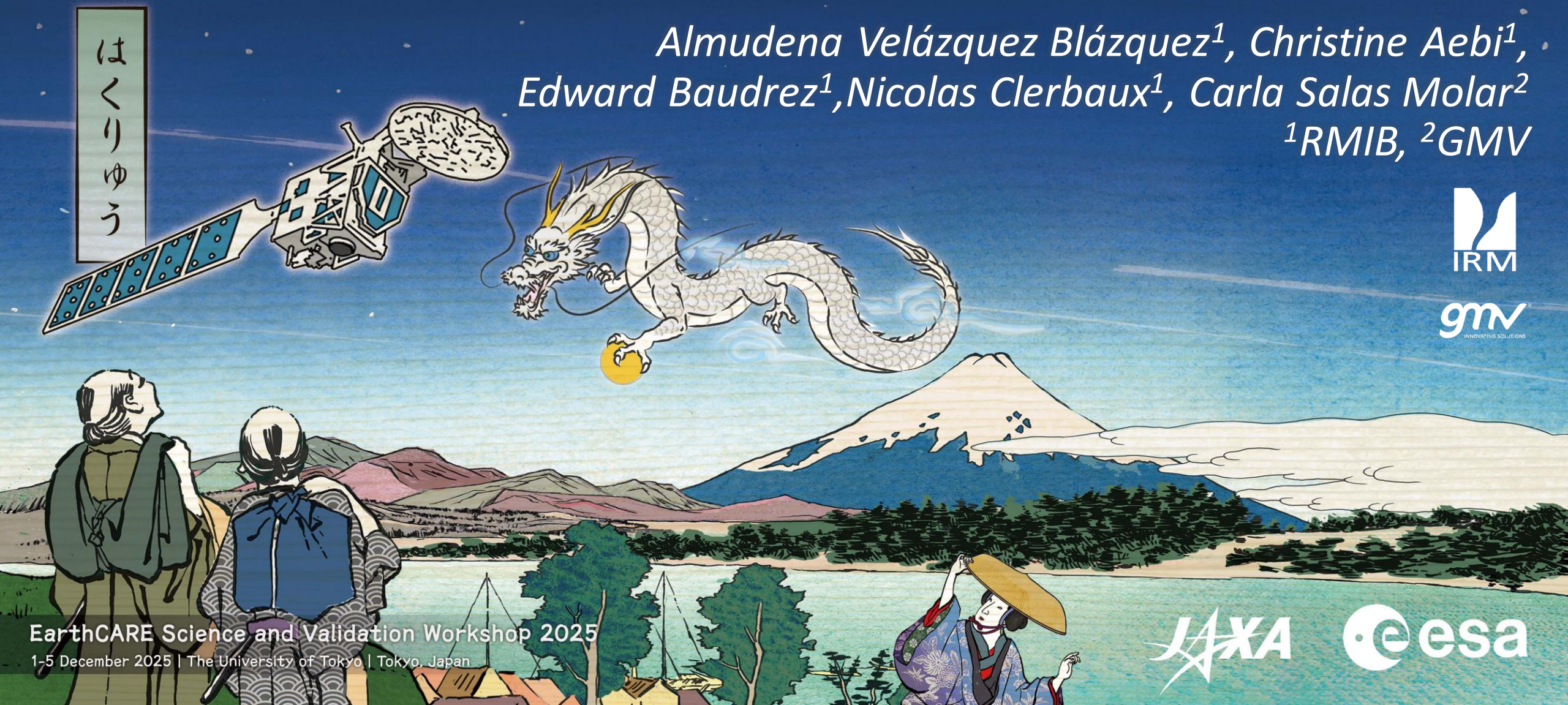# BM-RAD and BMA-FLX updates and validation

Almudena Velázquez Blázquez[1], Christine Aebi[1], Edward Baudrez[1],Nicolas Clerbaux[1], Carla Salas Molar[2]

[1]RMIB, [2]GMV

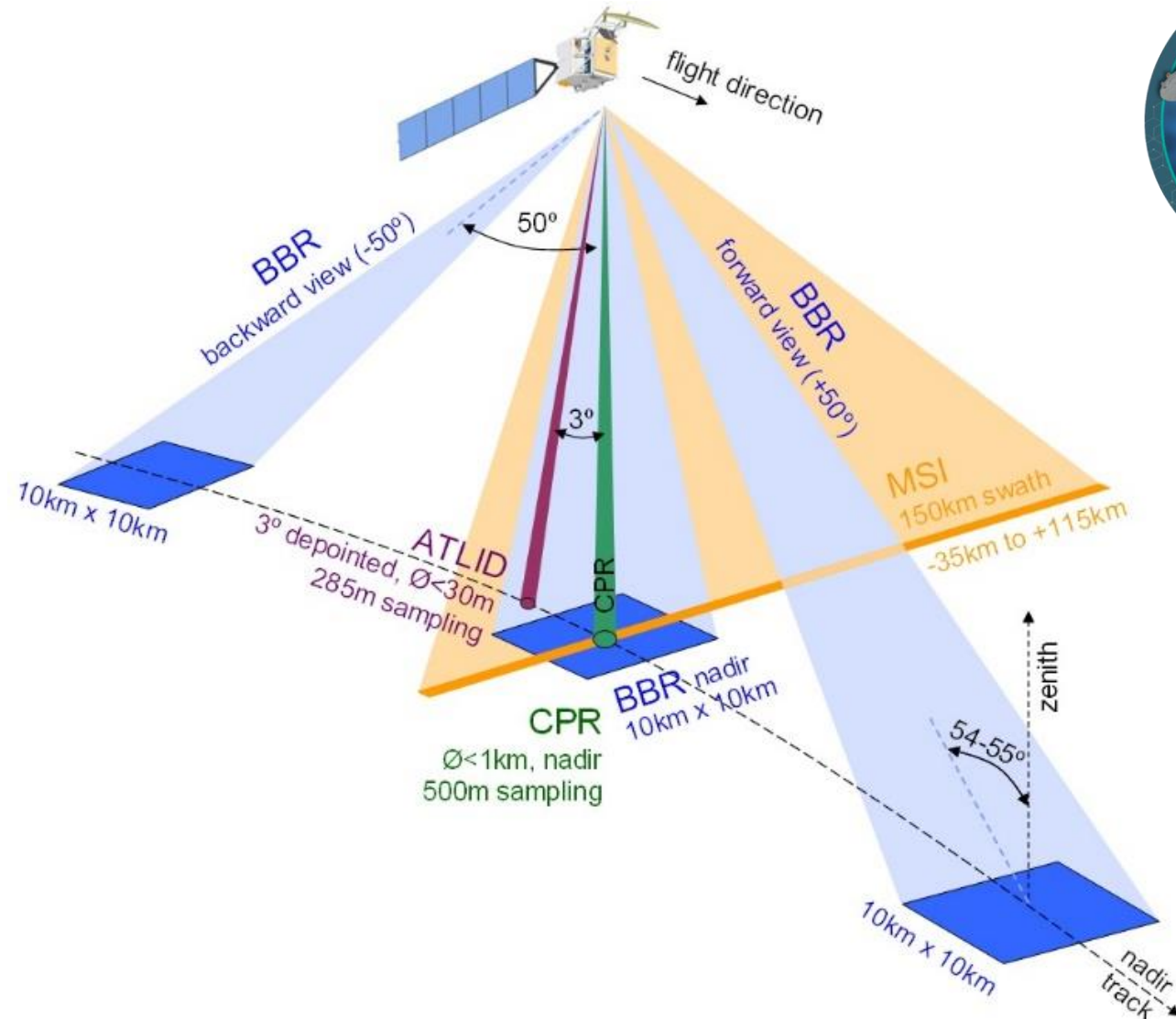EarthCARE Science and Validation Workshop 2025
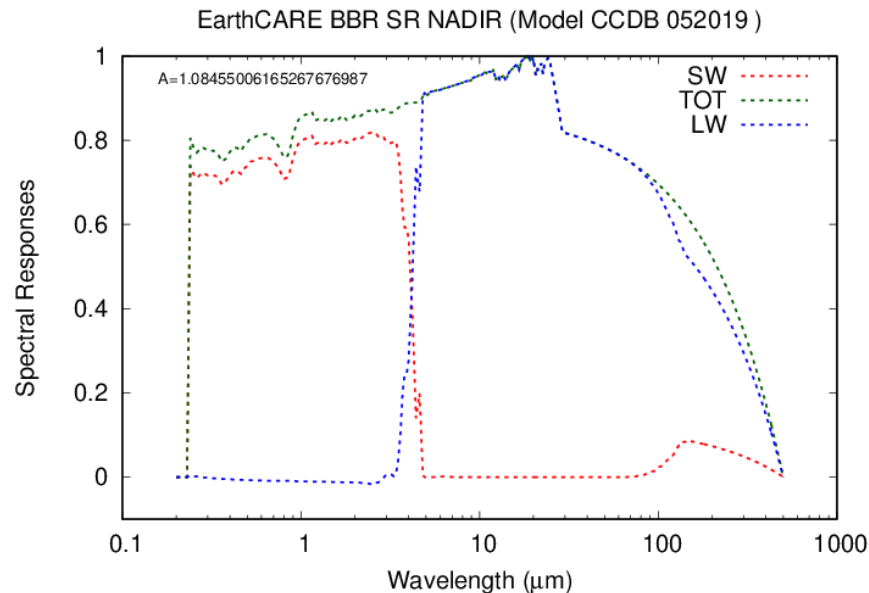1-5 December 2025 | The University of Tokyo | Tokyo, Japan

Outline

BM-RAD

- **BBR SW** and **TW** measurements are converted into **solar** and **thermal** **unfiltered radiances**

- Two unfiltering algorithms:
  - **Stand-alone** : BBR L1 and land use classification (SW & LW)
  - **SW MSI-based**: SW BBR L1 and MSI cloud mask and cloud phase
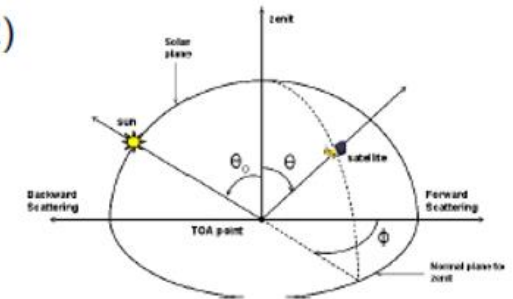

EarthCARE BBR SR NADIR (Model CCDB 052019)

BMA-FLX

- **BBR solar** and **thermal radiances** are converted to **fluxes**

$$F(\theta_0) = \int_{\theta=0}^{\frac{\pi}{2}} \int_{\phi=0}^{2\pi} L(\theta,\phi)\cos(\theta)\sin(\theta)d\theta d\phi$$

▶ Need of Angular Dependency Models (R)

$$F = \frac{\pi L(\theta,\phi)}{R(\theta,\phi)}$$


- In the LW: $R(\theta) = a_0 + a_1 z_1 + a_2 z_2 + a_3 z_1^2 + a_4 z_1 z_2 + a_5 z_2^2$

  $z_1 = BT_{10.8\ \mu m}$ and $z_2 = BT_{12.0\ \mu m} - BT_{10.8\ \mu m}$

- In the SW: feed-forward back-propagation ANN using CERES and MODIS data

Inputs: BM-RAD, M-RGR, M-CM, M-COP, A-CTH, X-MET

BM-RAD / BMA-FLX 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	✓		

AD PSF definition
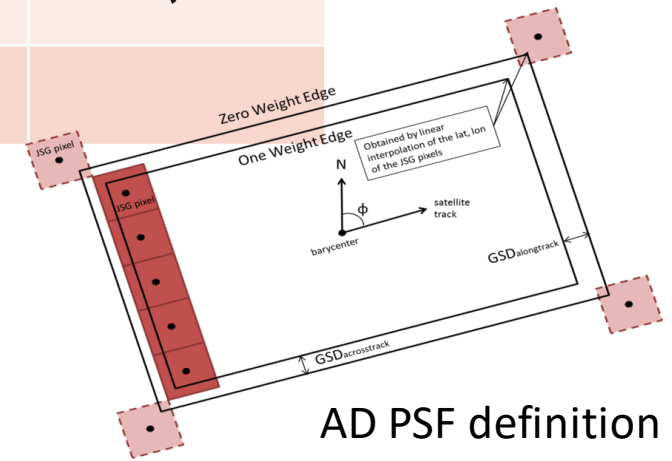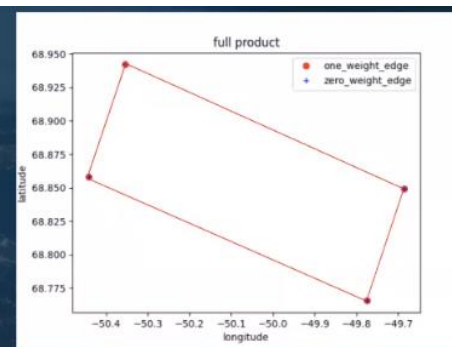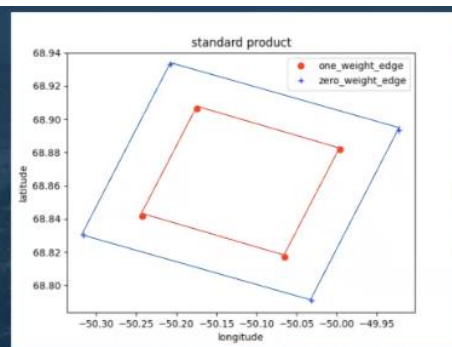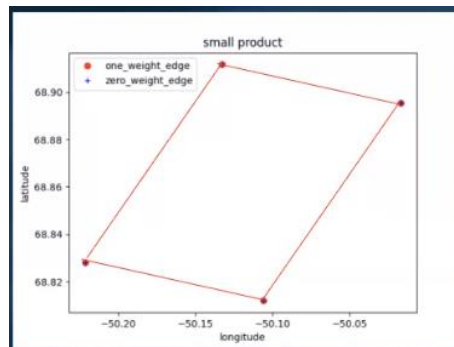
BBR L2 baselines: BM-RAD

Baseline BM-RAD	Start Date (Frame)	Stop Date	Most important Updates
BC	18 November 2025 (8374A)	On-going	Full resolution edge coordinates are now valid for the nadir view
BA	8 July 2025 (06307A)	18 November 2025 (8376B)	No changes from AC, baseline update and used in reprocessing
AC	27 May 2025 (05651C)	8 July 2025 (06307B)	Change of the SW Gain Ratios used in the LW calculation in the Assessment Domain (AD) resolution to be consistent with CCDB change in the BBR L1 update
AB	18 Dec 2024 (03169C)	27 May 2025 (05651B)	Change in the calculation of the LW radiances in the AD Resolution to be consistent with the other resolutions (Standard, Small, Full)

AC baseline used for full reprocessing → BA

DO NOT USE baseline AB

BBR L2 baselines: BMA-FLX

Baseline BMA-FLX	Start Date (Frame)	Stop Date	Most important Updates
BC	18 November	On going	No changes from baseline BB
BB	1 October 2025 (07636A)	18 November 2025	Added surf elevation, (COT) mean and error Solved small bug in the coregistration of the three BBR views. Solar reference level improvement when COT is Fill Value
BA	8 July 2025 (06307A)	1 October 2025 (07643B)	No changes from AB, baseline update and used in reprocessing
AB	09 May 2025 (05368B)	8 July 2025 (06307B)	Solar reference level height for co-registration is now selected using the MSI Cloud Optical Thickness (COT)
AA	25 July 2024	09 May 2025 (05368A)	- Some changes since launch without update of baseline - Impacted by L1 inputs updates: BM-RAD, M-RGR, M-CM, M-CLD

**Baseline used for full reprocessing → BA**

DO NOT USE baseline AB or AA

Co-registration of LW radiances

- The height defined by the CTH derived from brightness temperature (M-COP) is a good estimator to co-register the BBR radiances in LW.
- RL is defined as the 90th percentile of the altitude of the highest cloud in the BBR domain.

Co-registration of SW radiances

- Views are co-registered at a RL defined as the vertical level in the nadir domain that minimizes the flux differences between the nadir, aft and fore flux retrievals
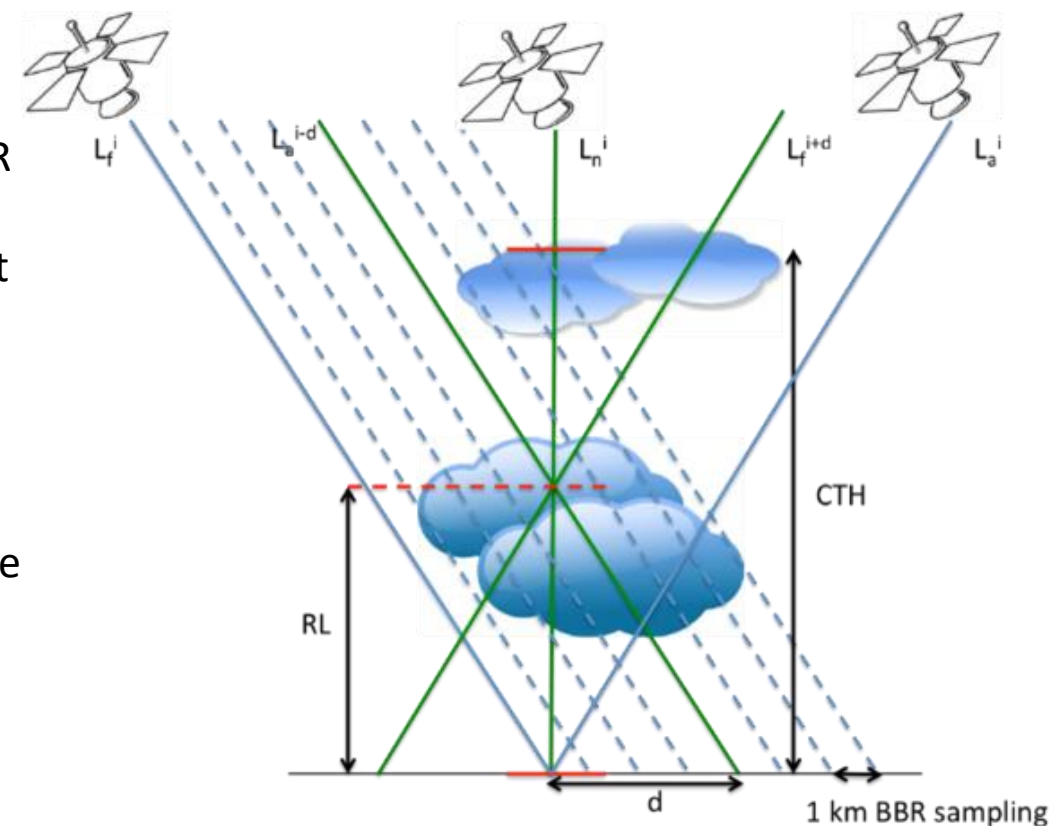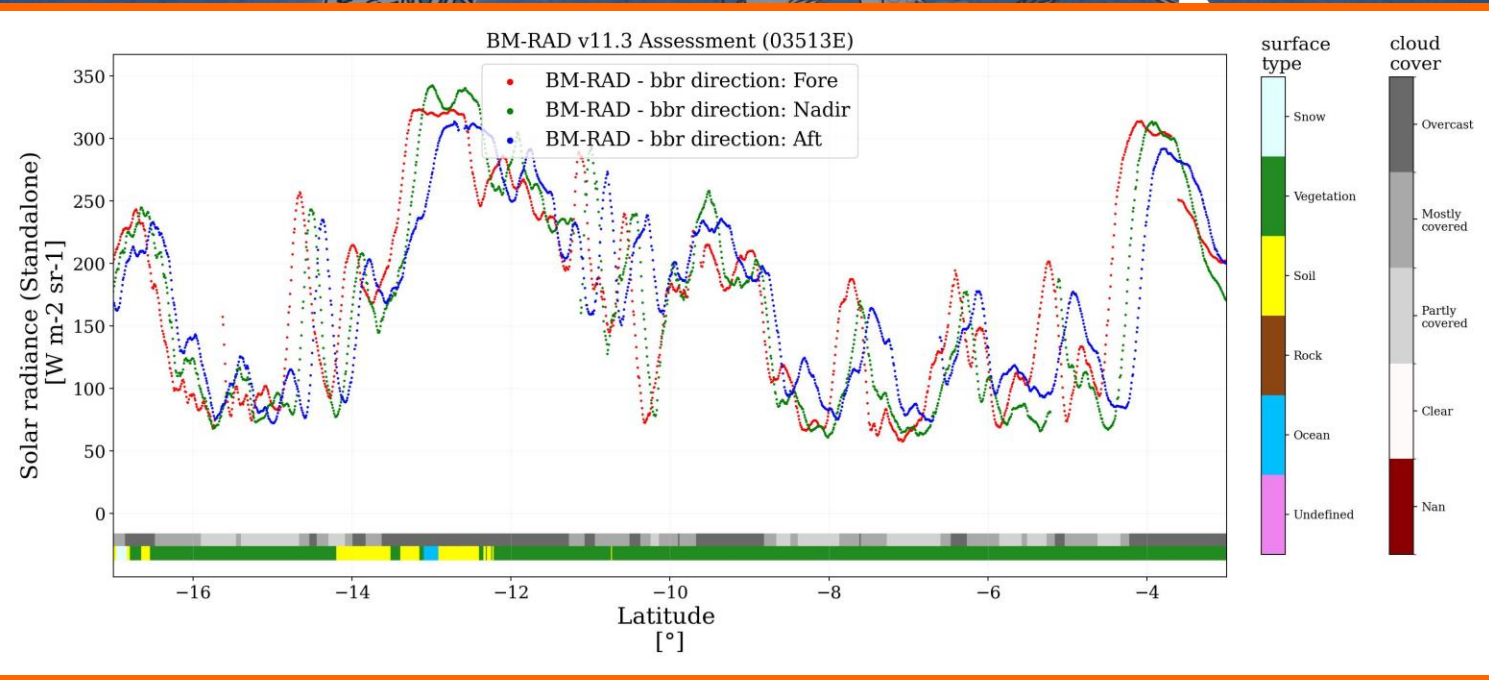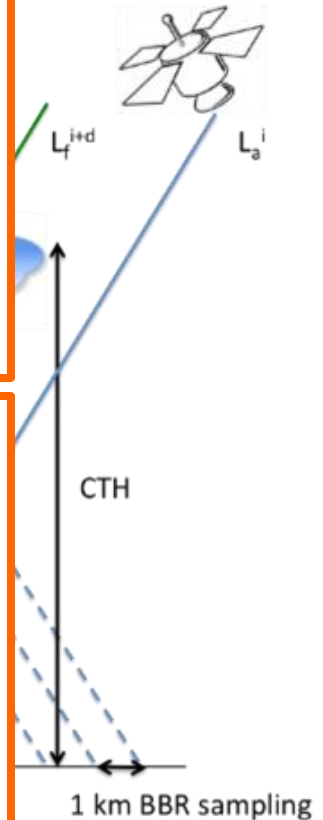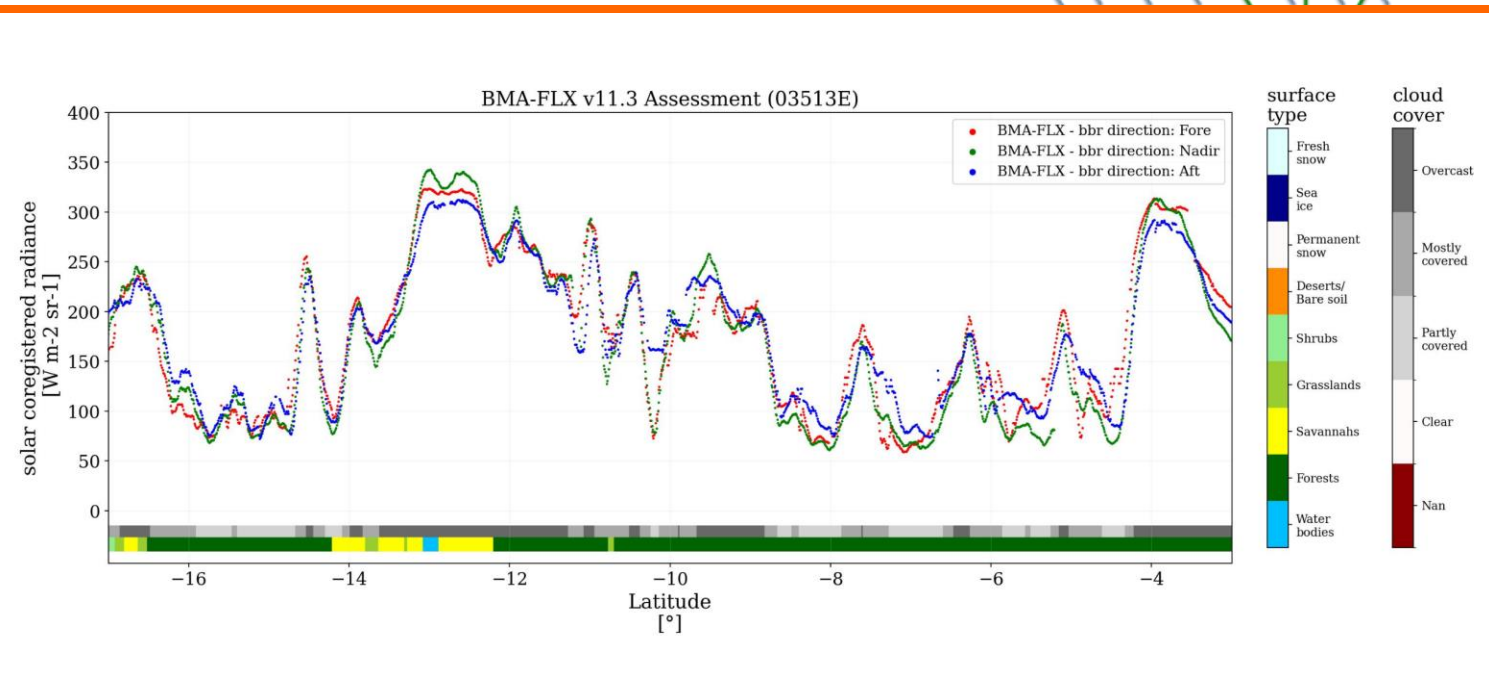
Reference level hei

Co-registration of LW ra

- The height defined by temperature (M-COP) radiances in LW.
- RL is defined as the 90 cloud in the BBR doma

Co-registration of SW ra

- Views are co-registered nadir domain that mini nadir, aft and fore flux
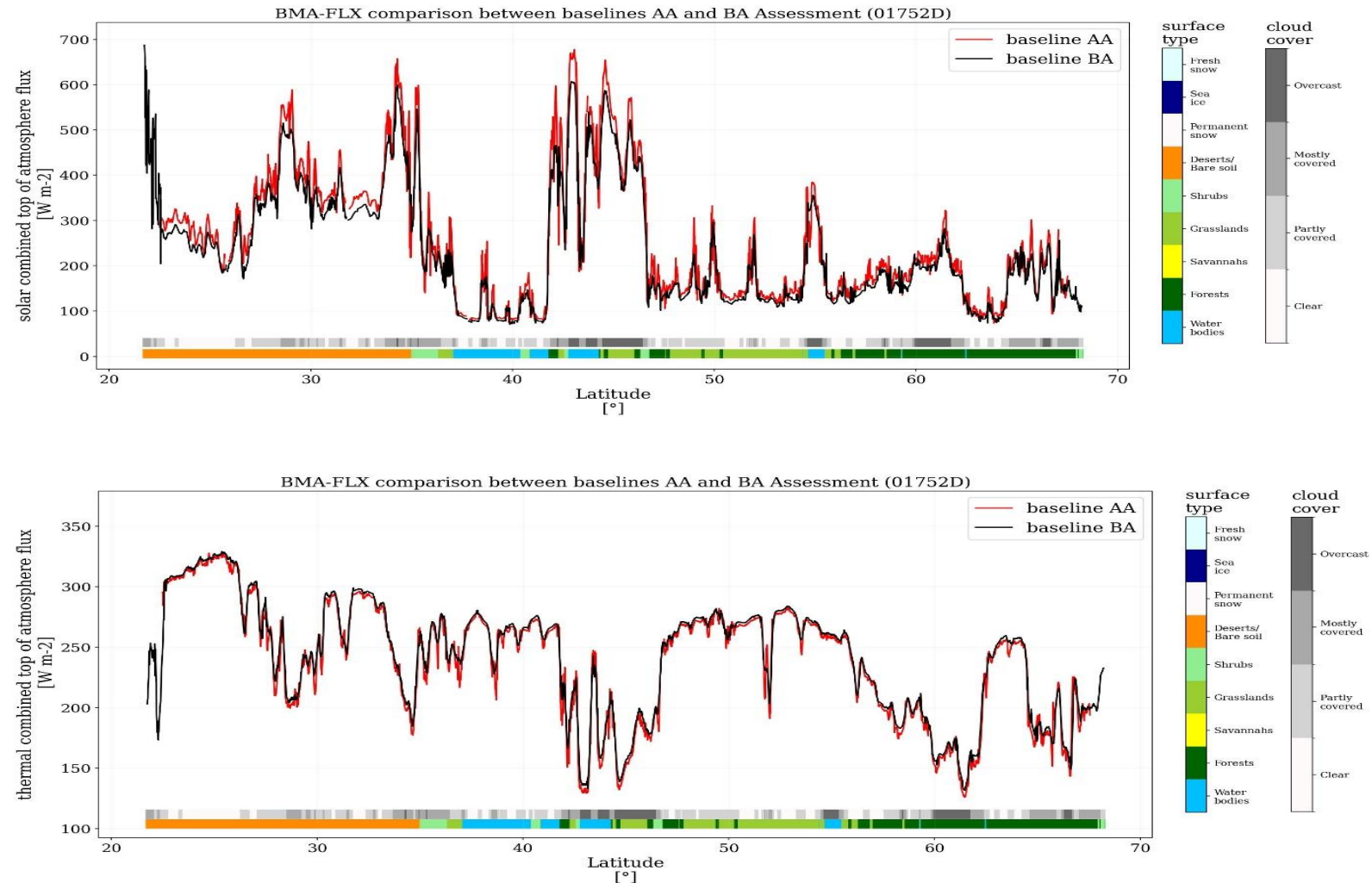
BMA-FLX radiometric level update

Radiometric level of BMA-FLX fluxes BA updated indirectly via BM-RAD/B-NOM/B-SNG

↓↓SW
↑LW

- LUT of Radiances vs Blackbody Temperatures updated to account for Far Infrared sensitivity

- SW Gain ratios updated to account to reduce stripping in the B-SNG product and to correct pre-launch SW calibration
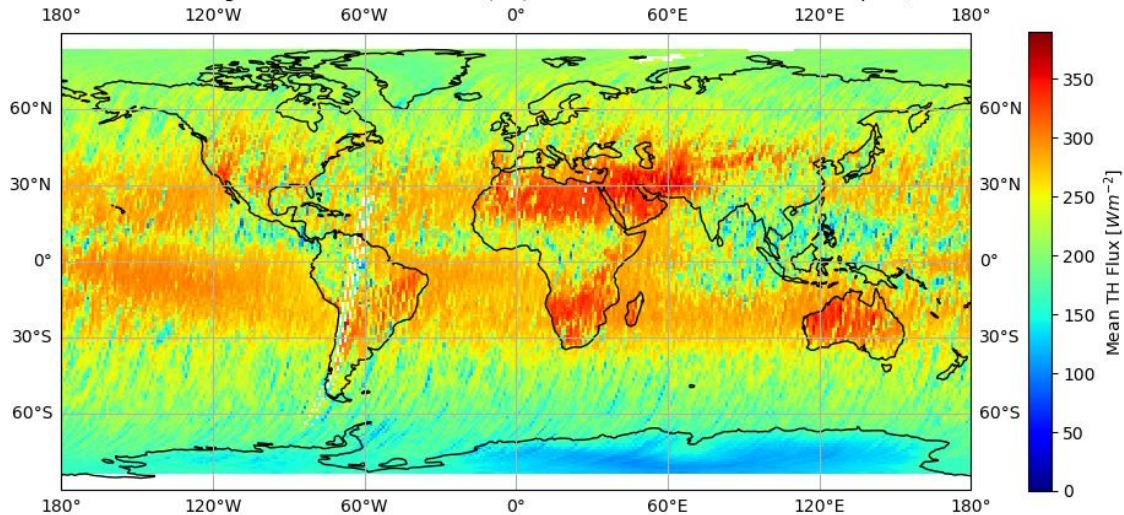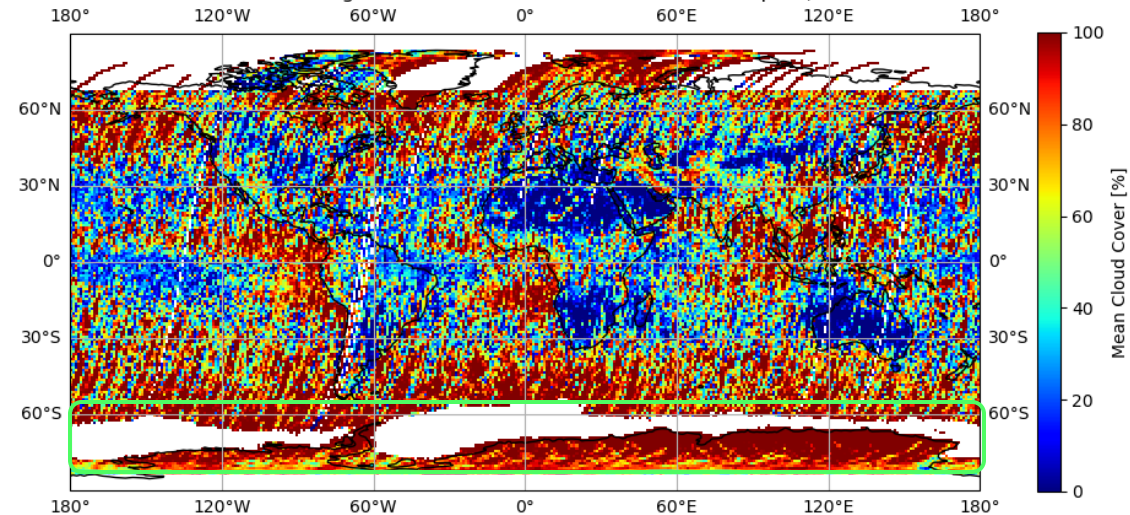
USE BASELINES BA+

BMA-FLX comparison between baselines AA and BA Assessment (01752D)

BMA-FLX comparison between baselines AA and BA Assessment (01752D)

BMA-FLX (BA)

Systematic issue with cloud cover in frames F

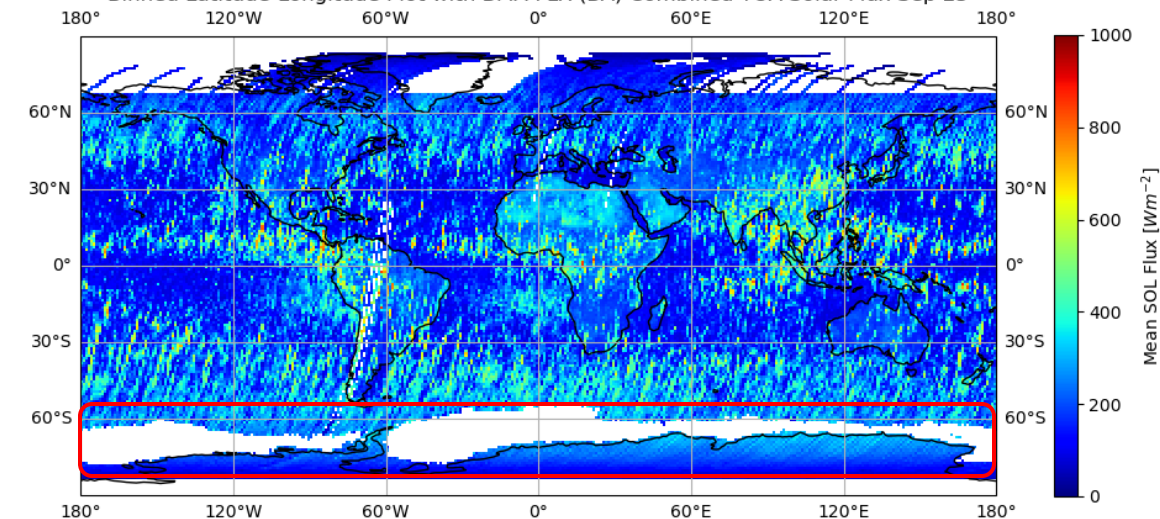Binned Latitude-Longitude Plot with BMA-FLX (BA) Combined TOA Thermal Flux Sep 25, SZA<90°

Binned Latitude-Longitude Plot with BMA-FLX Cloud Cover Sep 25, SZA<90°

Binned Latitude-Longitude Plot with BMA-FLX (BA) Combined TOA Thermal Flux Sep 25, SZA>90°
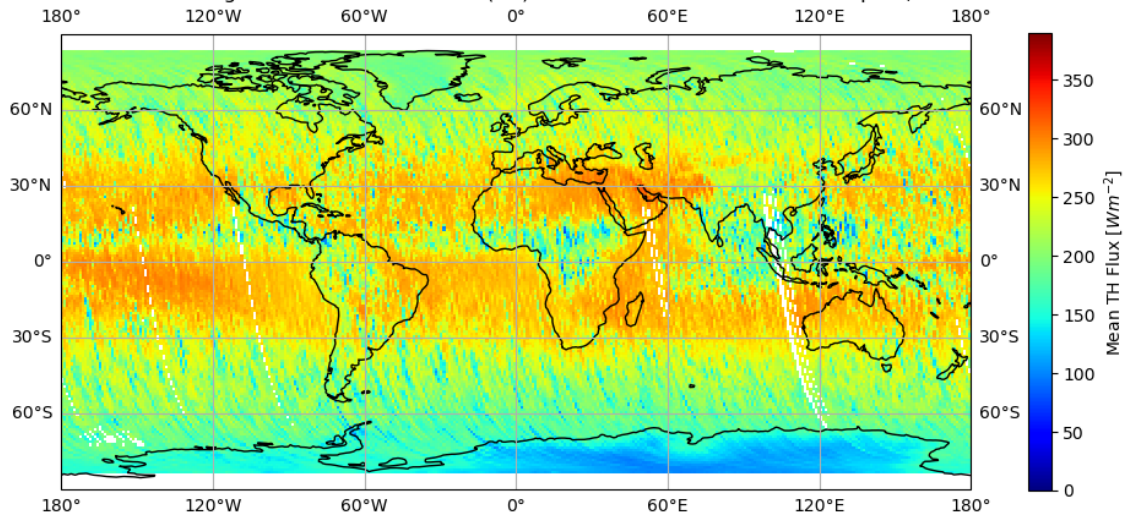
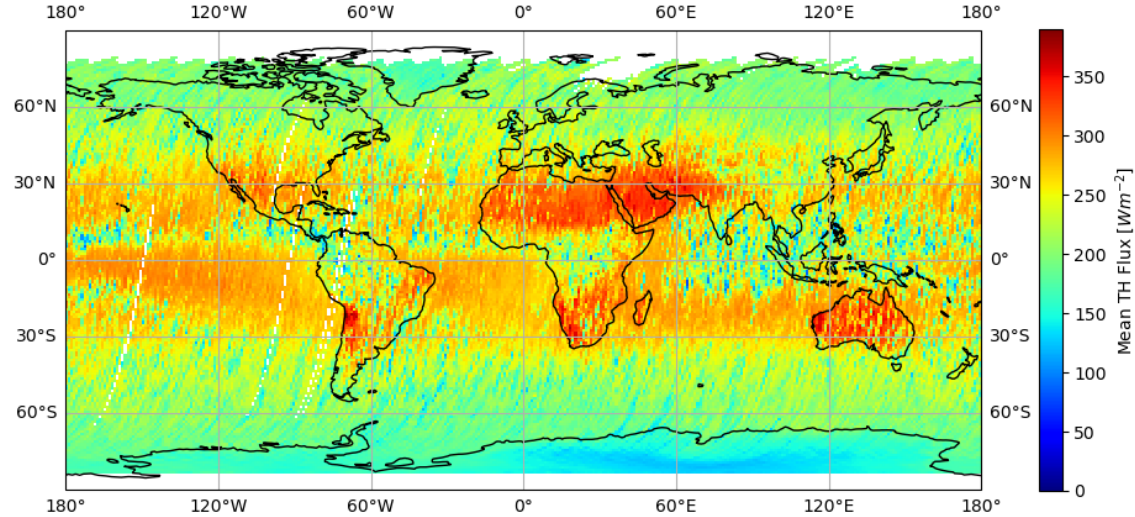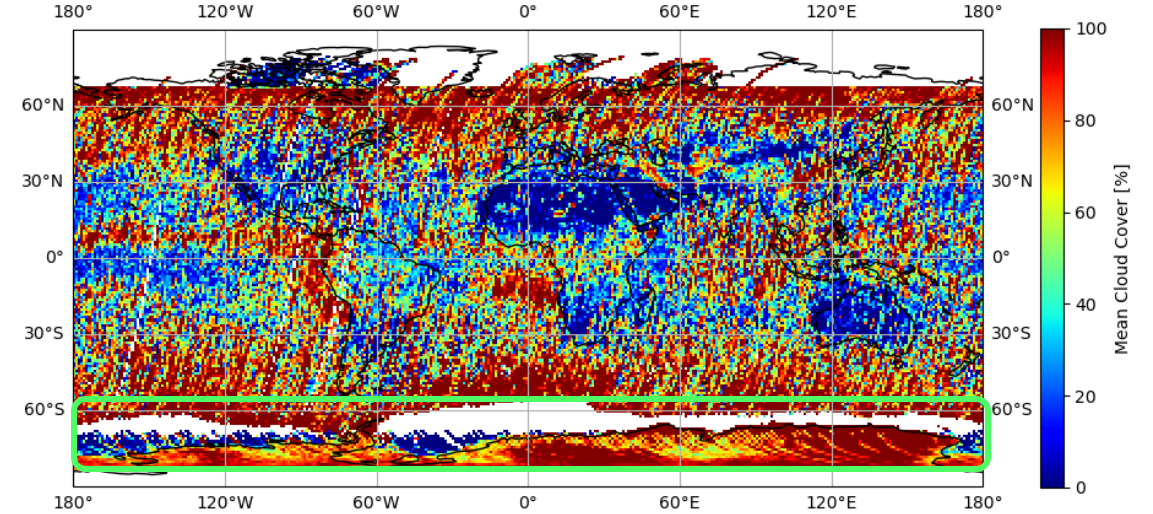Binned Latitude-Longitude Plot with BMA-FLX (BA) Combined TOA Solar Flux Sep 25

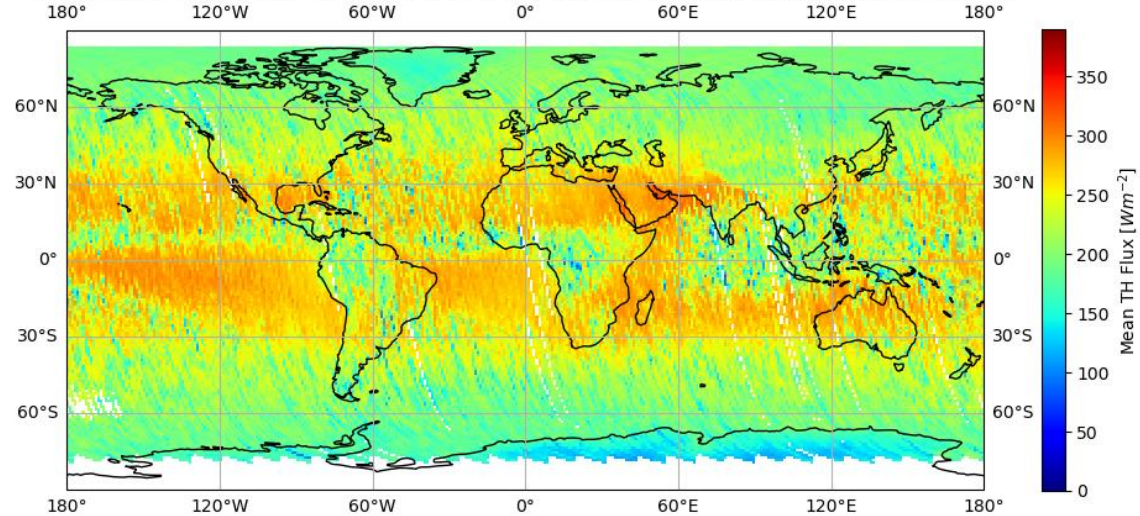3-12-2025

BMA-FLX (BB)

Systematic issue with cloud cover in frames F

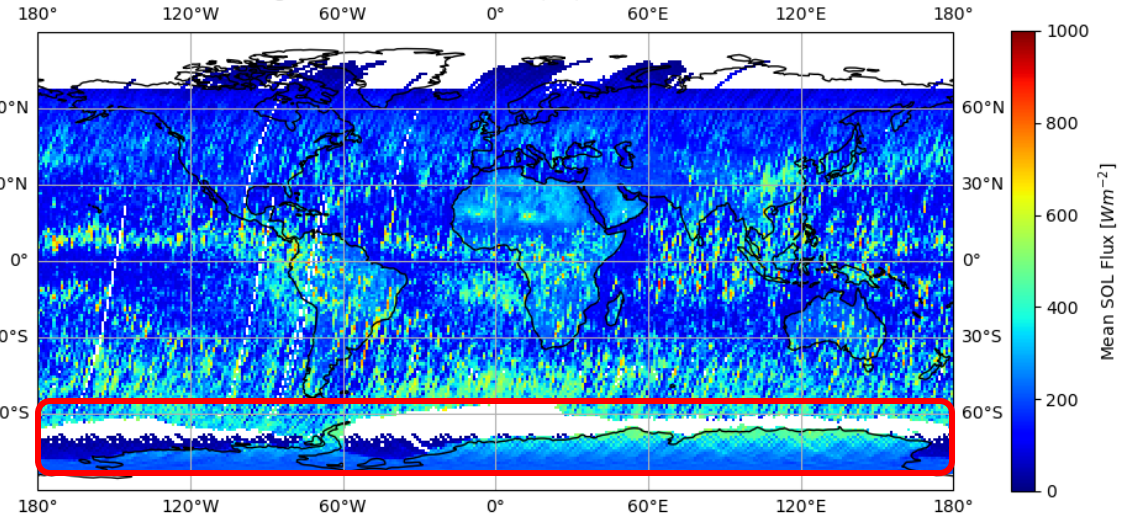Binned Latitude-Longitude Plot with BMA-FLX (BB) Combined TOA Thermal Flux Oct 25, SZA<90°

Binned Latitude-Longitude Plot with BMA-FLX (BB) Cloud Cover Oct 25, SZA<90°

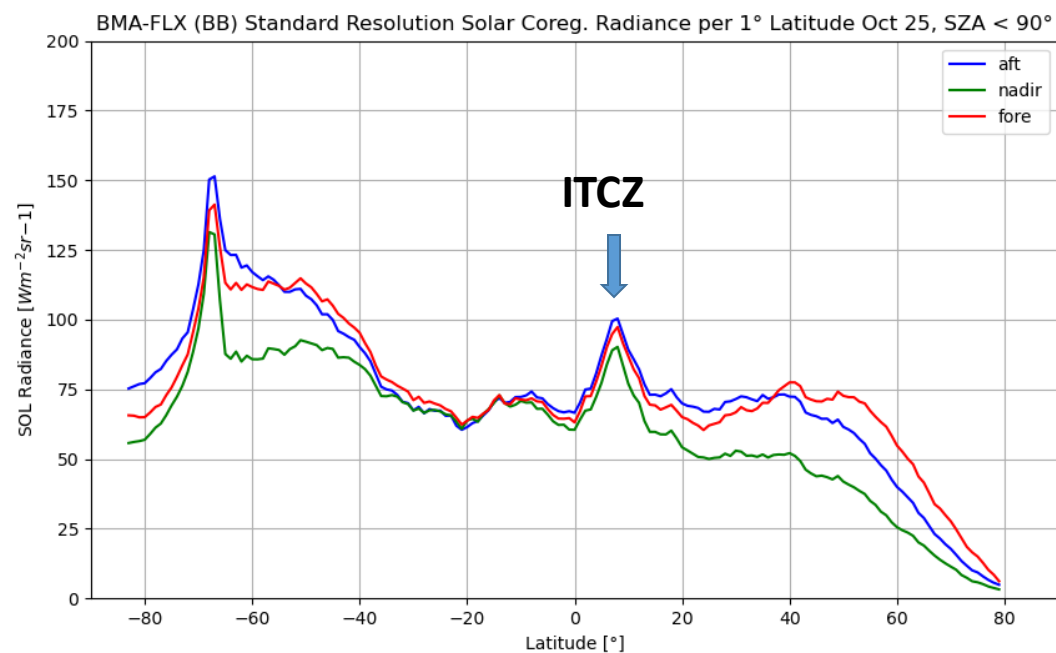Binned Latitude-Longitude Plot with BMA-FLX (BB) Combined TOA Thermal Flux Oct 25, SZA>90°

Binned Latitude-Longitude Plot with BMA-FLX (BB) Combined TOA Solar Flux Oct 25
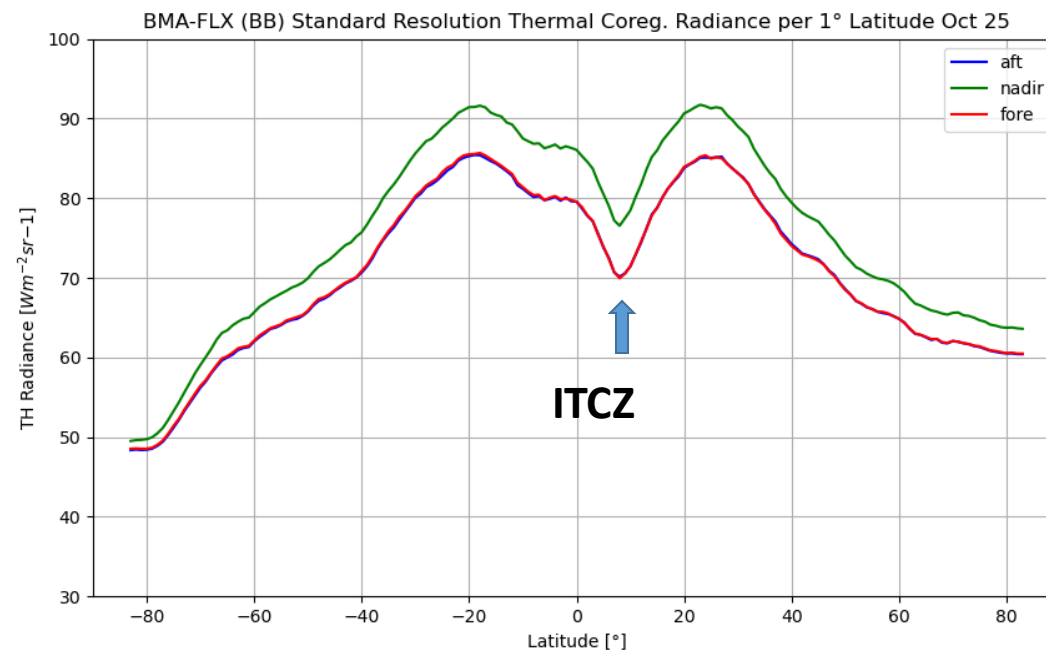
Latitudinal means: Radiances (BB)

SOLAR

BMA-FLX (BB) Standard Resolution Solar Coreg. Radiance per 1° Latitude Oct 25, SZA < 90°

ITCZ

THERMAL

BMA-FLX (BB) Standard Resolution Thermal Coreg. Radiance per 1° Latitude Oct 25

ITCZ

Latitudinal means: Fluxes (BB)

SOLAR
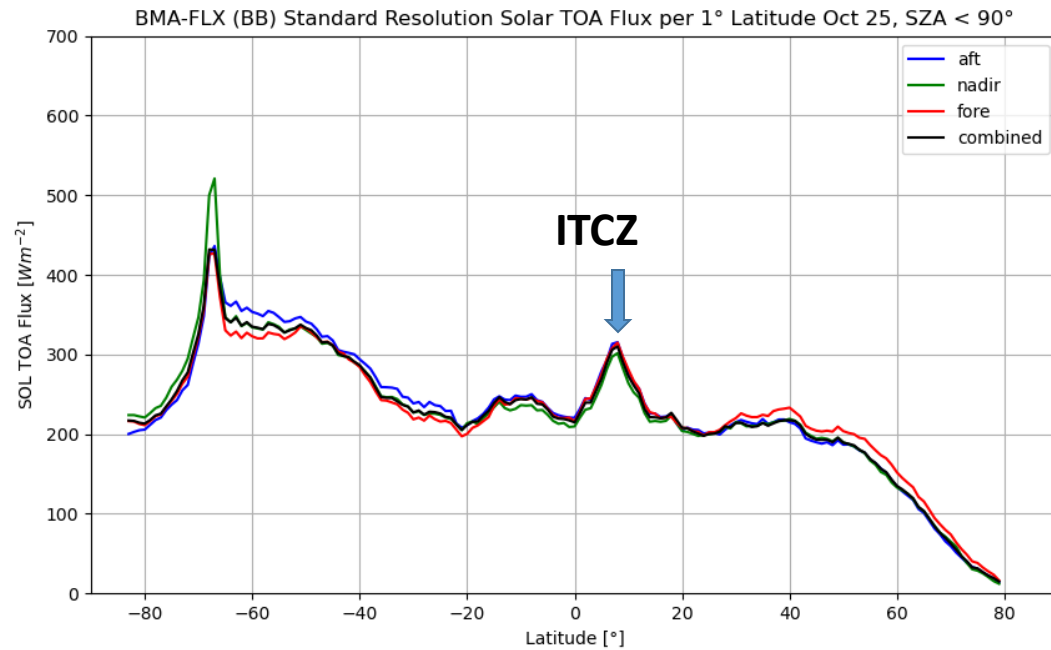
BMA-FLX (BB) Standard Resolution Solar TOA Flux per 1° Latitude Oct 25, SZA < 90°

ITCZ

THERMAL

BMA-FLX (BB) Standard Resolution Thermal TOA Flux per 1° Latitude Oct 25

ITCZ
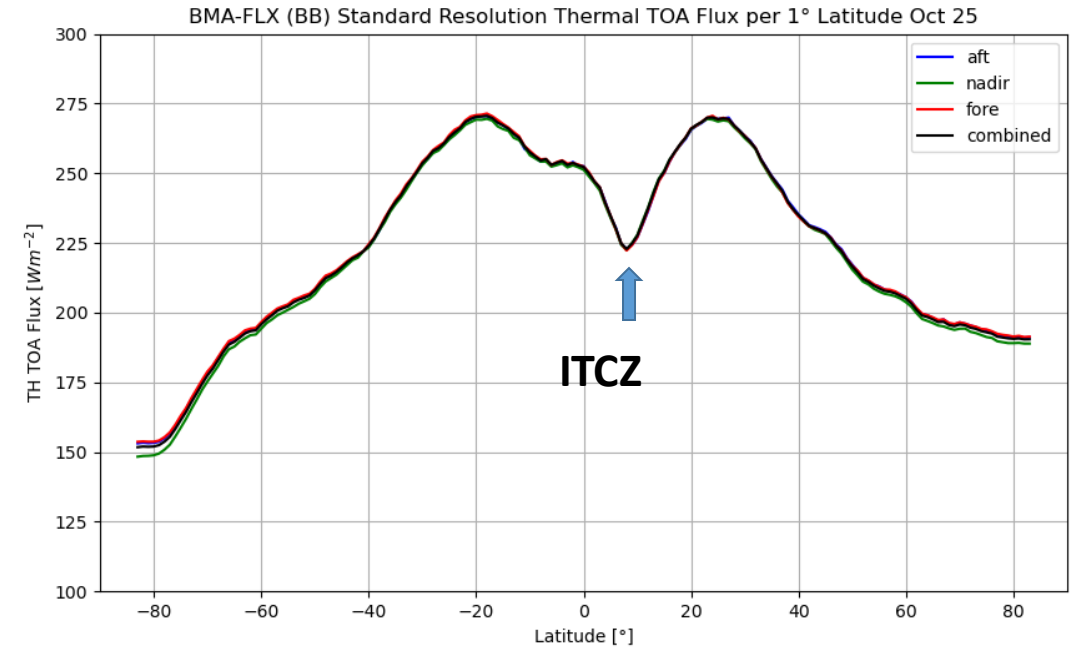
GERB/BBR comparisons baseline BA: SW and LW Radiances

- **GERB-1 is over the Indian ocean**

- **Data from 28 May 2025 to 5 August 2025**

- **Only nadir comparisons**

GERB VZA < 3 deg
Δdist < 3 km
Δtime < 5 min

- GERB 1 user corrections applied
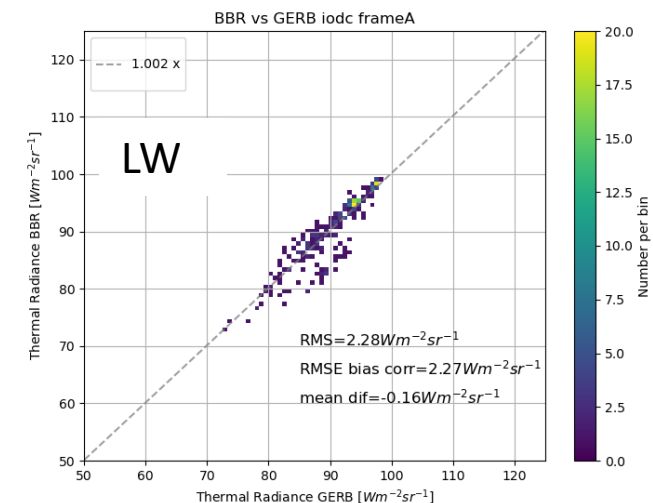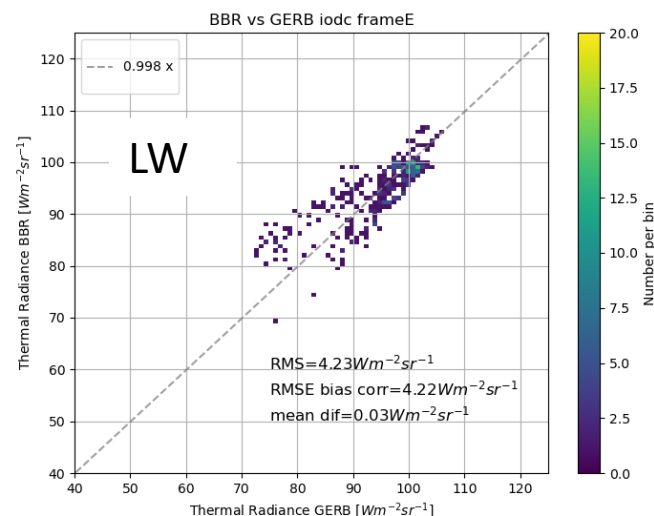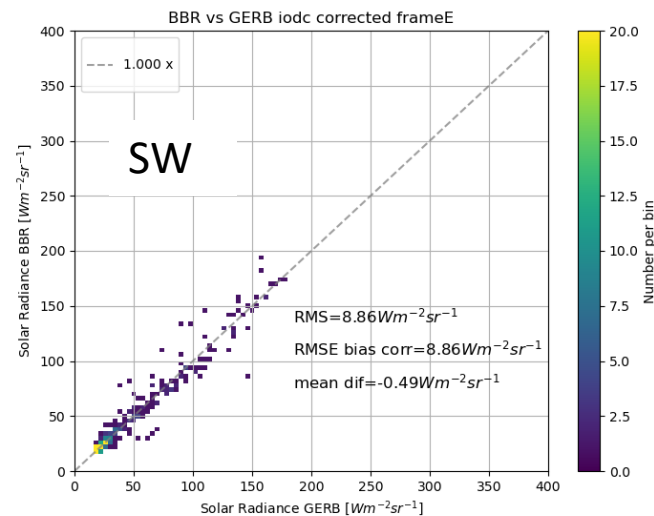
SW — BBR vs GERB iodc corrected frameE
RMS=8.86$Wm^{-2}sr^{-1}$
RMSE bias corr=8.86$Wm^{-2}sr^{-1}$
mean dif=-0.49$Wm^{-2}sr^{-1}$

LW — BBR vs GERB iodc frameE
RMS=4.23$Wm^{-2}sr^{-1}$
RMSE bias corr=4.22$Wm^{-2}sr^{-1}$
mean dif=0.03$Wm^{-2}sr^{-1}$

LW — BBR vs GERB iodc frameA
RMS=2.28$Wm^{-2}sr^{-1}$
RMSE bias corr=2.27$Wm^{-2}sr^{-1}$
mean dif=-0.16$Wm^{-2}sr^{-1}$

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GERB/BBR comparisons baseline BA: SW and LW Radiances

- **GERB-3 at 0deg**

- **Data from 28 May 2025 to 5 August 2025**

- **Only nadir comparisons**

GERB VZA < 3 deg
Δdist < 3 km
Δtime < 5 min

- BBR solar radiances are slightly higher than GERB

31

10th August 2024
to 30th April 2025

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

Terra FM1 - day
Terra FM1 - night
Aqua   FM3 - day
Aqua   FM3 - night
NOAA20 FM6 - day
NOAA20 FM6 - night
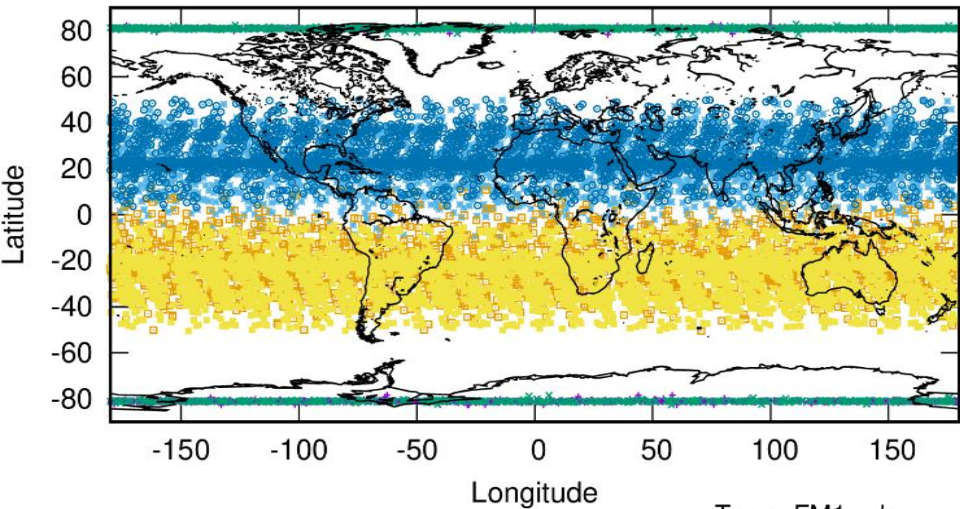
SW flux vs CERES SSF:

Aft : BBR = 1.037 CERES

Nadir: BBR = 1.025 CERES

Fore : BBR = 1.021 CERES

Combined: BBR = 1.022 CERES

→ **See poster Annex 41**

BMA-FLX(BA) combined vs CERES SSF

Combined

RMS=47.58 Wm^{-2}
RMSE bias corr=47.19 Wm^{-2}
mean dif=-3.33 Wm^{-2}
N=6599

BMA-FLX(BA) aft vs CERES SSF

Aft

RMS=55.5 Wm^{-2}
RMSE bias corr=54.6 Wm^{-2}
mean dif=-6.27 Wm^{-2}
N=6086

BMA-FLX(BA) nadir vs CERES SSF

Nadir

RMS=61.53 Wm^{-2}
RMSE bias corr=61.15 Wm^{-2}
mean dif=-4.48 Wm^{-2}
N=6156

BMA-FLX(BA) fore vs CERES SSF

Fore

RMS=55.86 Wm^{-2}
RMSE bias corr=55.57 Wm^{-2}
mean dif=-3.33 Wm^{-2}
N=6085

BMA-FLX (BA) vs CERES SSF: LW Flux

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

10th August 2024
to 30th April 2025

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
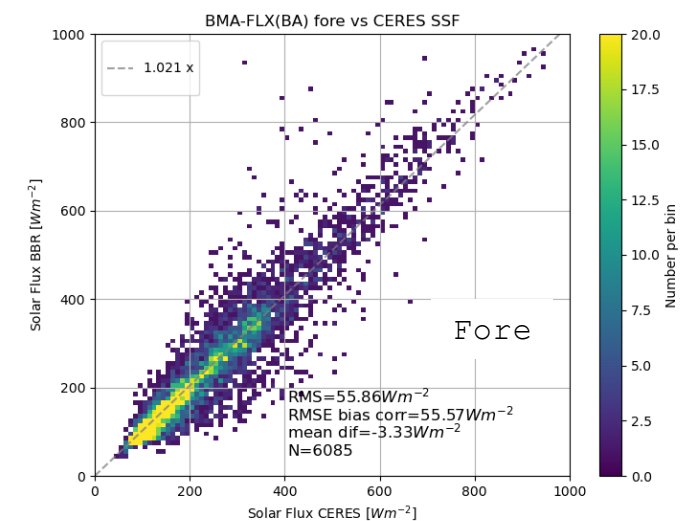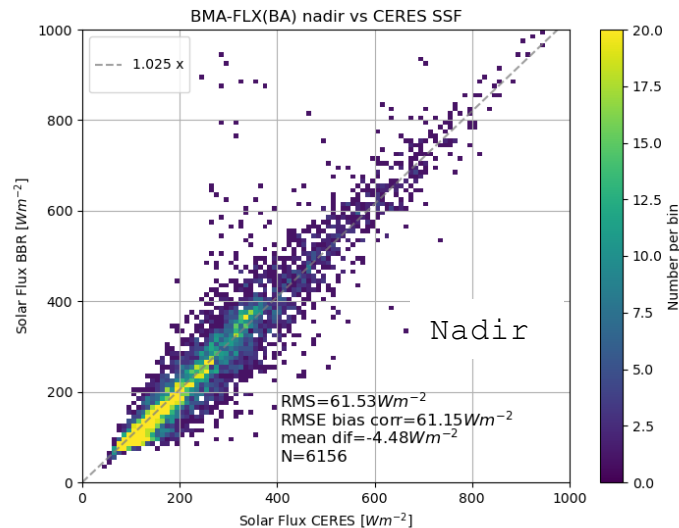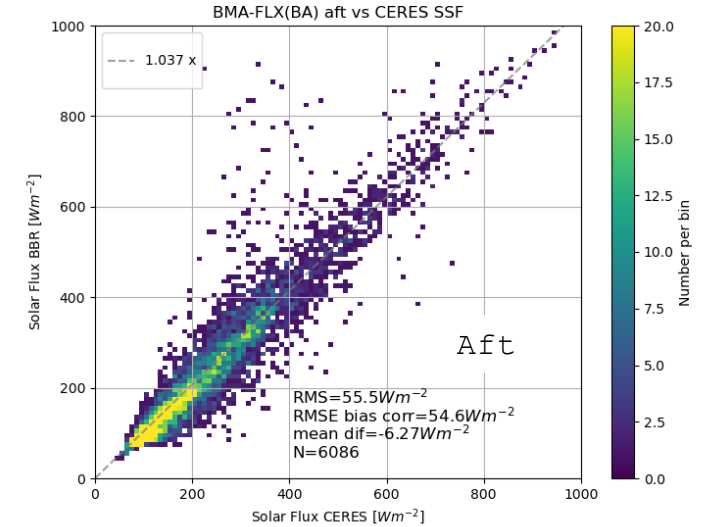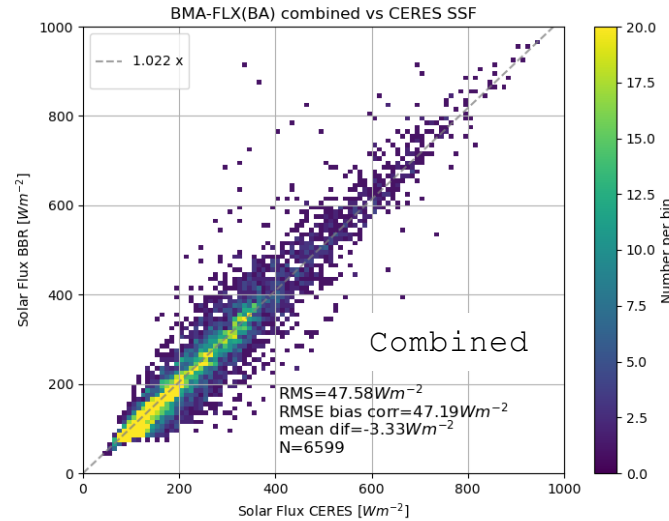NOAA20 FM6 - day
NOAA20 FM6 - night

→ **See poster Annex 41**

BMA-FLX(BA) combined vs CERES SSF

0.979 x

Combined

RMS=10.14Wm^{-2}
RMSE bias corr=8.59Wm^{-2}
mean dif=5.54Wm^{-2}
N=13943

BMA-FLX(BA) aft vs CERES SSF

0.978 x

Aft

RMS=11.57Wm^{-2}
RMSE bias corr=10.2Wm^{-2}
mean dif=5.59Wm^{-2}
N=13074

BMA-FLX(BA) nadir vs CERES SSF

0.976 x

Nadir

RMS=11.43Wm^{-2}
RMSE bias corr=9.71Wm^{-2}
mean dif=6.18Wm^{-2}
N=13082

BMA-FLX(BA) fore vs CERES SSF

0.979 x

Fore

RMS=11.91Wm^{-2}
RMSE bias corr=10.69Wm^{-2}
mean dif=5.44Wm^{-2}
N=13055

Preliminary MTG Fluxes comparison – Aug 2025. BMA-FLX baseline BA. Shortwave (Frame 06745E, day 20250805), Longwave nighttime (Frame 06677A, day 20250801), Shortwave (Frame 06777D, day 20250807), Longwave daytime (Frame 06718E, day 20250803).
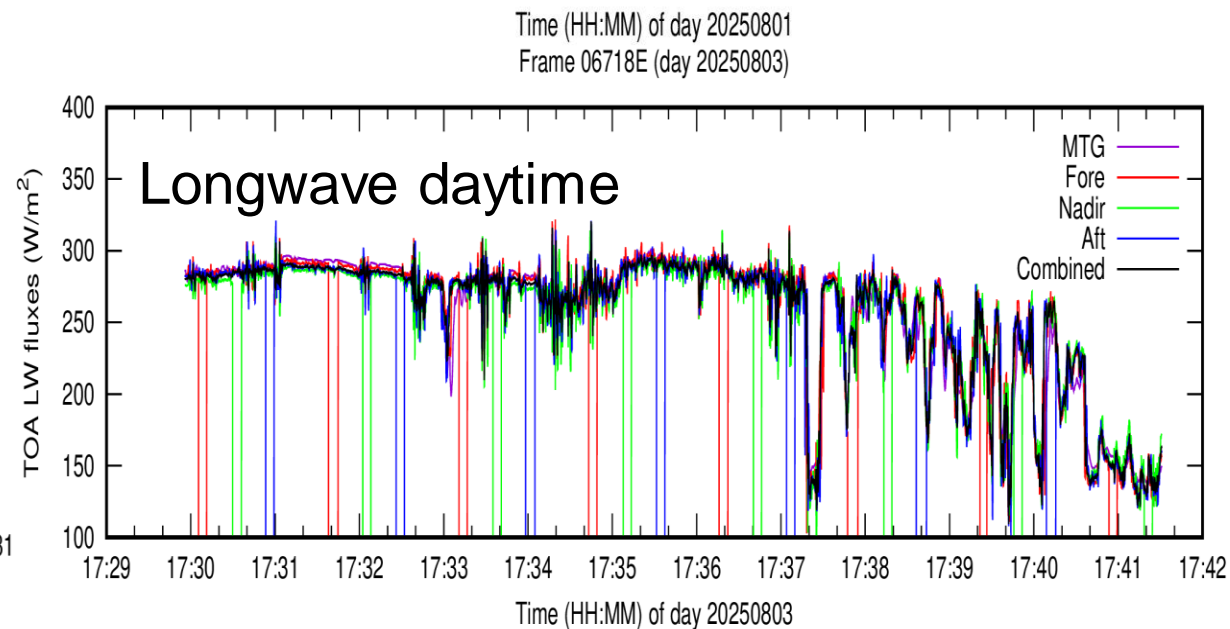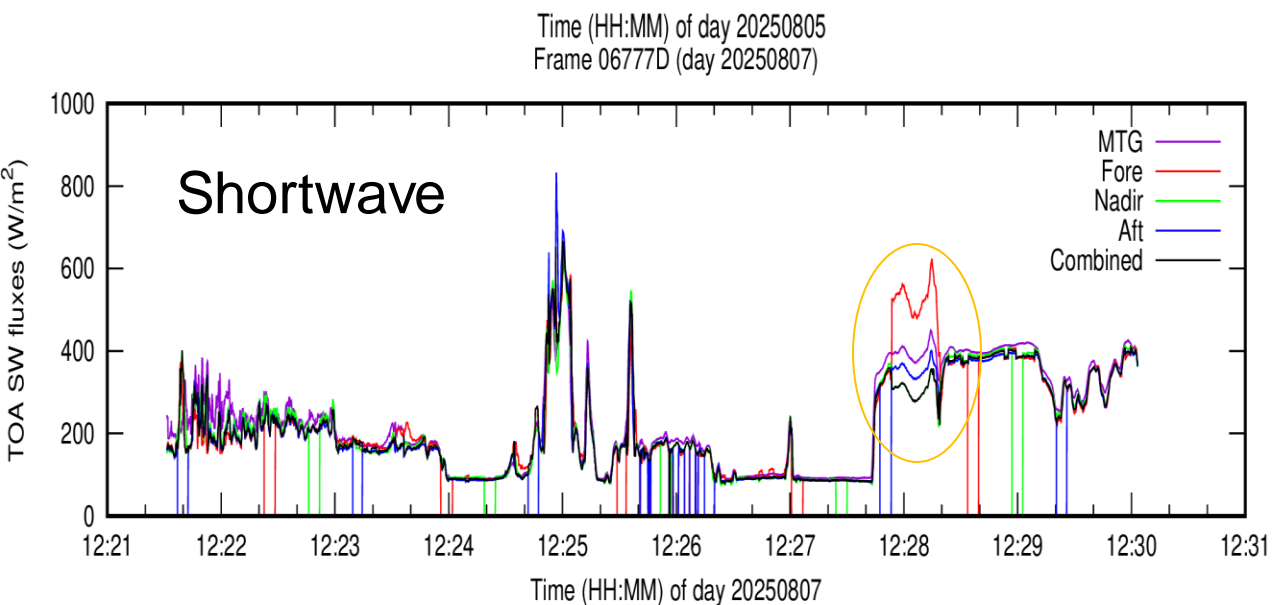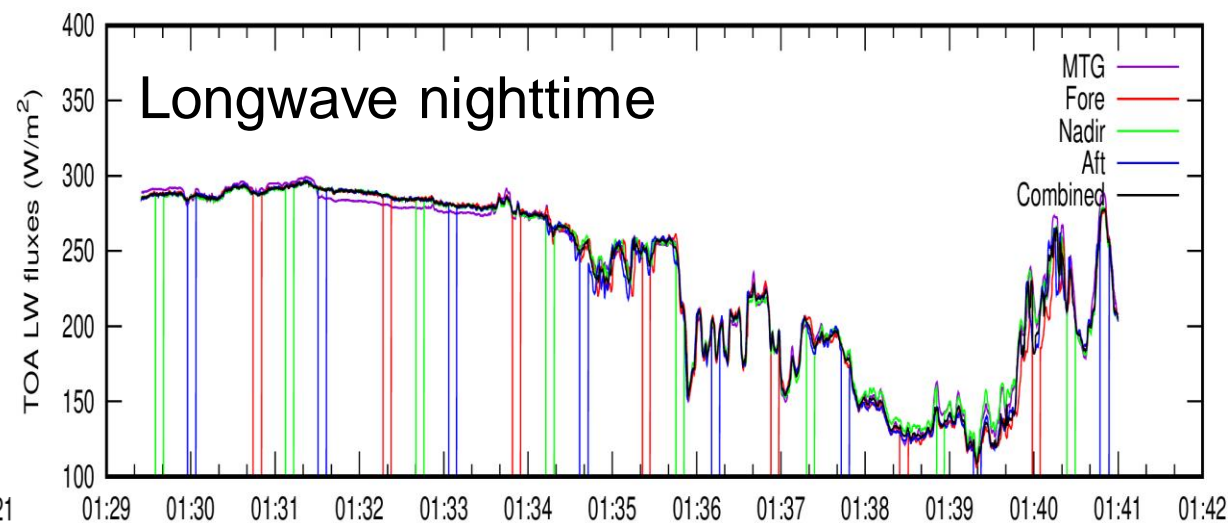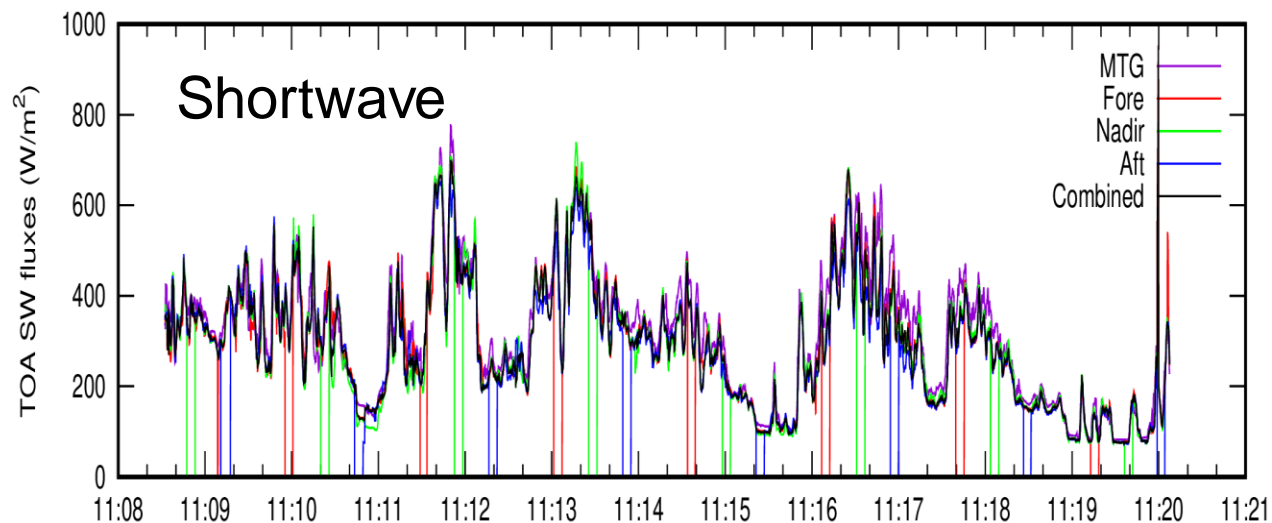
Summary

- BM-RAD and BMA-FLX data available since 25th July 2024

- Update of radiometric level since baseline BA

- Baseline BC available for BM-RAD and BMA-FLX since 18/11/2025

- BBR on standby since 20/11/2025 till 01/12/2025, when it will be operated in a 20 days cycle (5 days operational, followed by 15 days on standby) to save Chopper Drum Mechanism rotations in order to extend lifetime

- Very good agreement between the 3-BBR telescopes

- In general good agreement with CERES and GERB, being the BBR SW radiances and fluxes slighty higher than those of CERES and the LW ones slightly lower.

- Still some on going work:
  - SW fluxes → Sensitive to co-registration of the off-nadir views, cloud mask/properties, CTH, MSI radiances, ADMs, etc.
  - LW fluxes→ RL improvement

Closure posters: Annex 35, Annex 38
BBR-CERES comparisons: Annex 41

Recommendations to users

- Use baseline BA+

- Choose resolution -> No combined flux in the Full resolution

- If radiance comparisons using the 3 BBR-views -> BMA-FLX co-registered radiances

- Check quality status flags

- Read disclaimers for BM-RAD and BMA-FLX
- BM-RAD and BMA-FLX description in:

Velázquez Blázquez, A., Baudrez, E., Clerbaux, N., and Domenech, C.: Unfiltering of the EarthCARE Broadband Radiometer (BBR) observations: the BM-RAD product, Atmos. Meas. Tech., 17, 4245–4256, https://doi.org/10.5194/amt-17-4245-2024, 2024.

Velázquez Blázquez, A., Domenech, C., Baudrez, E., Clerbaux, N., Salas Molar, C., and Madenach, N.: Retrieval of top-of-atmosphere fluxes from combined EarthCARE lidar, imager, and broadband radiometer observations: the BMA-FLX product, Atmos. Meas. Tech., 17, 7007–7026, https://doi.org/10.5194/amt-17-7007-2024, 2024.

- Questions? https://ecvt.csde.esa.int/forum/
              almudena.velazquez@meteo.be