



EarthCARE 2026 Science and Validation workshop

8–12 June 2026 | Rhodes House | Oxford, UK

Towards Radiative Closure in EarthCARE Evaluation of TOA Flux Retrievals



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Radiative closure

Evaluation on how well the retrieved atmospheric properties reproduce the observed radiative measurements

The radiance requirement aims to achieve closure by using EarthCARE's cloud and aerosol properties, along with additional data, to simulate observed radiances as a final validation of the retrieved properties

Radiative transfer results contained in the ACMB-DF product for the radiative closure assessment

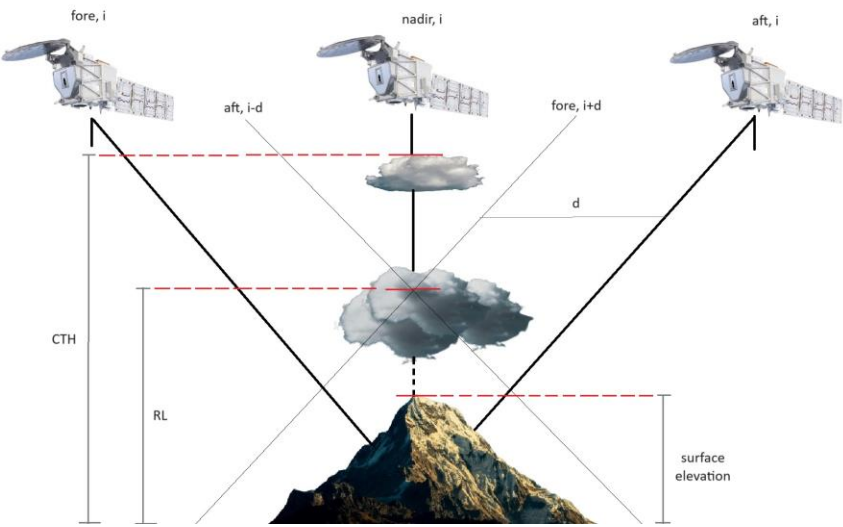
Barker, H. W., Cole, J. N. S., Villefranque, N., Qu, Z., Velázquez Blázquez, A., Domenech, C., Mason, S. L., and Hogan, R. J.: Radiative Closure Assessment of Retrieved Cloud and Aerosol Properties for the EarthCARE Mission: The ACMB-DF Product, Atmos. Meas. Tech., 18, 3095–3107, <https://doi.org/10.5194/amt-18-3095-2025>, 2025.

Assessment of the radiative closure – Evolution and Current Status



<https://www.earthcarescience.net/science/radiative-closure>

BMA-FLX



* Artificial Neuronal Network
** Angular Distribution Model

Solar/Thermal unfiltered radiances for each view, L_j

ANN*
ADM**⁻-based

↓

+

Illumination and viewing geometry **BM-RAD**
Surface type **BM-RAD, X-MET**
Cloud cover **M-CM**

Anisotropic factor for each view, R_j

↓

Solar/Thermal top-of-atmosphere flux for each BBR view, F_j

Co-registration at the
reference level
(different for SW and LW)

↓

+

Cloud optical thickness **M-COP**

Solar/Thermal combined top-of-atmosphere flux
obtained from the weighted average of the retrieved
radiative fluxes for each BBR telescope

ACMB-DF (ALL-DF)

From ACM-RT...

1D broadband flux profiles

Based on the **Independent Column Approximation (ICA)**, which assumes that radiation is not transferred horizontally to adjacent columns



ACMB-DF

Comparison to BMA-FLX TOA** fluxes

* Radiative Transfer
** Top-of-atmosphere

EC data → RT* sims → radiances/fluxes

Assessment Resolution
(5x21 JSG pixels)

3D solutions of the RT equation

- Used to study the 3d interaction of radiation with the three phases of water
- Monte Carlo RT algorithm



- Radiance-to-flux conversion using the same methodology as BMA-FLX SW algorithm.
- Comparison to BMA-FLX TOA fluxes

ALL-RAD



Standard Resolution
(10x10 km² in the BBR grid)

Radiative flux computation with 1D RT

- One-dimensional plane-parallel RT simulations
- Code of mstrnX applied to atmospheric profiles.



output

- SW Radiative Flux
- LW Radiative Flux
- SW Radiative Heating Rate
- LW Radiative Heating Rate



estimate

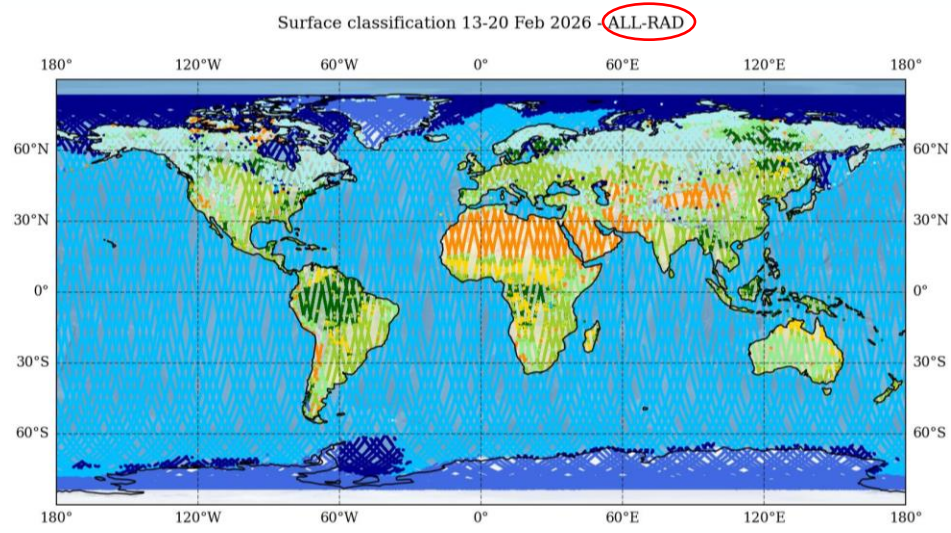
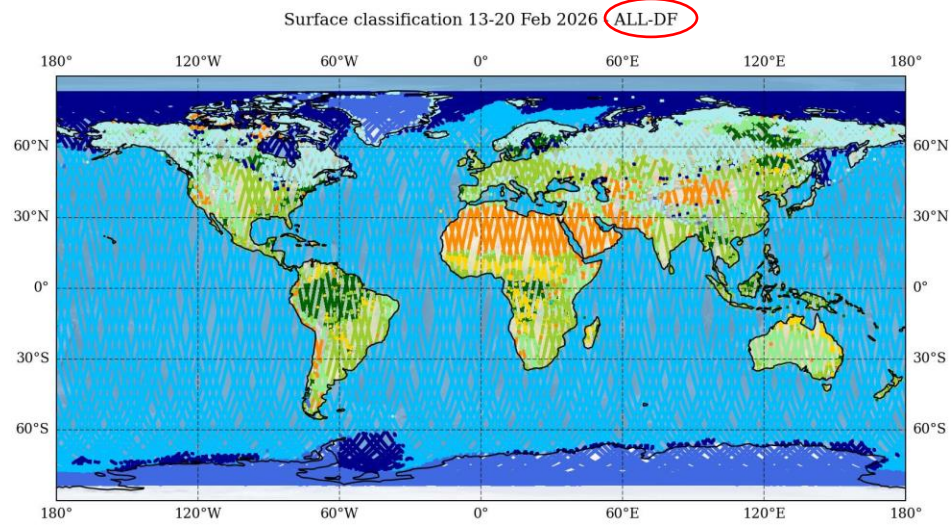
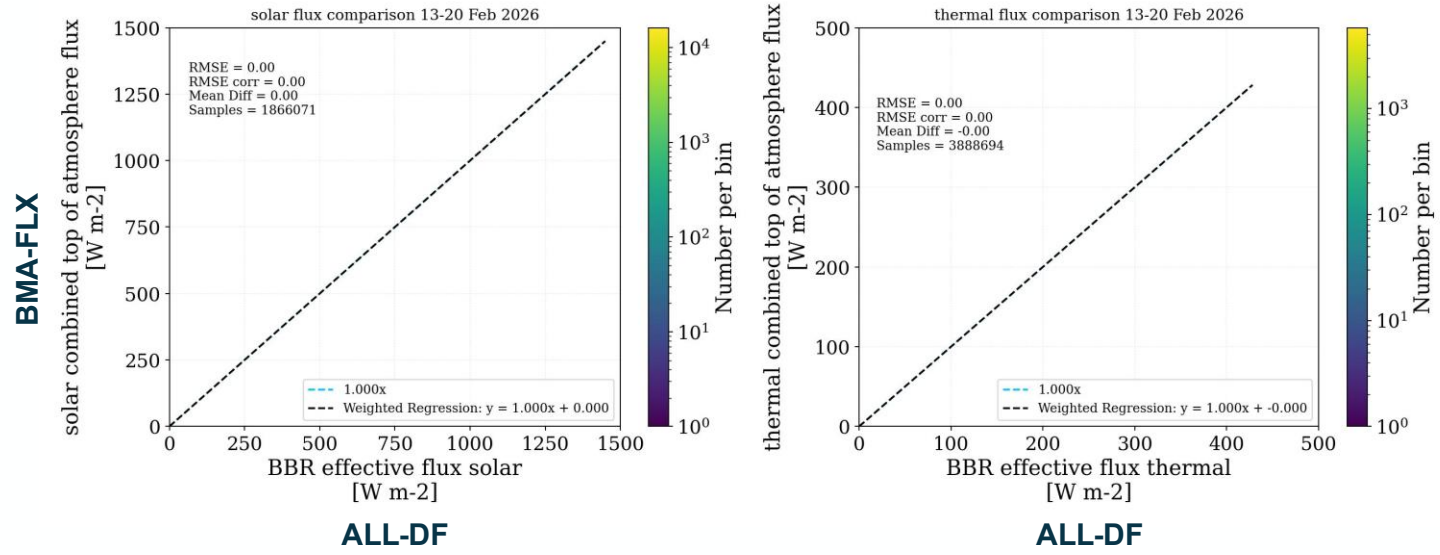
- Aerosol Radiative Effect (ARE)
- Cloud Radiative Effect (CRE)

Data crossmatch



- Crossmatch made using “time”
- Data from the frame margins is excluded
- Check:
 - Density plot using BMA-FLX fluxes from both BMA-FLX and ALL-DF
 - World maps using coordinates from ALL-DF/ALL-RAD but surface classification from BMA-FLX

Frame	Latitude start (degrees North)	middle (degrees North)	Latitude end (degrees North)
A	-22.5	0	22.5
B	22.5	45	67.5
C	67.5	northern edge	67.5
D	67.5	45	22.5
E	22.5	0	-22.5
F	-22.5	45	-67.5
G	-67.5	southern edge	-67.5
H	-67.5	-45	-22.5



Solar Closure Throughout the Mission

BMA-FLX baseline

ALL-DF baseline

Under investigation

ALL-DF area for improvement

ALL-DF inputs area for improvement

BMA-FLX area for improvement

BMA-FLX inputs area for improvement

AA, AA

AB, AB

BA, BA

BC, BC

current

8-10 Dec 2024

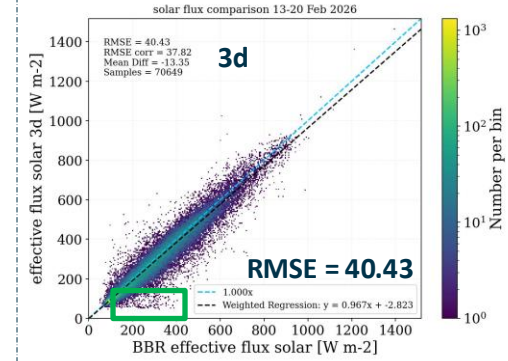
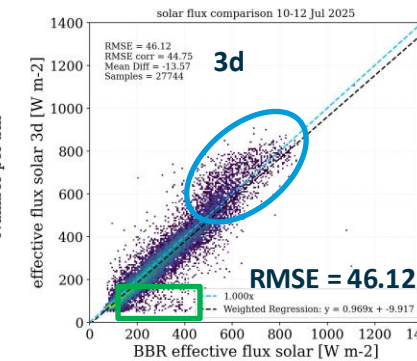
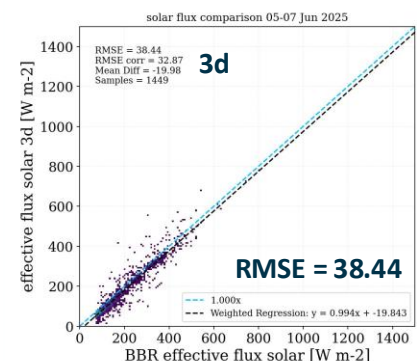
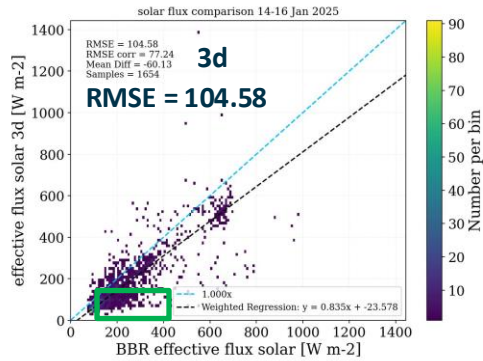
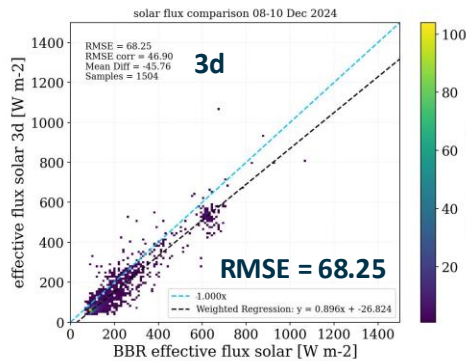
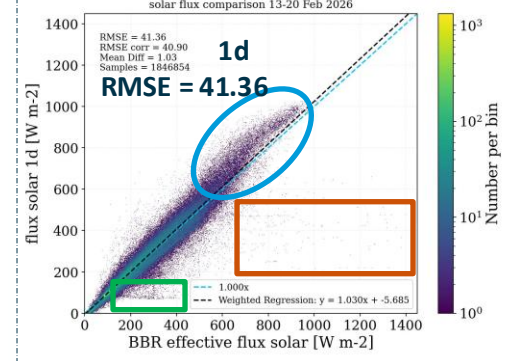
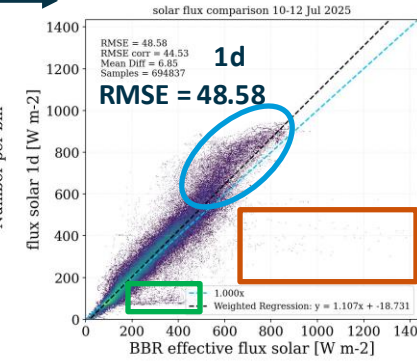
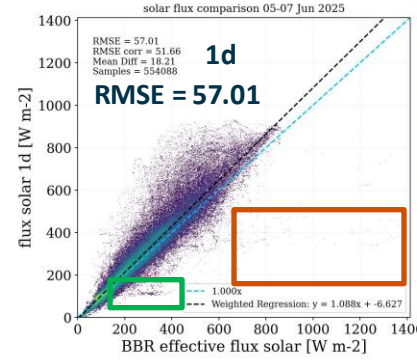
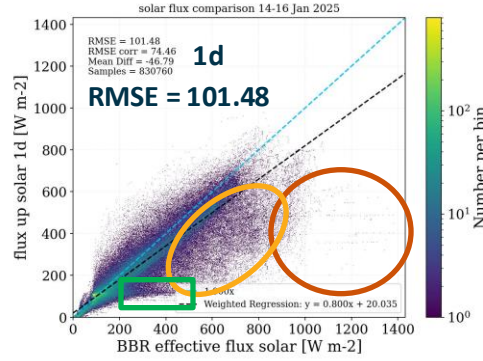
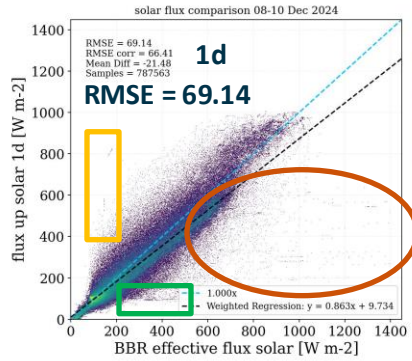
14-16 Jan 2025

5-7 Jun 2025

10-12 Jul 2025

13-20 Feb 2026

+140k 1d samples!!!



three-day period

+26k 3d samples!!!

one-week period

Thermal Closure Throughout the Mission



BMA-FLX baseline

ALL-DF baseline

Under investigation

ALL-DF area for improvement

ALL-DF inputs area for improvement

BMA-FLX area for improvement

BMA-FLX inputs area for improvement

AA, AA

AB, AB

BA, BA

BC, BC

current

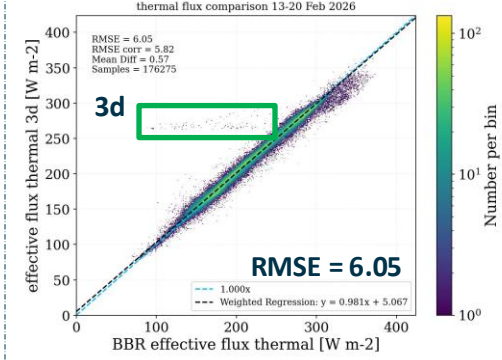
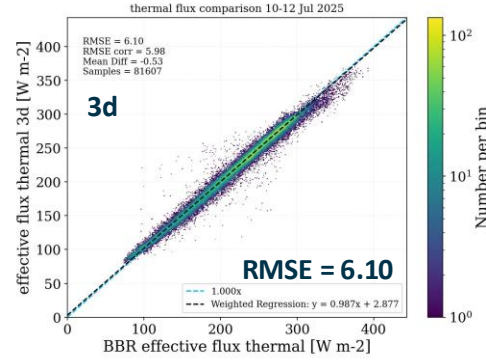
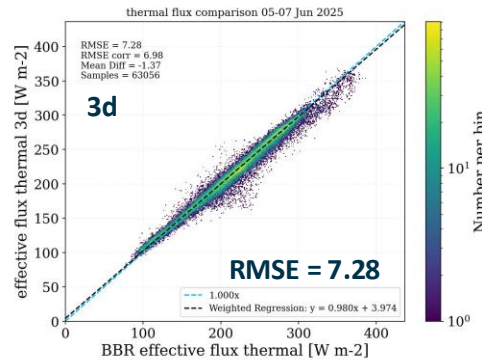
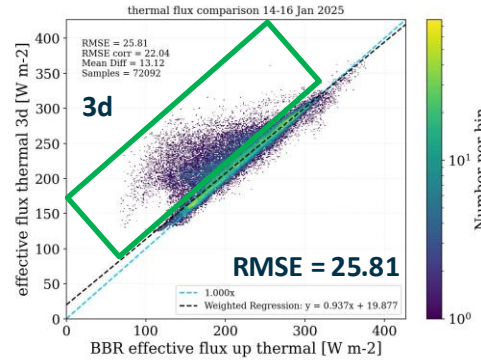
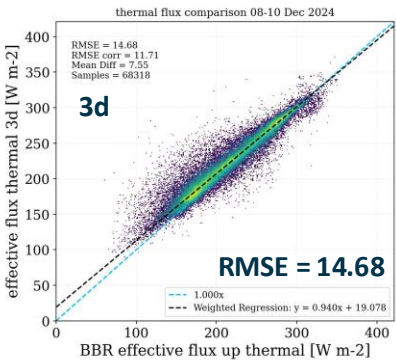
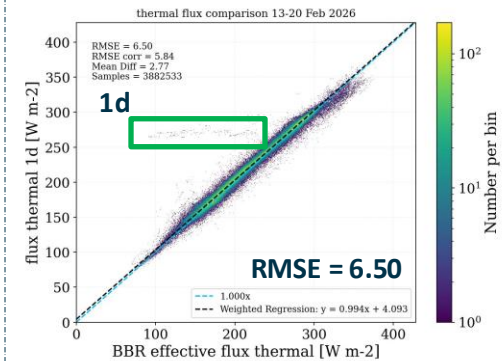
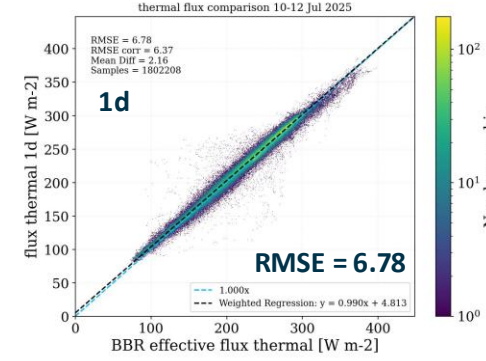
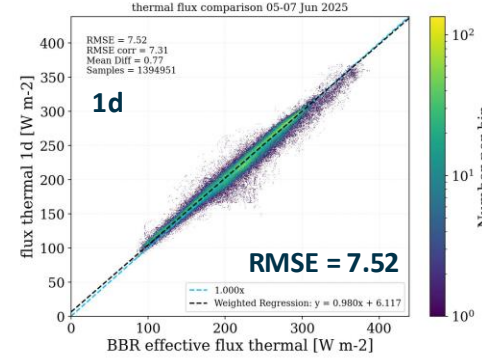
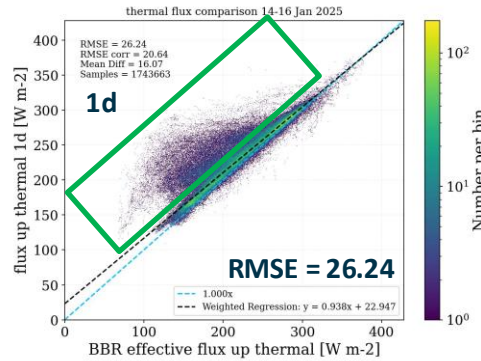
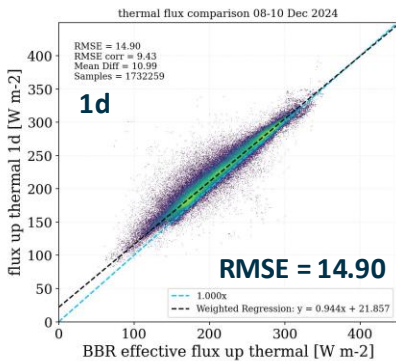
8-10 Dec 2024

14-16 Jan 2025

5-7 Jun 2025

10-12 Jul 2025

13-20 Feb 2026



three-day period

one-week period

Closure Throughout the Mission



AC: ACM-COM improved liquid clouds and ice cloud profiles

AC: ACM-CAP updated ice size distribution and optics assumptions

AC: ACM-RT improved thermal radiance and 3D solar Monte Carlo RT model

AC: BM-RAD improved SW calculations

RMSE ACMB-DF/BMA-FLX TOA fluxes [Wm⁻²]

AB: M-CLD improved retrievals over desert

AB: BM-RAD improved LW calculations

AB, BB: BMA-FLX improvement of the solar flux coregistration

General								
	Solar				Thermal			
	ALL-DF 1d	# 1d	ALL-DF 3d	# 3d	ALL-DF 1d	# 1d	ALL-DF 3d	# 3d
8-10 Dec 2024 (AA)	69.14	~790k	68.25	~1.5k	14.90	~1.7M	14.68	~70k
14-16 Jan 2025 (AA)	101.48	~830k	104.58	~1.7k	26.24	~1.7M	25.81	~70k
5-7 Jun 2025 (AB)	57.01	~550k	38.44	~1.5k	7.52	~1.4M	7.28	~60k
10-12 Jul 2025 (BA)	48.58	~700k	46.12	~30k	6.78	~1.8M	6.10	~80k
13-20 Feb 2026 (BC)	41.36	~1.8M	40.43	~70k	6.50	~4M	6.05	~180k
Baseline CA: already in preparation... L2 reprocessing happening in the Fall 2026								

AD: ACM-CAP tuning of configuration parameters relating to ice and liquid clouds

BA: ACM-RT increase on solar and thermal 3D RT data

BC: ACM-CAP improved quality of retrievals in ice clouds

BC: ACM-RT improved use of aerosol and cloud inputs

BC: ACM-RT fixed treatment of sea-ice

For more information on baseline changes, check the product disclaimers in the [EarthCARE Product Data Handbook](#)

Current status



Day and night frames (A-H)

Baselines

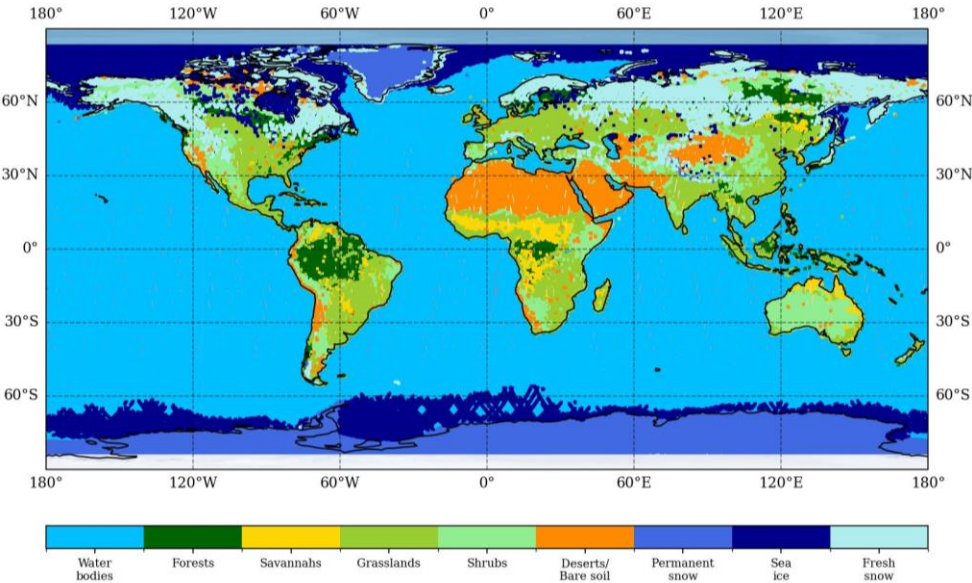
- BMA-FLX baseline BC
- ALL-DF baseline BC
- ALL-RAD baseline BA

Time period (one month)

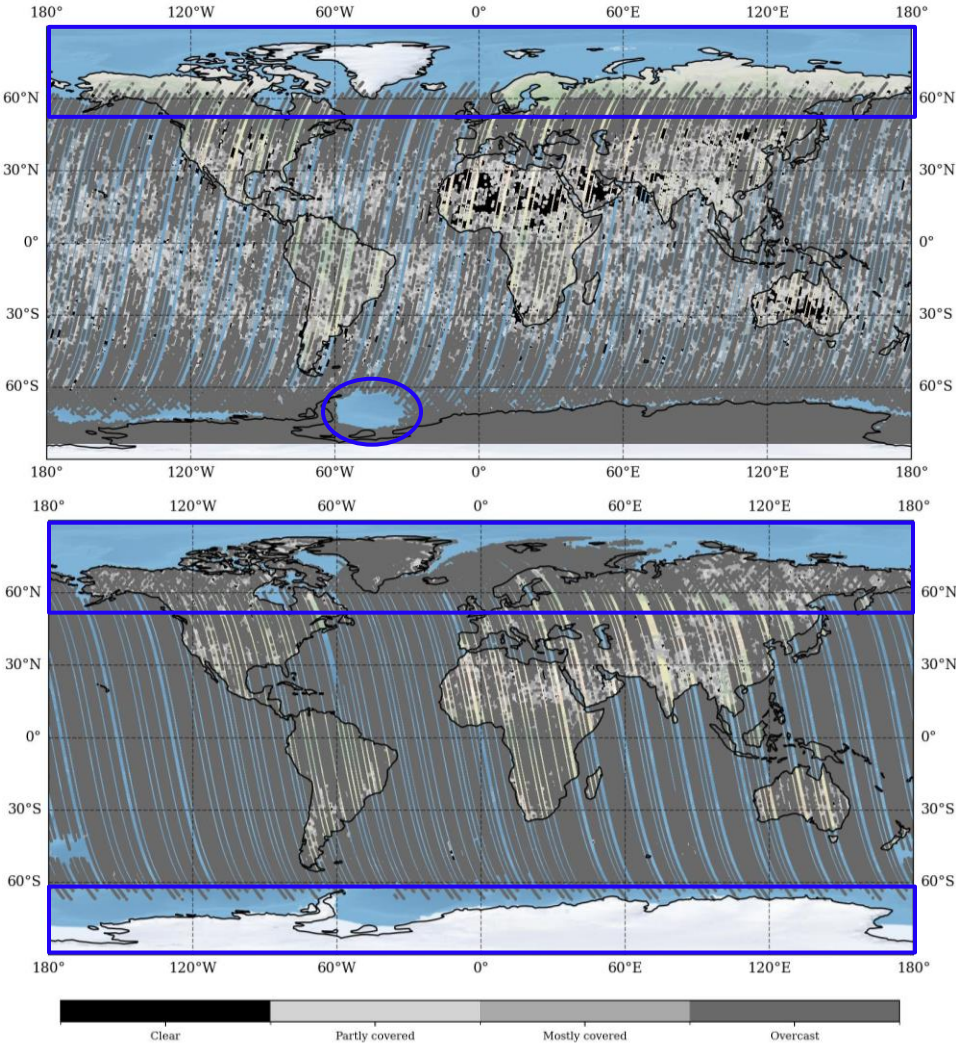
01 Dec 2025 – 31 Jan 2026

(BBR reduced operations
+ airborne campaigns)

Surface classification



Cloud cover



SAZ ≤ 90°

No retrievals over
sea-ice regions



SAZ > 90°

Current status

BMA-FLX area of interest

BMA-FLX inputs area for improvement

ALL-DF area for improvement

ALL-DF inputs area of interest

Under investigation

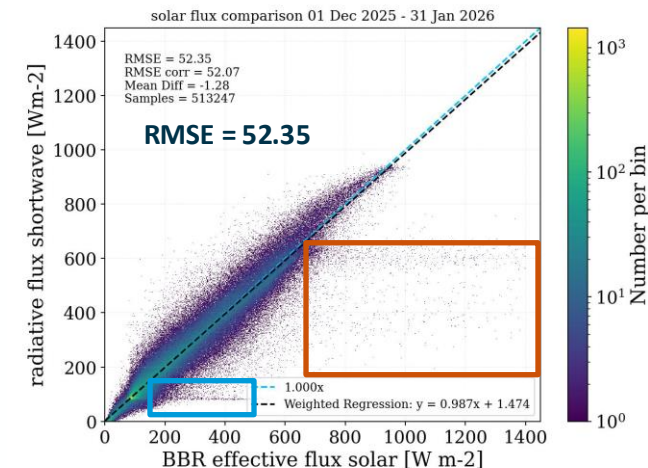
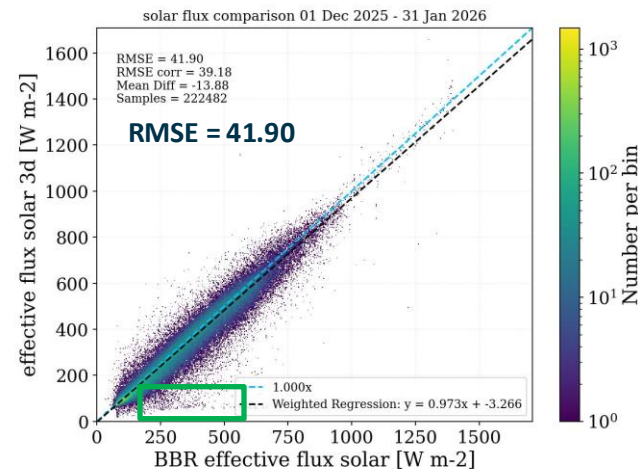
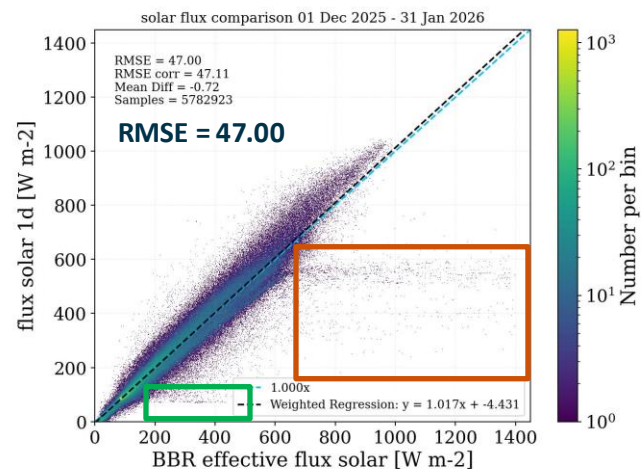
ALL-DF 1d

ALL-DF 3d

ALL-RAD 1d

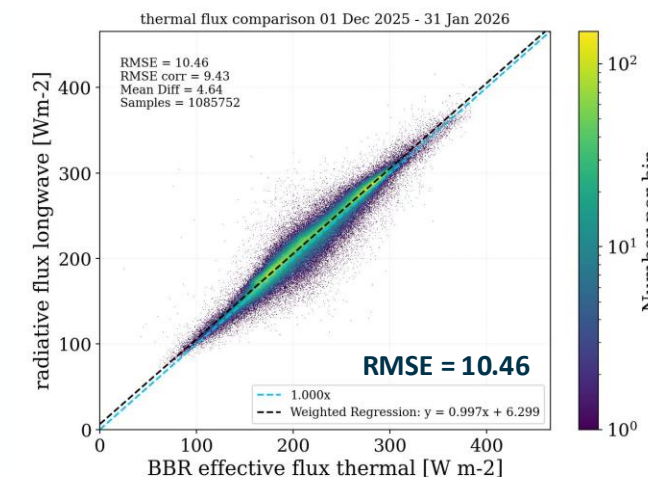
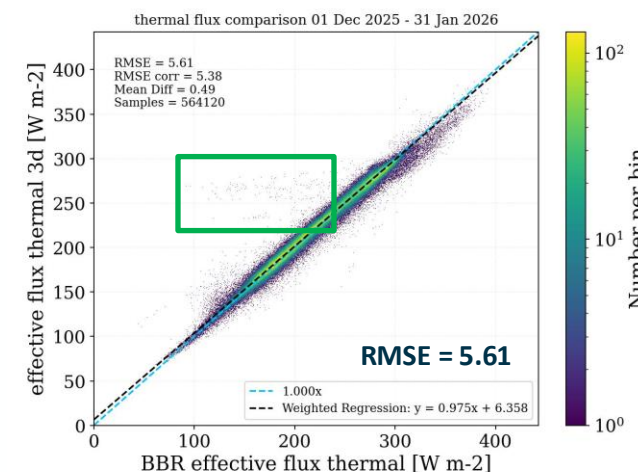
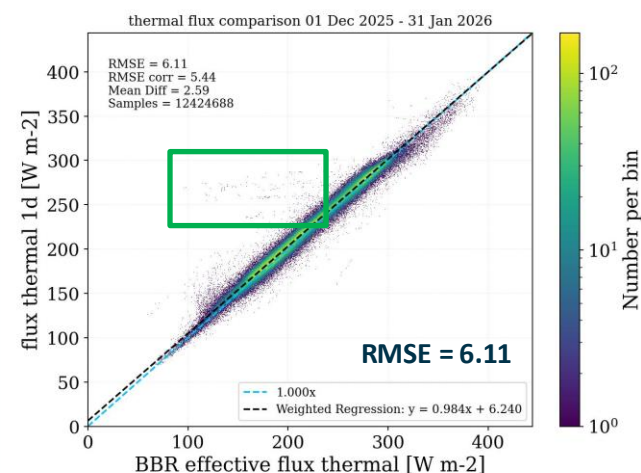
SOLAR

Assessment
Resolution



Standard
Resolution

THERMAL



Current status – updates

BMA-FLX area of interest

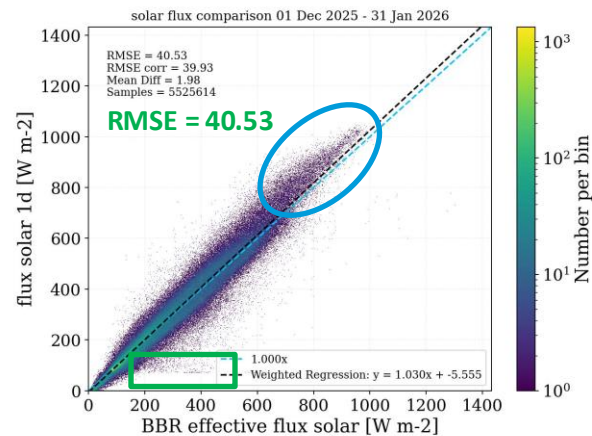
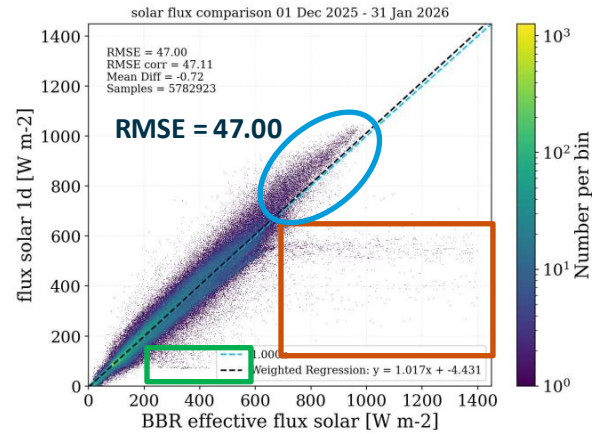
SOLAR

ALL-DF inputs area of interest

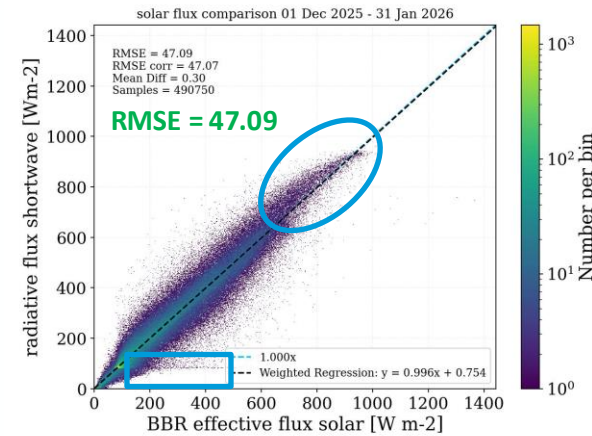
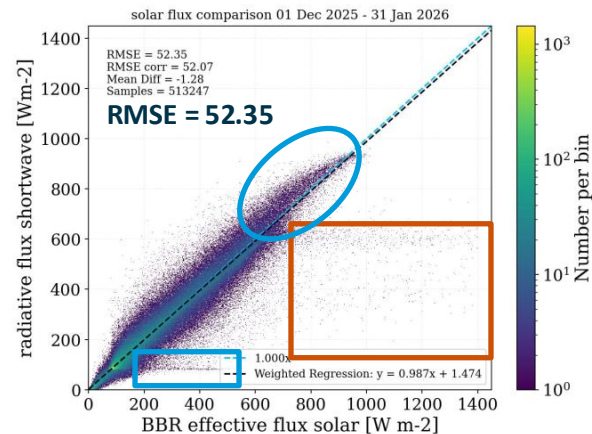
THERMAL

Under investigation

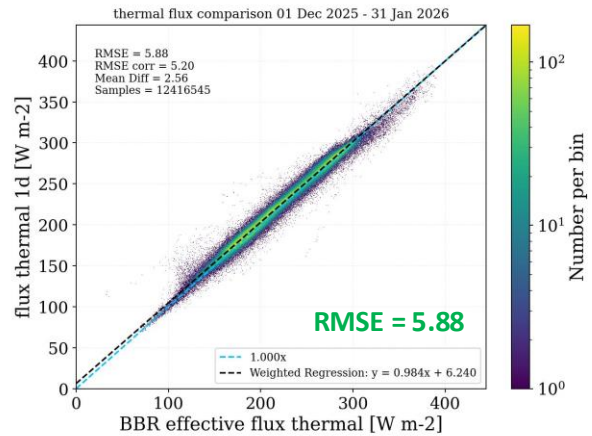
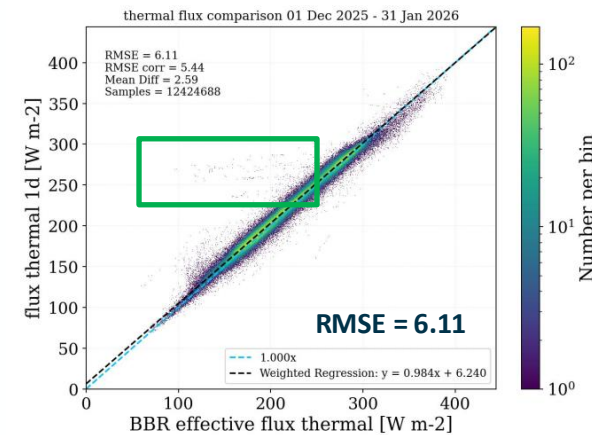
ALL-DF 1d



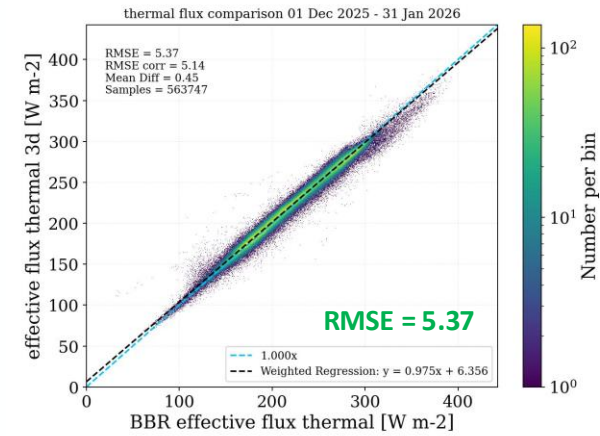
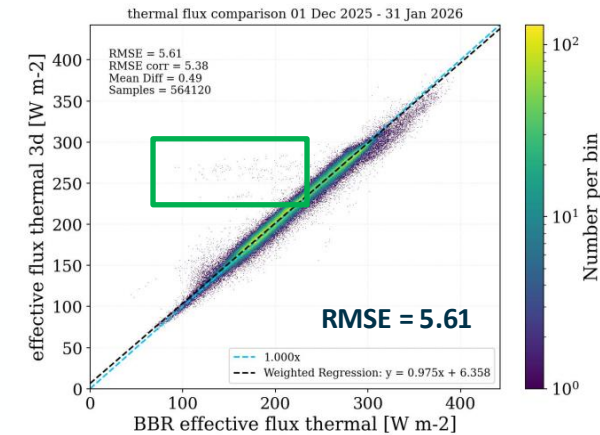
ALL-RAD 1d



ALL-DF 1d



ALL-DF 3d

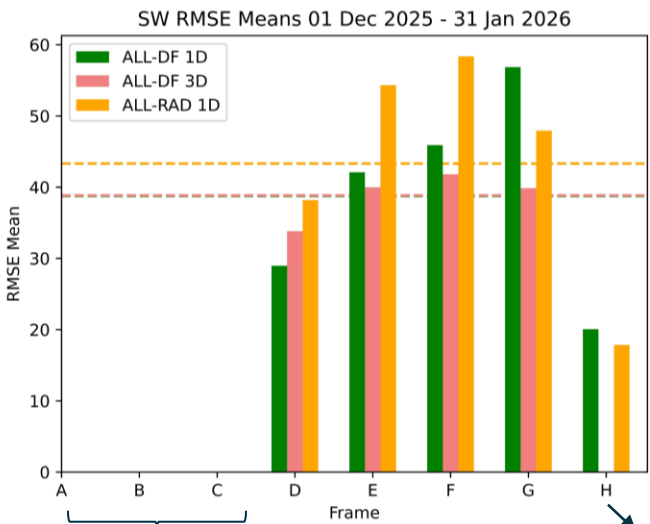
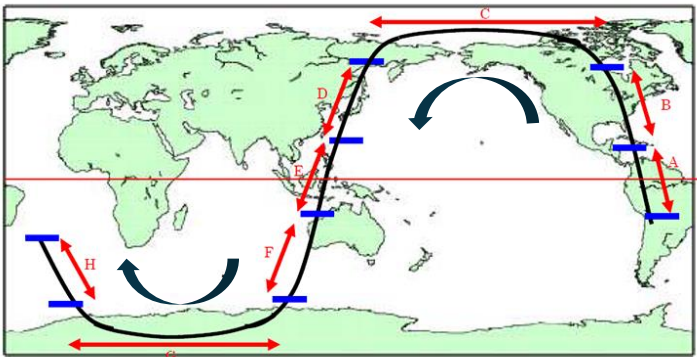


Current status – statistics



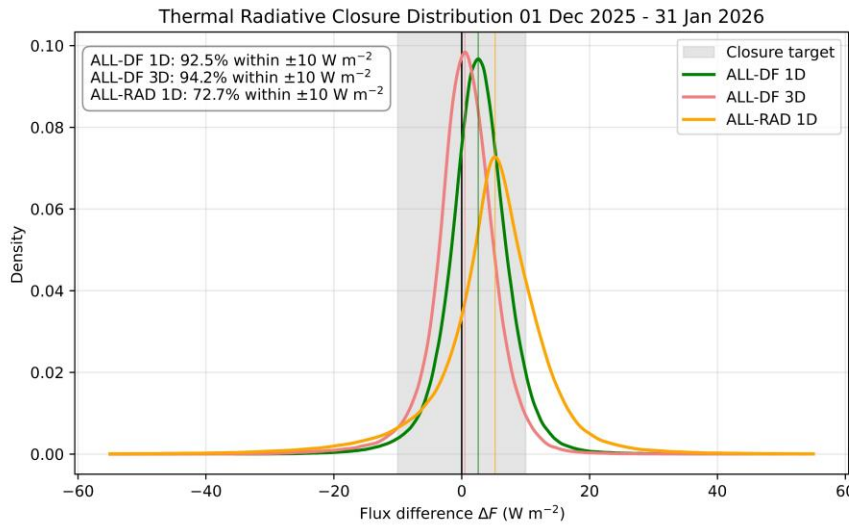
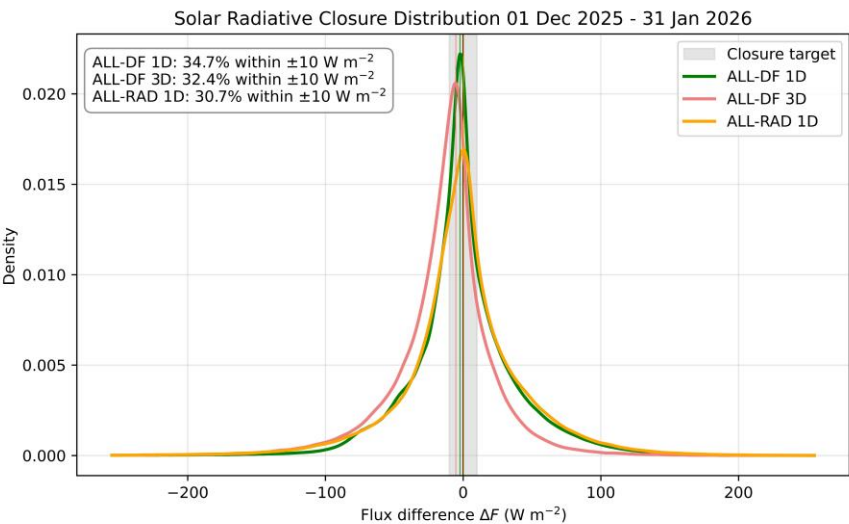
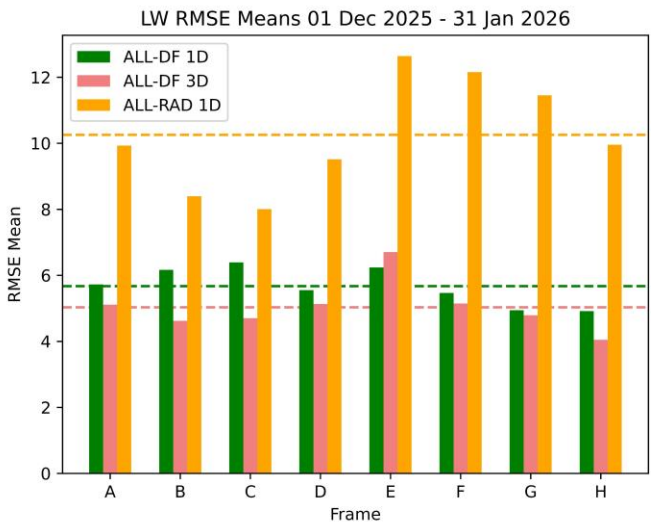
ALL-DF 1d
ALL-DF 3d
ALL-RAD 1d

Assessment Resolution
Standard Resolution



Night

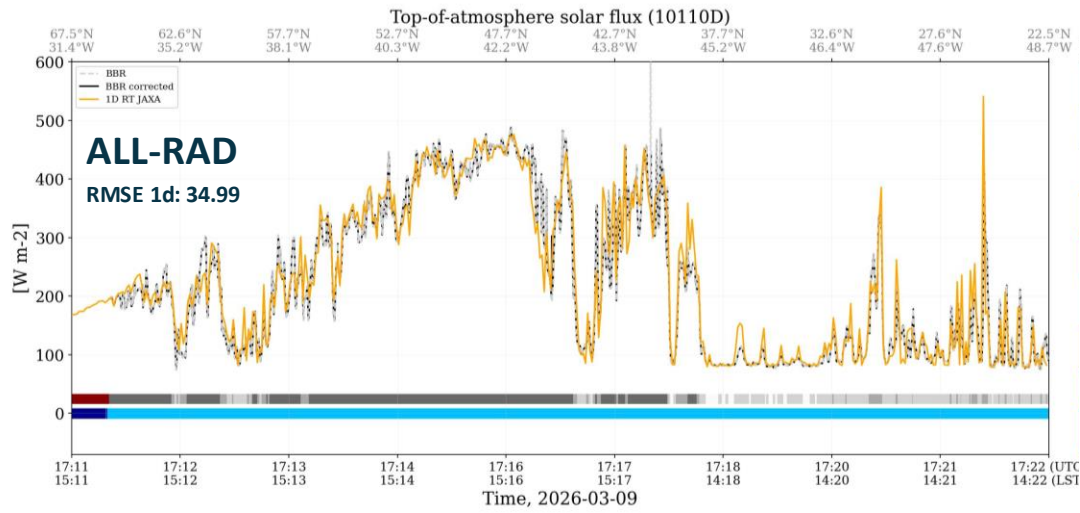
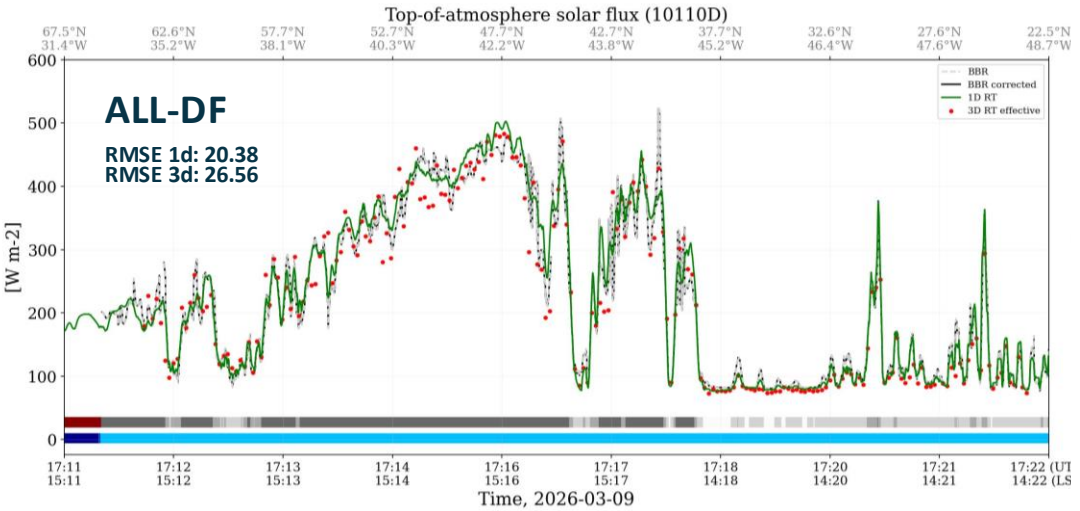
No 3d data for SZA > 70°



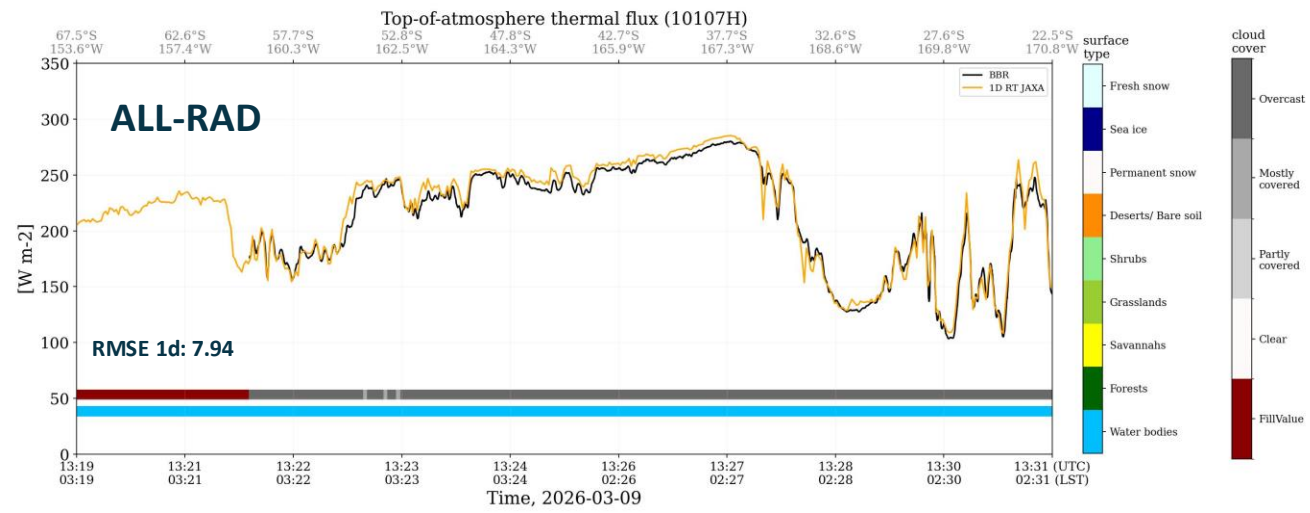
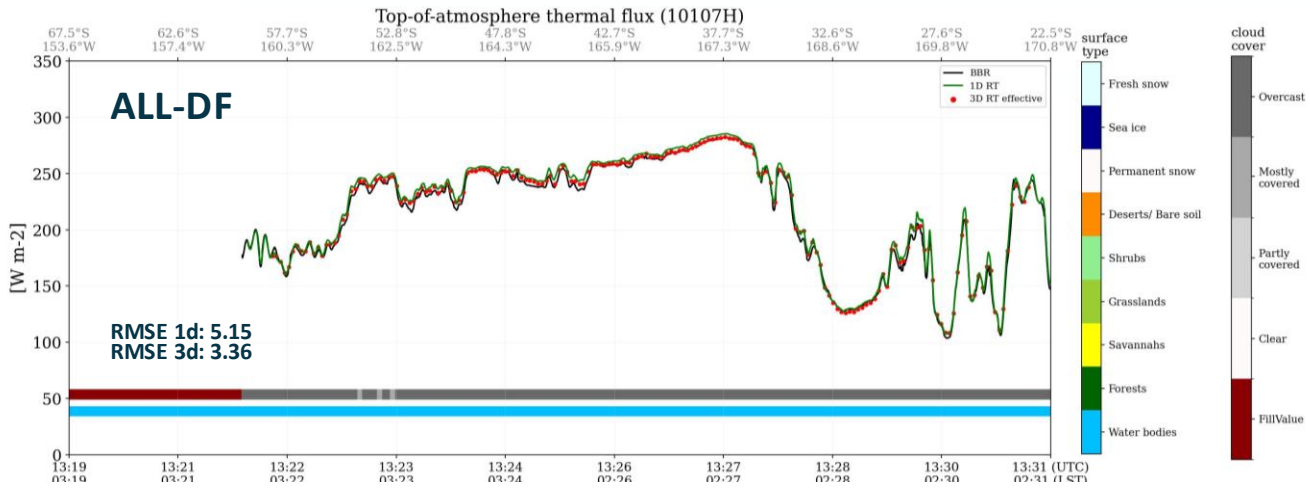
Current status – examples



SOLAR



THERMAL



Combined flux statistics							
One-month data: 01 December 2025 – 31 January 2026							
		Solar			Thermal		
Baseline	stats	ALL-DF 1d	ALL-DF 3d	ALL-RAD	ALL-DF 1d	ALL-DF 3d	ALL-RAD
BC	#	5 782 923	222 482	513 247	12 424 688	564 120	1 085 752
	RMSE [Wm ⁻²]	47.00	41.90	52.35	6.11	5.61	10.46
	Mean diff [Wm ⁻²]	-0.72	-13.88	-1.28	2.59	0.49	4.64
BC correction	#	5 525 614	TBD	490 750	12 416 545	563 747	-
	RMSE [Wm ⁻²]	40.53	TBD	47.09	5.88	5.37	-
	Mean diff [Wm ⁻²]	1.98	TBD	0.30	2.56	0.45	-



TBD

Currently not available. To be redone when the ALL-DF processor is updated

Note that not all the updates have been possible to reproduce in this analysis, meaning that the RMSEs will be lower in baseline CA

Summary



- In general, the agreement between ALL-DF/ALL-RAD and BMA-FLX solar and thermal fluxes is **good**, being slightly better the comparison between ALL-DF and BMA-FLX
- Both solar and thermal RMSEs are continuously improving, with current solar RMSEs around 40 Wm^{-2} and thermal RMSEs around 10 Wm^{-2}
 - Continuous improvement of retrievals, radiative transfer, and inputs
 - The major features have been solved, now dealing with minor updates
- Note that the BBR is taking measurements 25% of the time to extend its lifetime. Next BBR NOMINAL mode: 2026/06/16
- Currently working on alternatives to perform the closure when BBR is not nominal
- More about 3D RT effects in the next **EarthCARE Science Seminar!!!!** <https://www.earthcarescience.net/seminars>



Wednesday 17 June

2026

10:00 CEST, 17:00 JST, 04:00
EDT

There will be two talks, both lasting approximately 20–25 minutes, by

1. **Yudai Ezaki** (Tohoku University): "Observation-Based Assessment of Three-Dimensional Radiative Transfer Effects with EarthCARE"
2. **Gregor Walter** (TROPOS): "Impact of 3D Radiative Effects on EarthCARE Retrievals"

- Analysis to be repeated when the full mission is reprocessed with latest updates
- Addition of 1D ALL-RAD comparison plots in the Assessment Resolution (when available)
- Addition of 3D comparison plots using the Research Product by JAXA (when available)

Future work



EarthCARE 2026 Science and Validation workshop

8–12 June 2026 | Rhodes House | Oxford, UK

Thank you!

csalas@gmv.com

Carla Salas, Irene Hidalgo – GMV-ES

Almudena Velázquez, Edward Baudrez, Nicolas Clerbaux – RMIB

Jason Cole, Howard Barker – ECCC

Kentaroh Suzuki-san, Takashi Nagao-san – Utokyo

