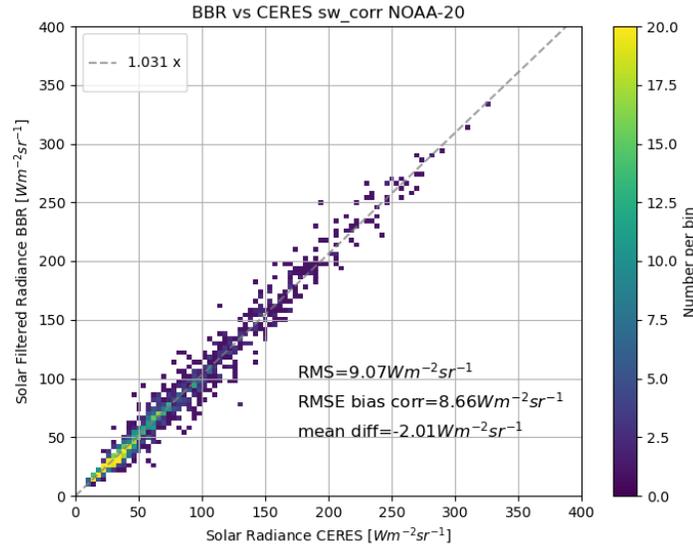


NOAA-20 only

CERES VZA < 3°
 $\Delta\text{dist} < 3 \text{ km}$
 $\Delta\text{time} < 5 \text{ min}$

Daytime

Nighttime

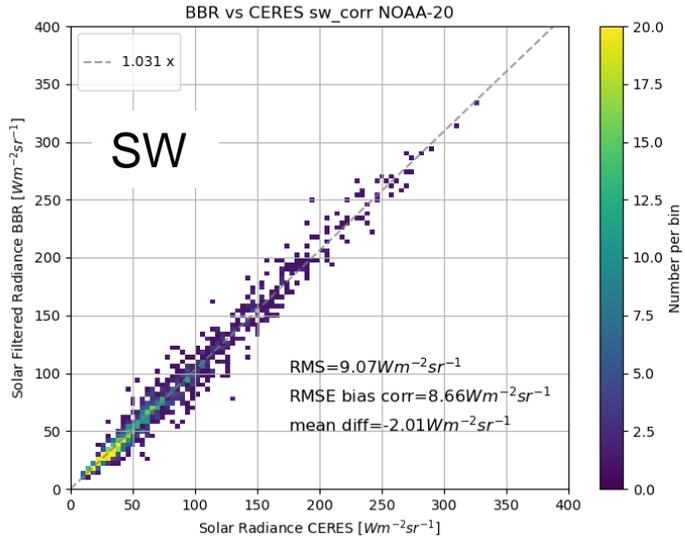




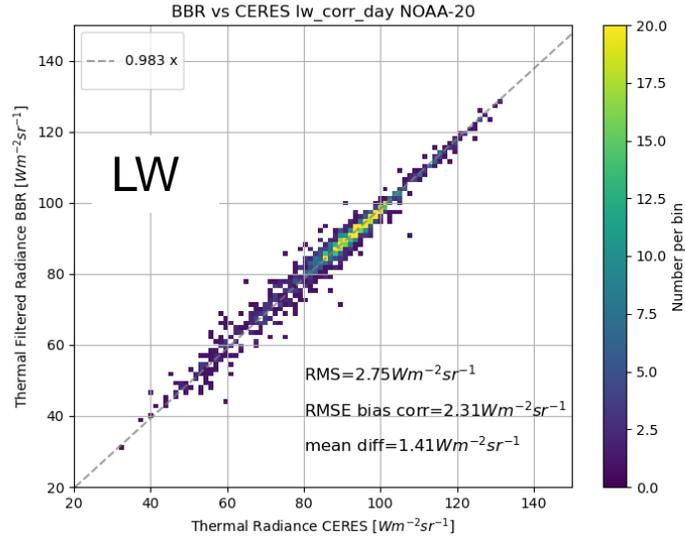
CERES FLASHflux and SSF comparison: SW and LW Radiance

SSF (NOAA-20 only)

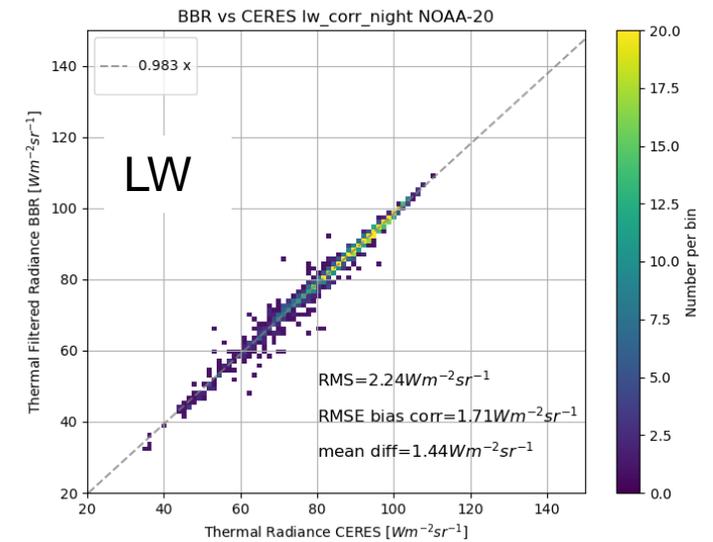
Daytime



Daytime

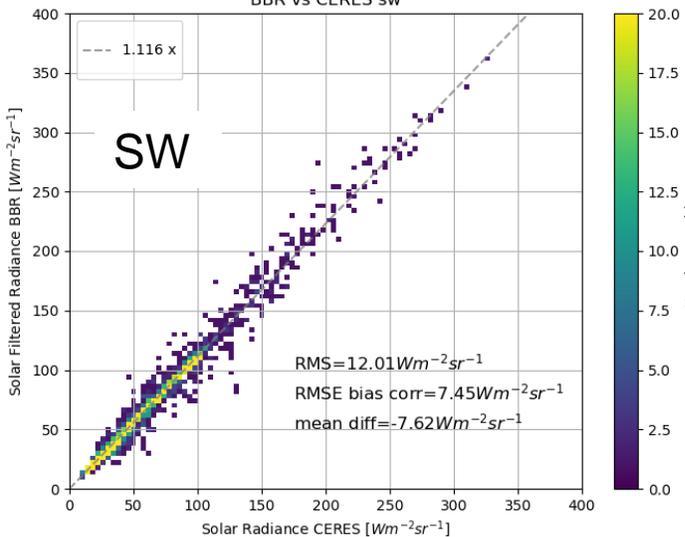


Nighttime

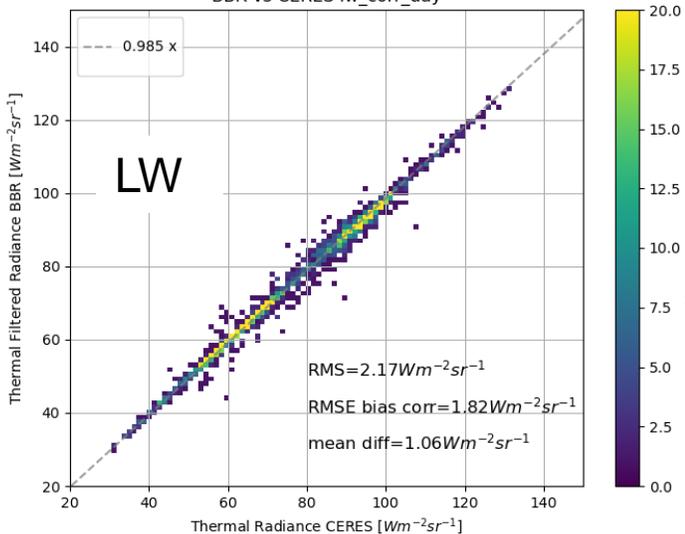


FlashFLUX

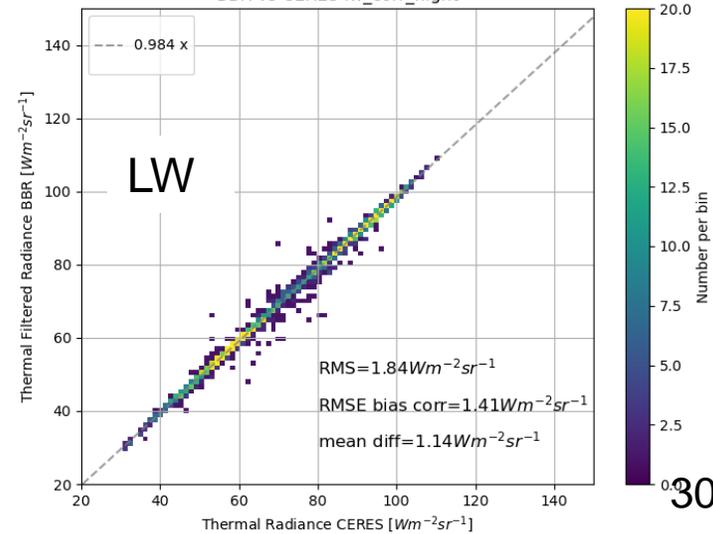
BBR vs CERES sw

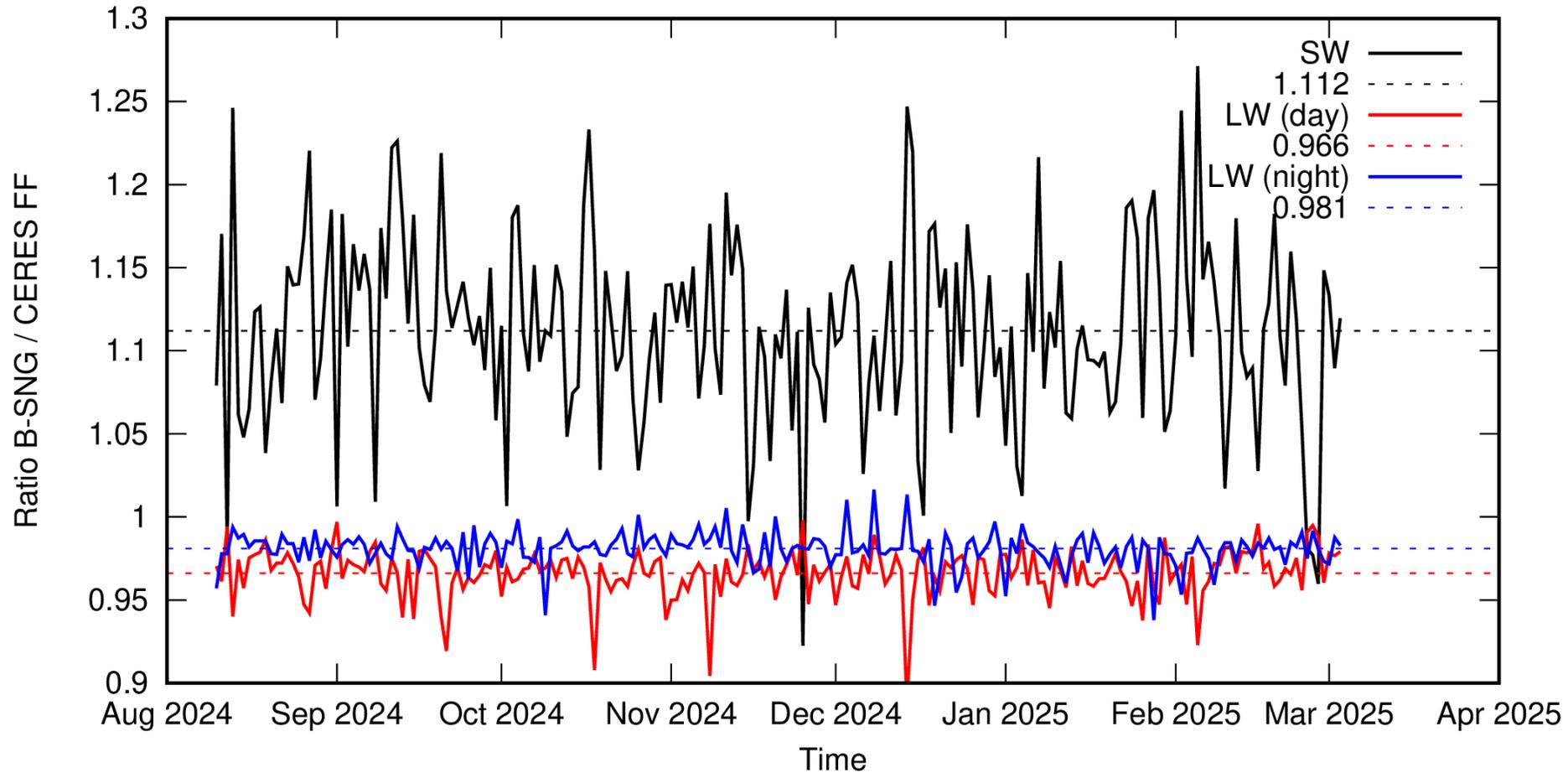


BBR vs CERES lw_corr_day



BBR vs CERES lw_corr_night





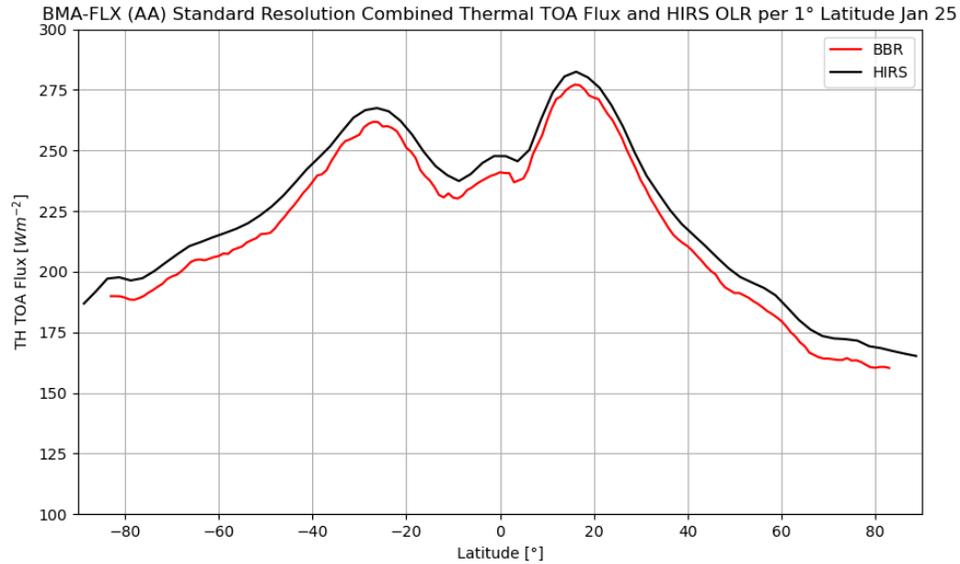
- No indication of temporal degradation so far.



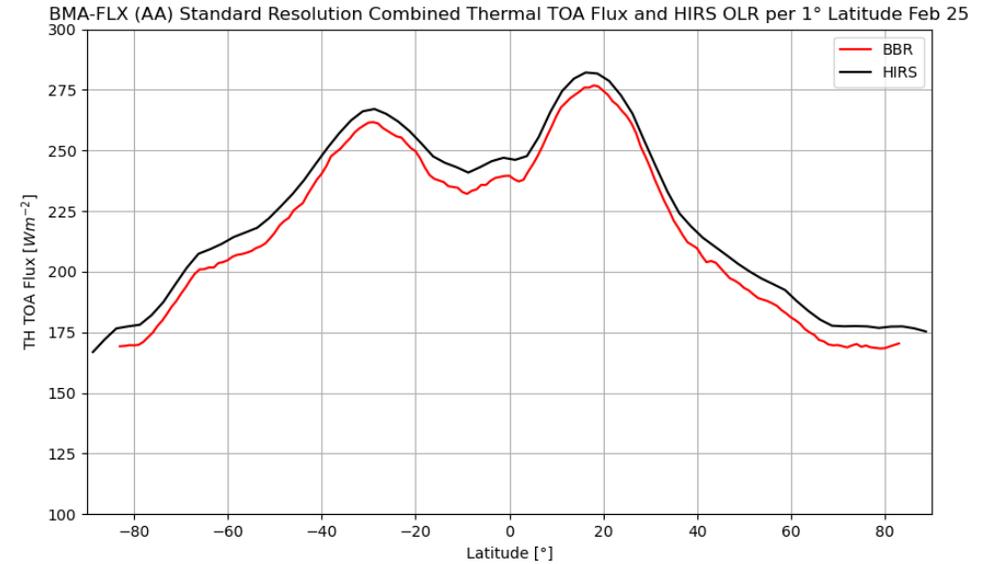
BMA-FLX – HIRS Comparison

HIRS NOAA OLR daily mean
BBR 14:00 descending node

January 2025

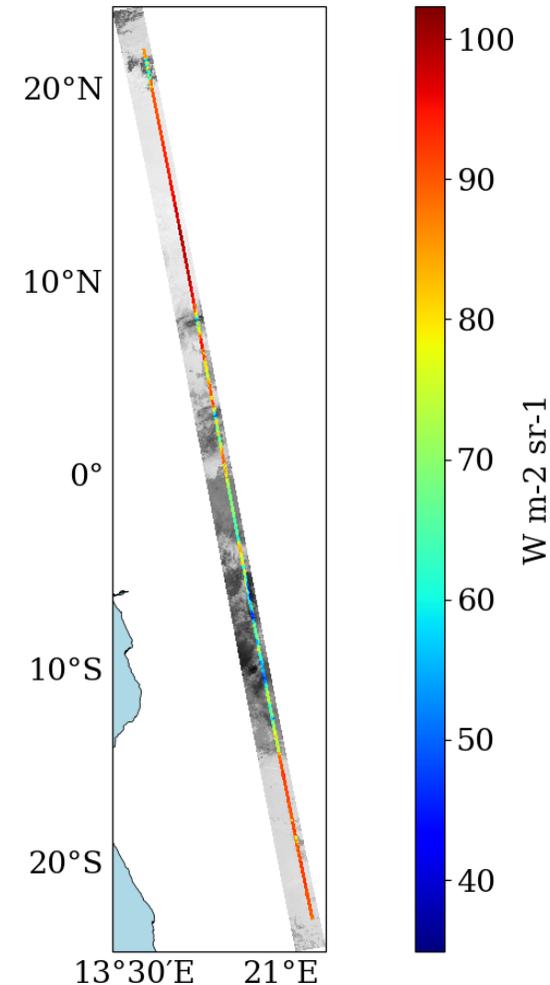


February 2025



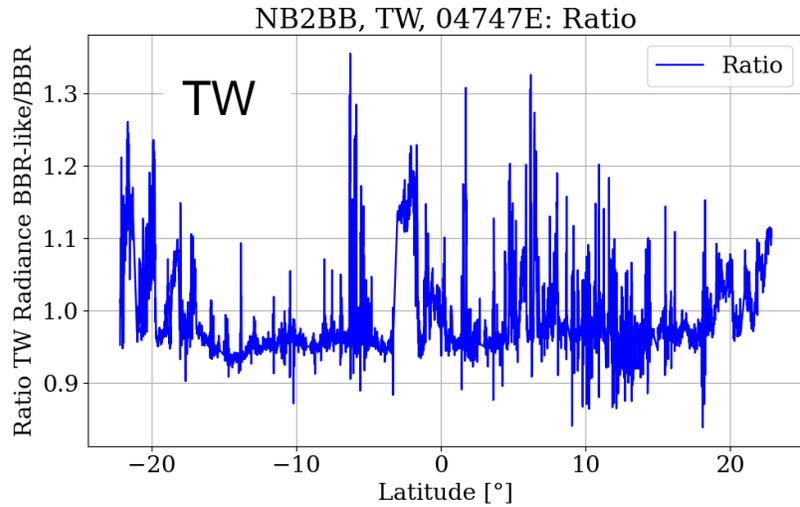
- The BBR-like broadband product is calculated from narrowband MSI VNS reflectances and TIR radiances, by using theoretical regressions derived from Radiative Transfer Model calculations.
- The estimated broadband shortwave reflectances are converted into radiances taking into account the Sun-Earth distance 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

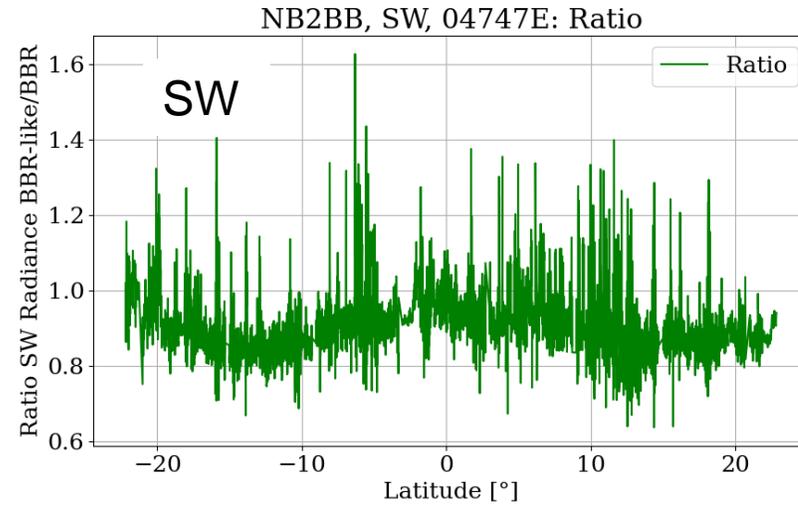
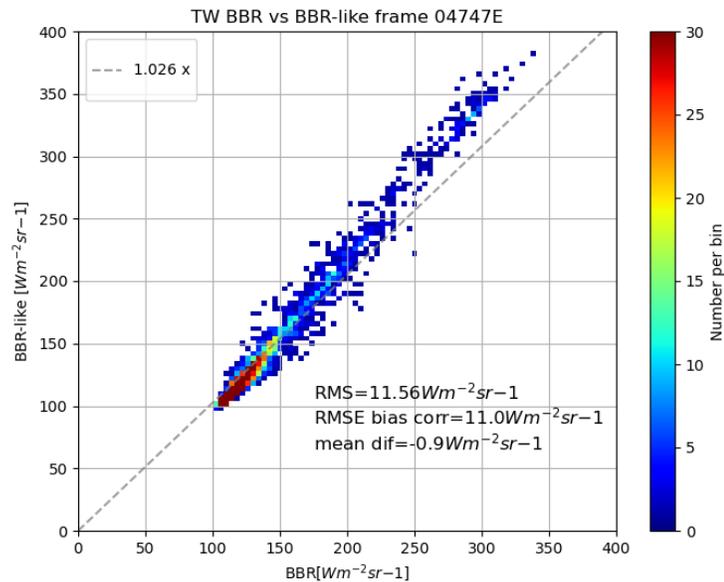




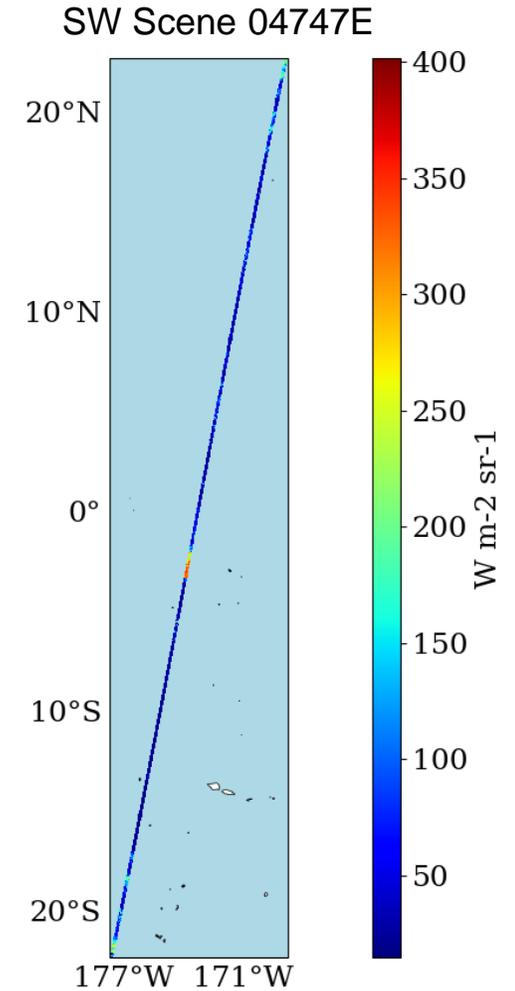
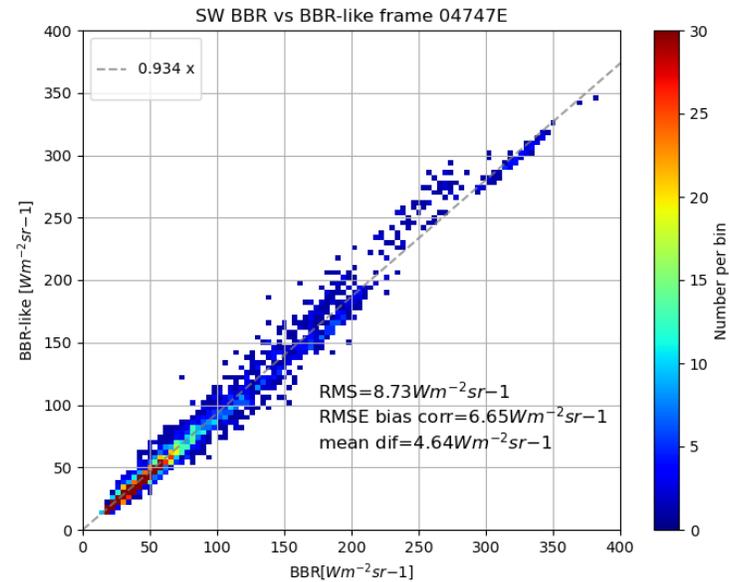
NB to BB: First Plots for Frame 04747E

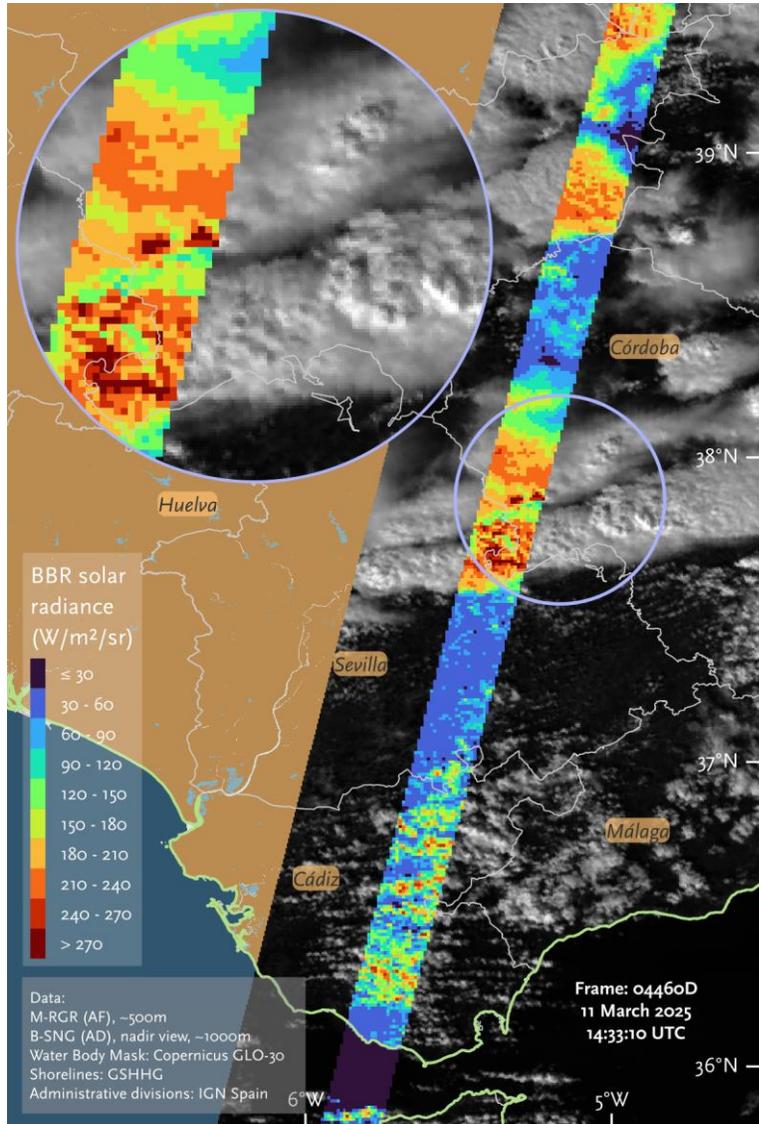


TW Mean ratio = 0.994 ± 0.061



SW Mean ratio = 0.911 ± 0.084





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EarthCARE's Broadband Radiometer observes major thunderstorms in Spain

This image shows how EarthCARE's Level-1 B-SNG broadband radiometer (BBR) product captures the signal of a major convective system - a large cluster of thunderstorms that can bring severe weather such as strong winds, heavy rainfall and flooding - in the south of Spain on 11 March 2025.

The Level-1 B-SNG product provides broadband measurements spectrally integrated from ultra-violet to the far infrared, in both solar and thermal channels, with an unprecedented spatial resolution of 600 m across-track by 1100 m along-track.

The image shows the nadir BBR observation, in colour, over the larger multispectral imager (MSI) swath, in greyscale.

Similar observations are captured from a forward and backward direction. Combining these three views allows us to estimate the reflected solar flux and the emitted thermal flux with an level of accuracy of better than 10 W/m², as required for the radiometric scientific goal of the EarthCARE mission.

The BBR and MSI are two of four instruments on board ESA's Earth Cloud, Aerosol and Radiation Explorer (EarthCARE) satellite. Both Level-1 and some Level-2 products are now open to the public and are available for scientific use.

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- Continuation of the monitoring of various parameters in L1 and L2 (including new baseline-releases).
- Continuation of the analysis of changes per month or even per day.
- Monitoring potential issues/ageing of the instruments with the BBR-like product.
 - Calculation/Analysis of more frames.
- Starting to define and look at different Earth Targets, such as deserts, clear ocean, DCC.
- Continuation of the analysis with GERB and CERES data:
 - Using FlashFLUX data for monitoring and at a later stage the SSF product for science.