The EarthCARE BBR Products and first comparison with CERES

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CERES Science Team Meeting
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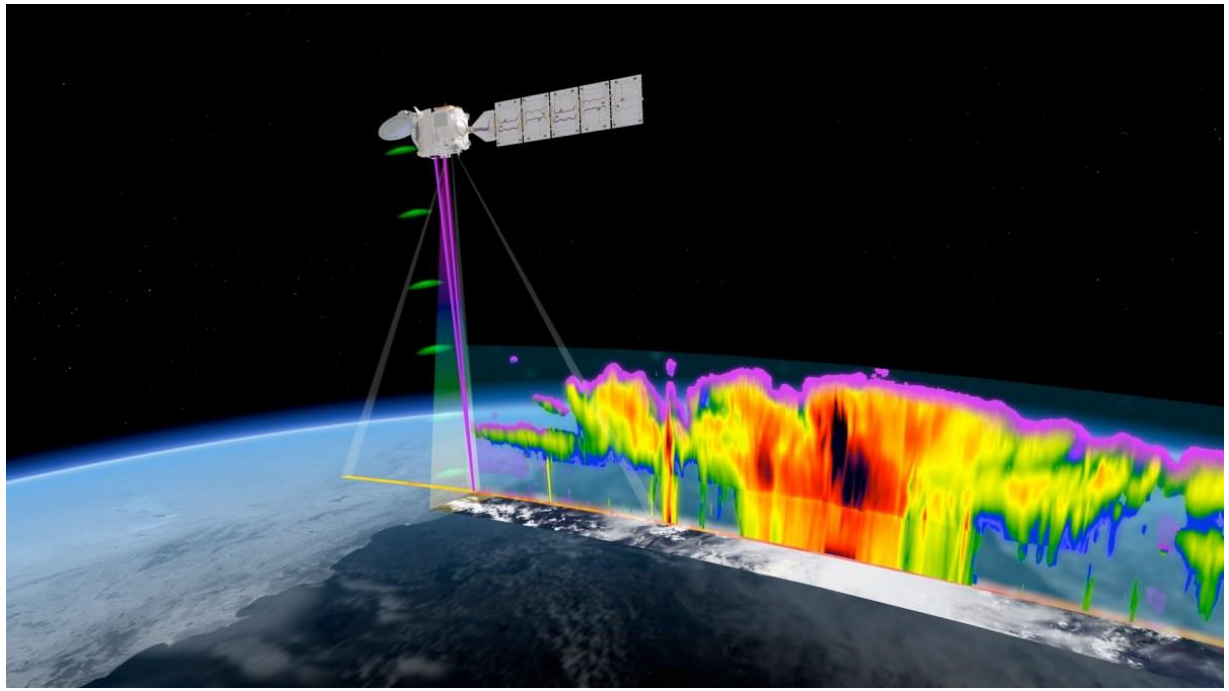
Content

- Overview and status of EarthCARE Mission
- Overview BBR instrument and products
- BBR L1 evaluation and evolution
- BBR L2 (preliminary) evaluation
- Summary



EarthCARE artist view

EarthCARE logo

EarthCARE overview

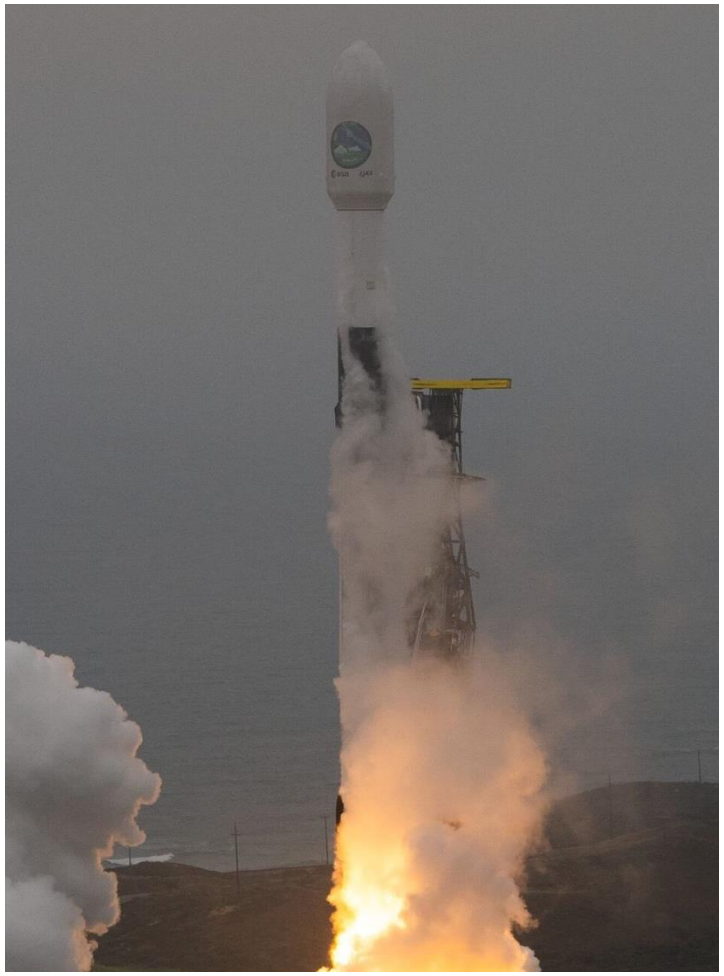
- EarthCARE : Earth Cloud Aerosol Radiation Explorer

- Mission objectives:
  - Observation and characterization of clouds and aerosols
  - Quantify effect on the SW/LW radiation

- Joint ESA/JAXA Earth Explorer mission

- Launched on 29th May 2024, commissioning completed Jan.28th 2025, now in exploitation phase.

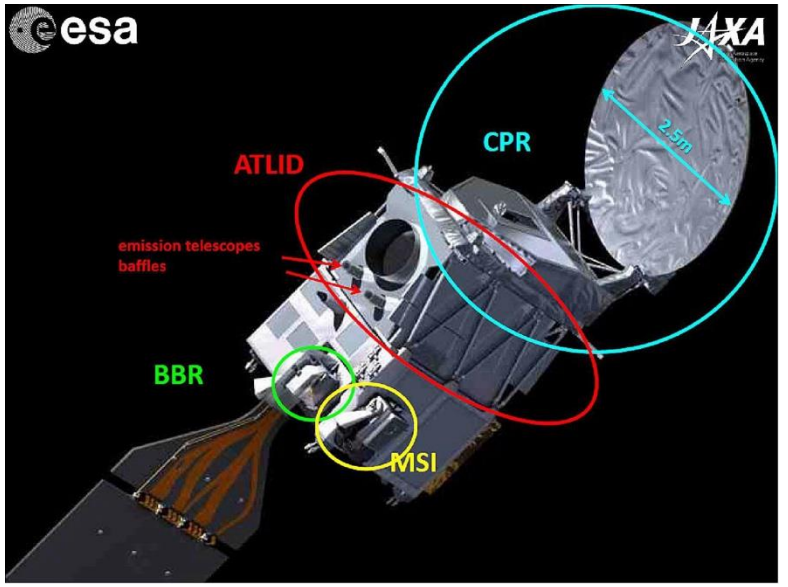
- Orbit : sun-synchronous, +/- 400 km altitude, descending ECT 2 PM, repeat cycle of 25 days

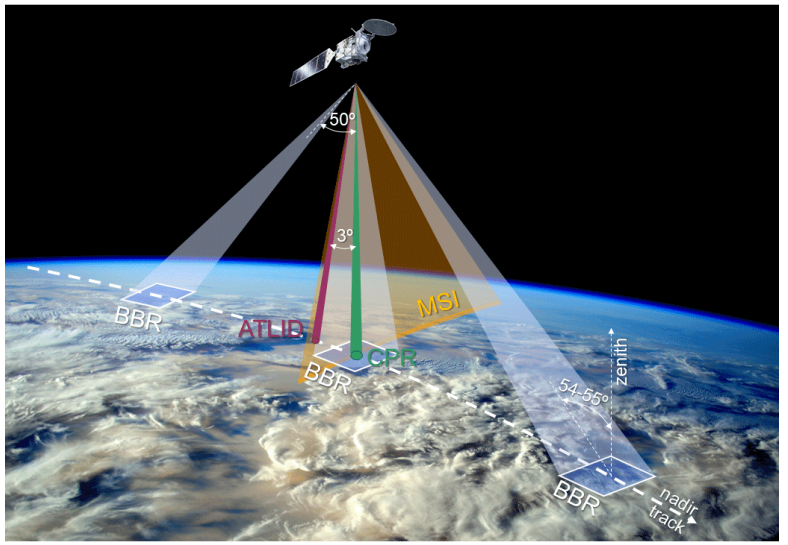


EarthCARE launch, 29th May 2024, Vandenberg Space Force Base,CA.(Falcon-9)

EarthCARE Instruments and Mission Objectives

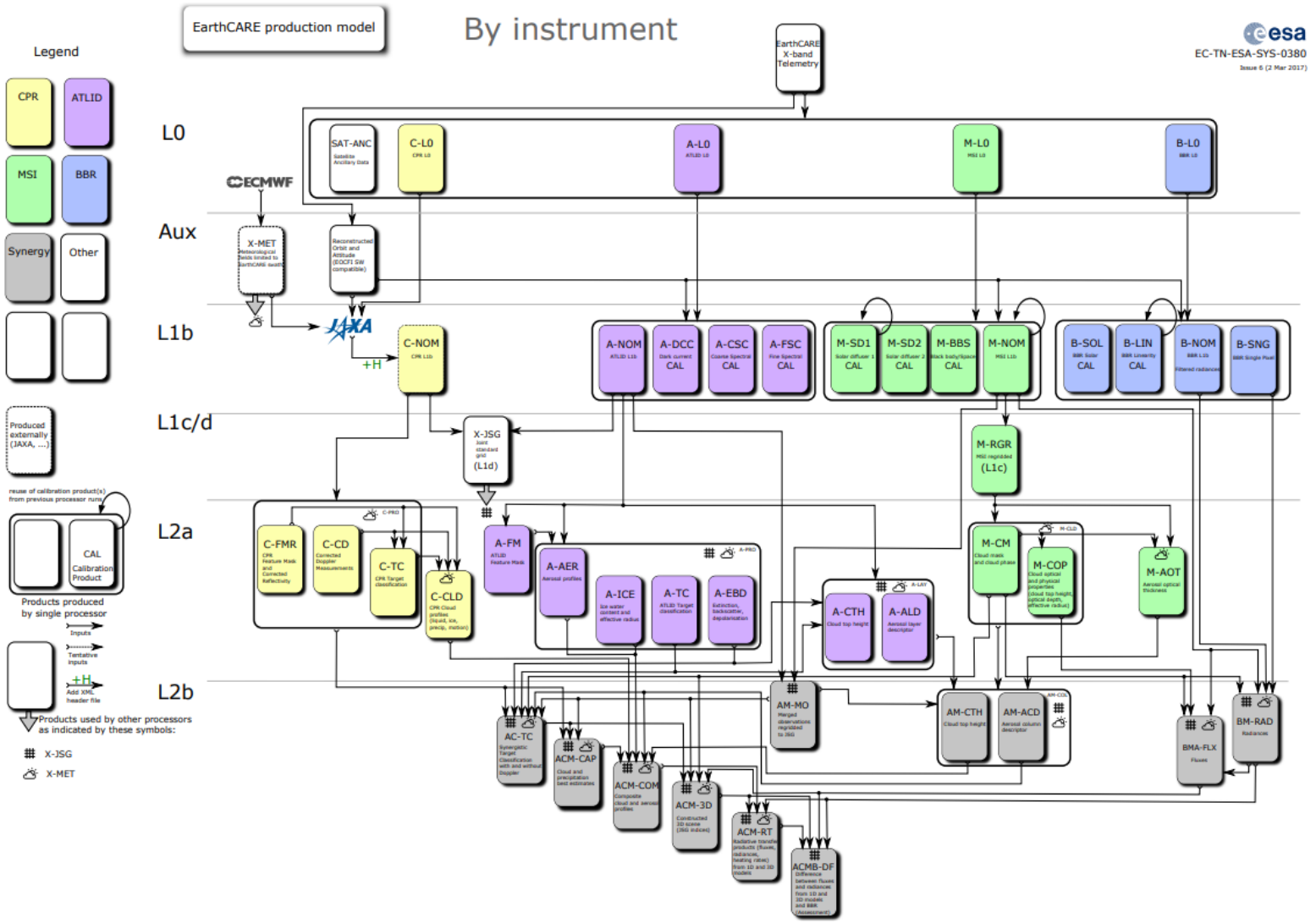
- EarthCARE payload of 4 instruments :
  - Cloud Profiling Radar (CPR), with Doppler capability
  - Atmospheric Lidar (ATLID)
  - MultiSpectral Imager (MSI), 7 bands
  - BroadBand Radiometer (BBR), with 3 views capability.
- 3-dim clouds/aerosols characterization from active instruments and imager
- 3-dim radiative transfer modelling (Monte-Carlo method) to compute corresponding SW/LW heating rate / fluxe profiles
- Scientific goal : scene reconstruction + fluxes with accuracy better than 10 W/m² (instantaneous)
- This accuracy is assessed “on-line” using the BBR (similarly to Ham et al., 2022).





Ham, S. H., Kato, S., Rose, F. G., Sun-Mack, S., Chen, Y., Miller, W. F., & Scott, R. C. (2022). Combining cloud properties from CALIPSO, CloudSat, and MODIS for top-of-atmosphere (TOA) shortwave broadband irradiance computations: Impact of cloud vertical profiles. *Journal of Applied Meteorology and Climatology*, *61*(10), 1449-1471.

EarthCARE Production Model (European part)



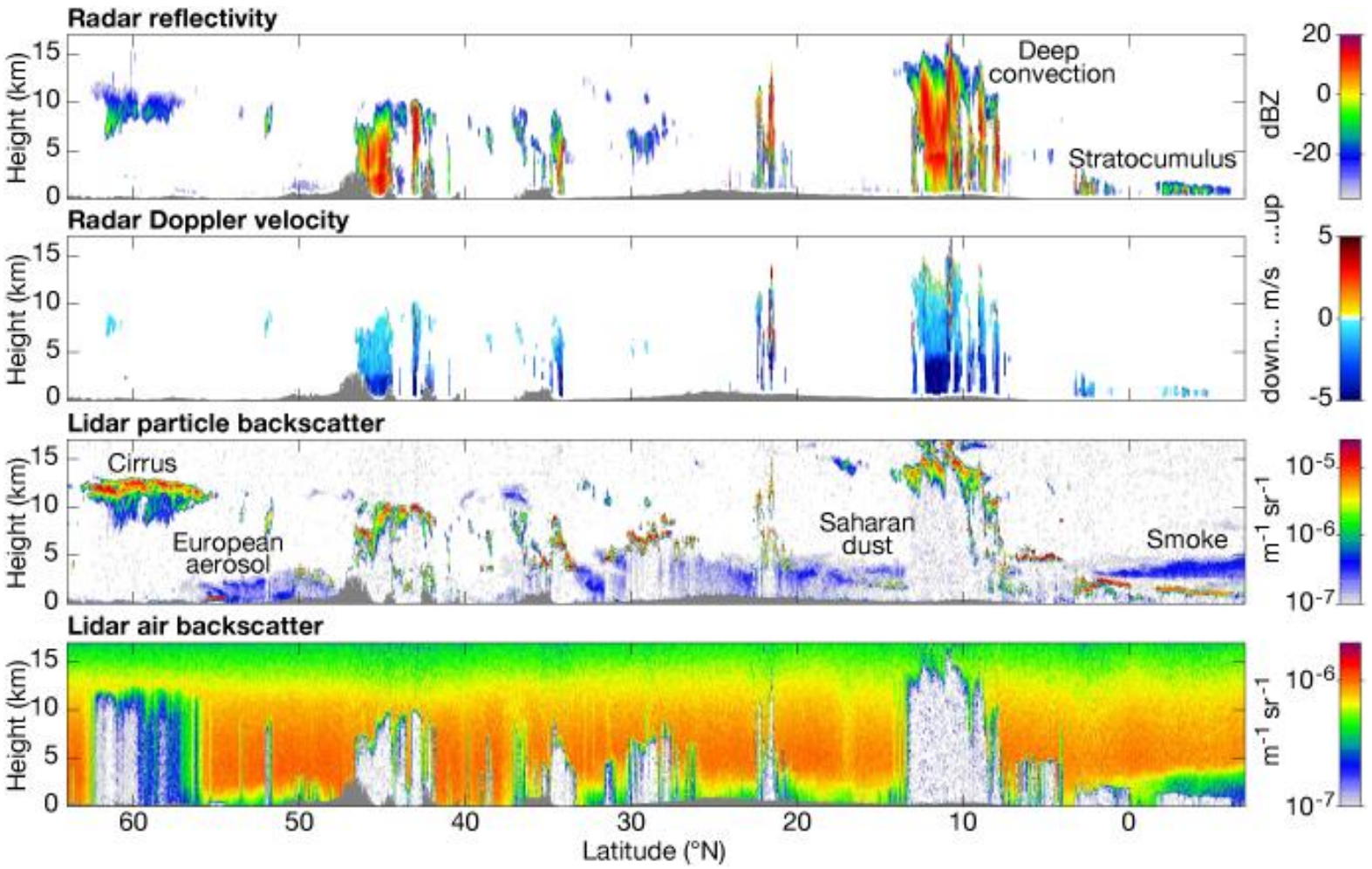
Note : all products are described in papers in a special issue of AMT: *"EarthCARE Level 2 algorithms and data products". (Open access).*

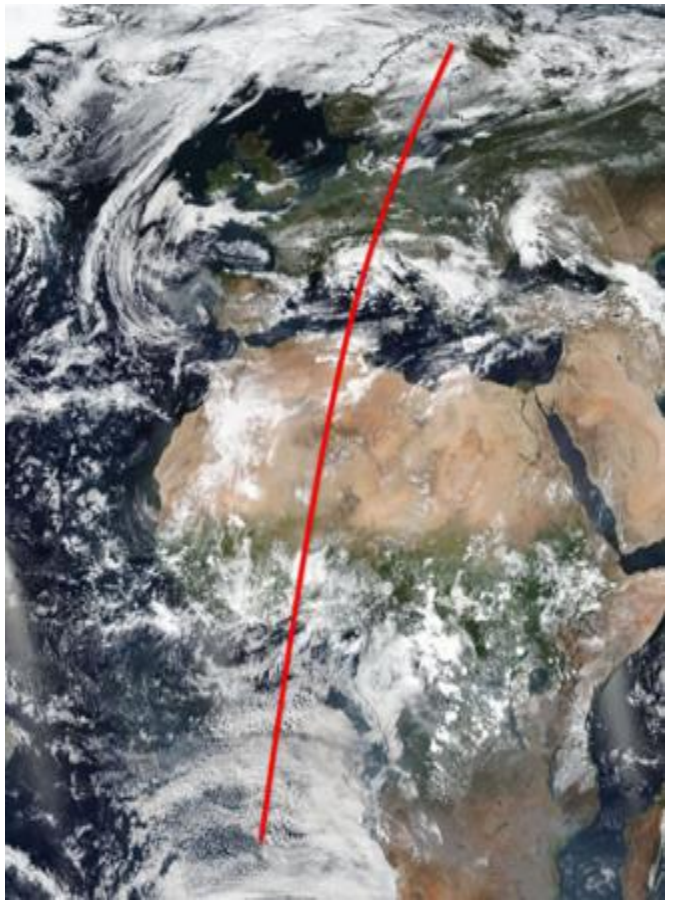
Level-1 : released in Jan. 2025

Level-2a : released in Mar. 2025 (1&2 sensors)

Level-2b : to be released in Dec. 2025 (3&4 sensors), already available to the Cal/Val teams

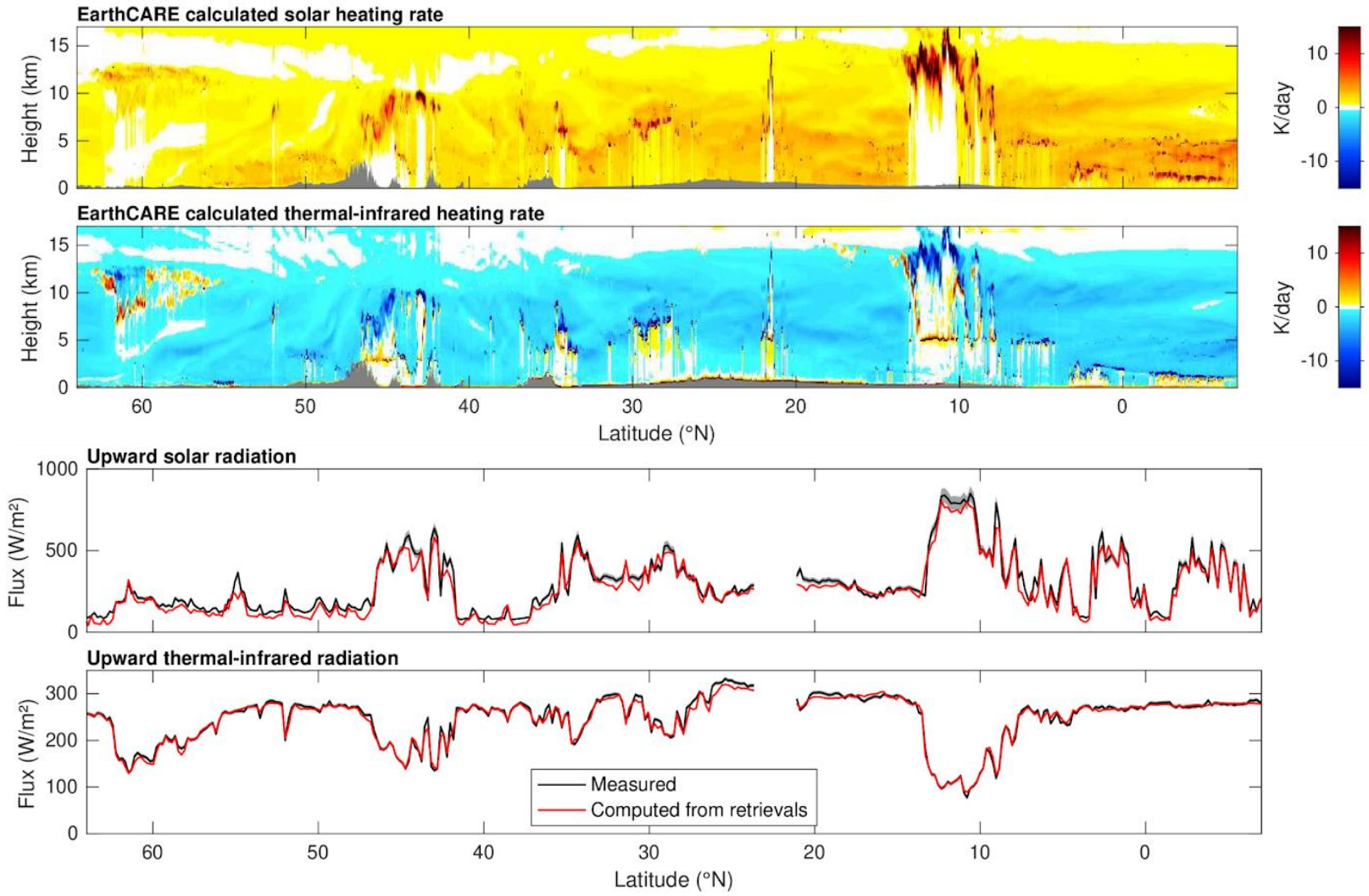
Some Illustrations (more on https://www.earthcarescience.net)

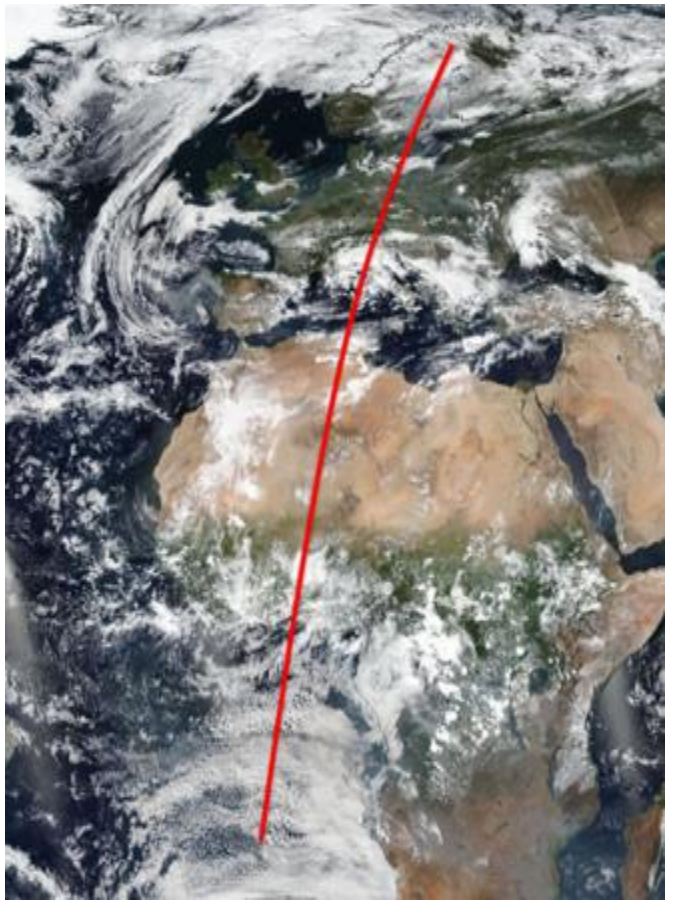




Frames 01752D and 01752E
(18 September 2024)

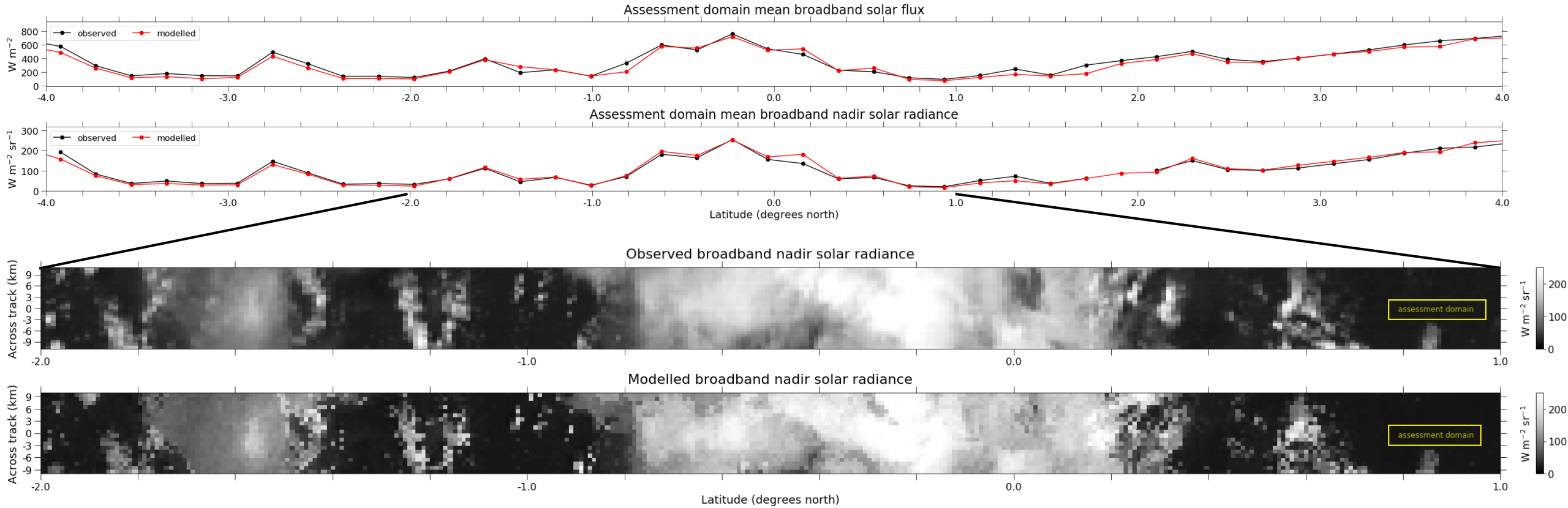
Illustrations (more on https://www.earthcarescience.net/)



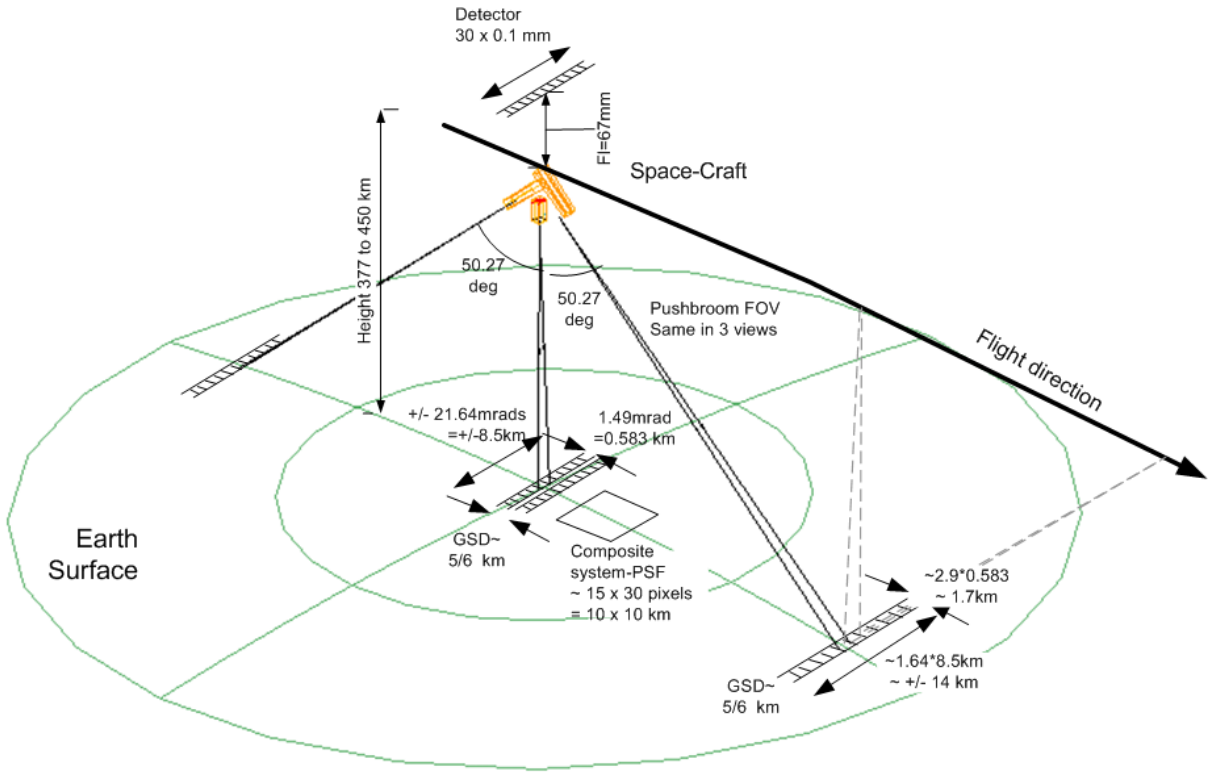


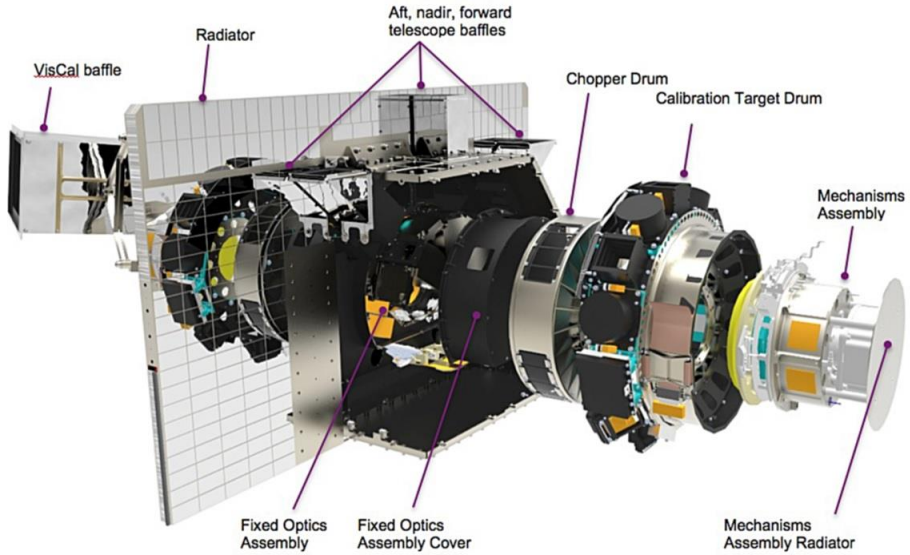
Frames 01752D and 01752E
(18 September 2024)

Illustrations (closure)

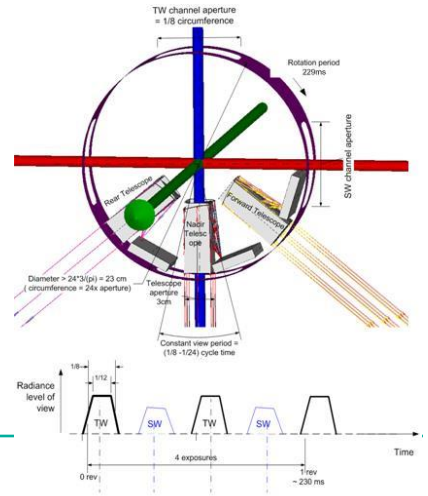


The BroadBand Radiometer (BBR) Instrument





- Detectors: 30 x 1 Vanadium Oxide microbolometer array
- Single mirror optics (Aluminum coating)
- Two spectral channels: **SW** (0.2 - 4µm) and **TW** (0.2 - >50µm)
- Radiometric accuracy: SW : 2.5 W m^{-2} sr^{-1} & LW: 1.5 W m^{-2} sr^{-1}



BBR calibration strategy

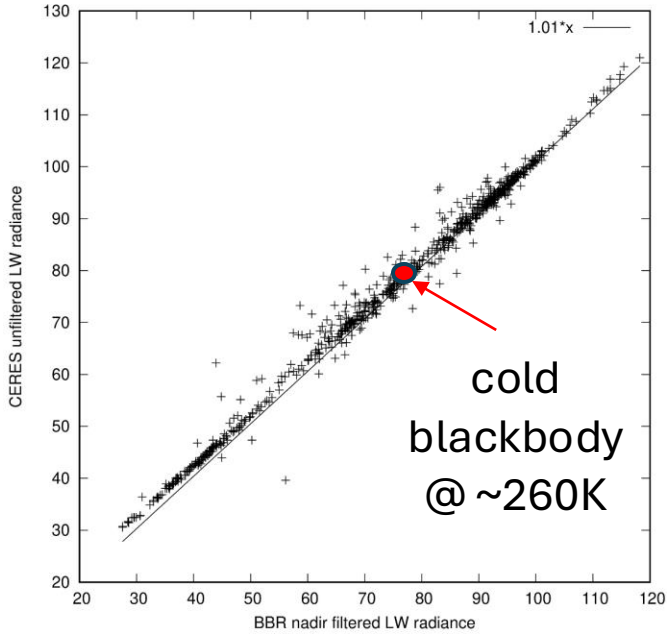
Longwave calibration each 88 sec :

- Observation of warm and cold blackbodies:
  → LW gain (G_{LW}) and offset for each of the 3 (views) x 30 detectors

warm blackbody @ ~302K

Shortwave calibration update, following LW calibration:

- Update the SW gain using 'fixed' B factors:
  → $G_{SW} = B * G_{LW}$
- Offset via observation of the cold blackbody



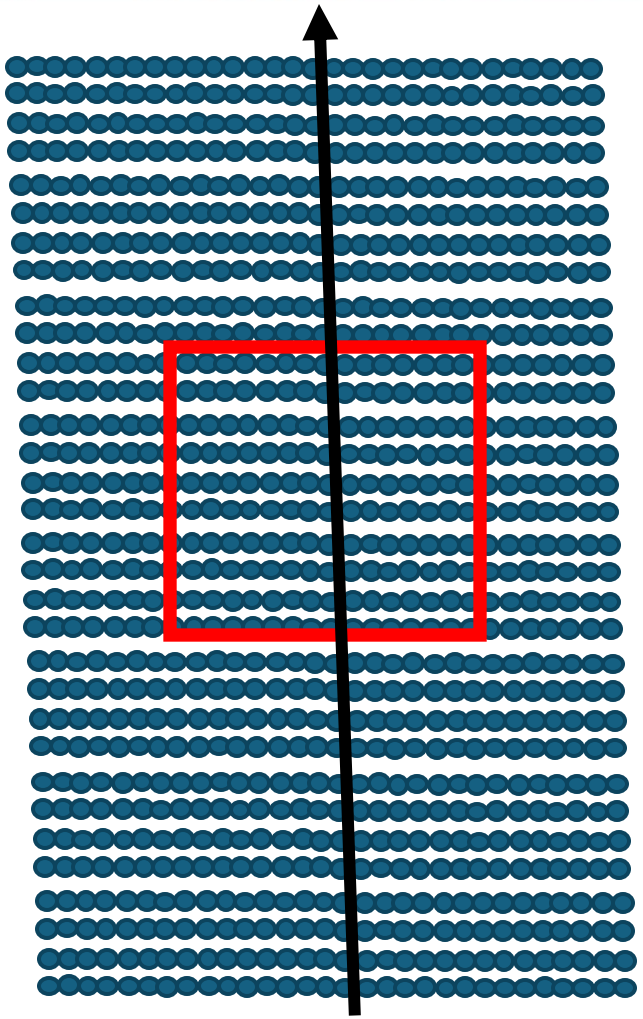
Solar calibration, every 2 months

- Monitoring using the sun diffuser (NDM)
- Spectral degradation via Monitoring Photo-Diodes (MPDs)

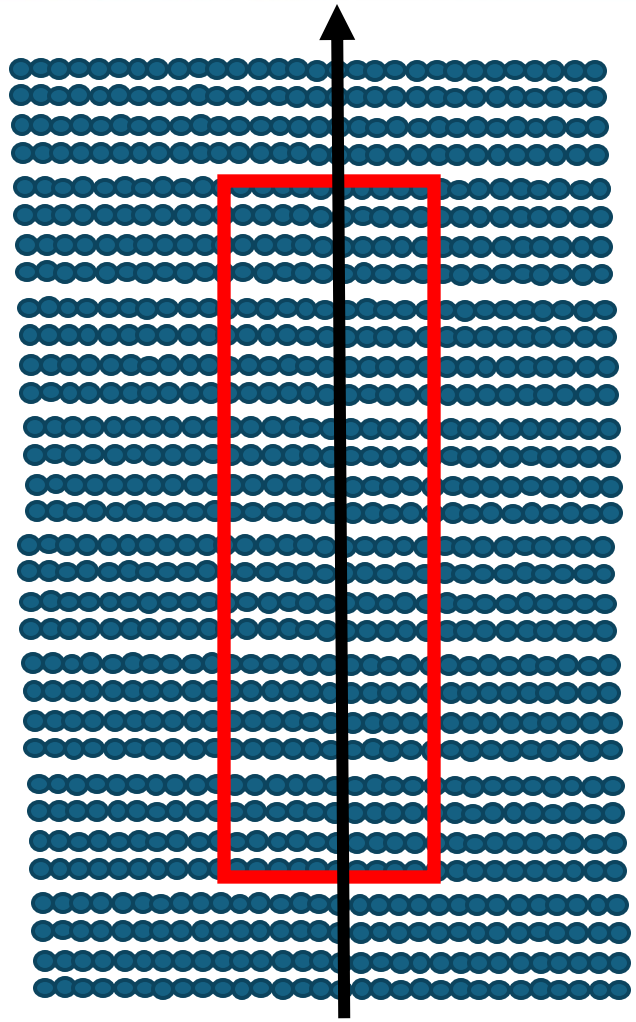
-> Done, results under analysis by ICMF

The B-SNG Level 1 Product

- 3 views along-track: aft, nadir, fore
- 30 detectors for each view
- 2 interleaved spectral bands: TW, SW (quartz filter)
- BBR instrument operated mostly at 75% of the CDM speed (configurable). For a same band (TW or SW):
  - dt = 0.1532 sec
  - along track sampling ~1113m
- Initially B-SNG was not foreseen to be released as a product (only B-NOM).
- B-SNG interesting for integration over other domains (e.g. the elongated assessment domain).
- B-SNG provides filtered TW and SW radiances



Standard 10x10km
nadir : 16 * 9 pixels
Aft/fore : 10 * 9 pixels

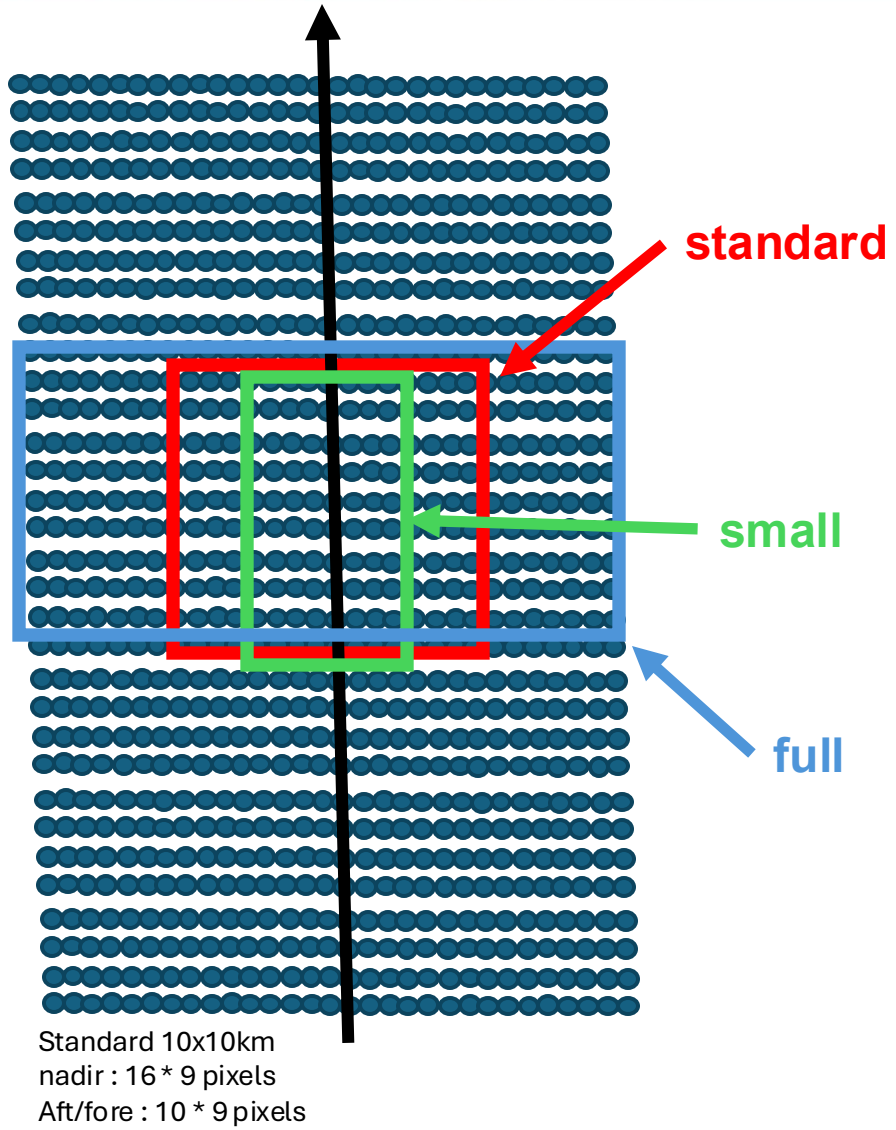


Assessment Domain (~5 x 21km)
nadir : 8 * 19 pixels
Aft/fore : 5 * 19 pixels

The B-NOM Level 1 Product

- Integrated into pre-defined domains:
  - **Standard** : 10km x 10km
  - **Small** : 5km x 10km
  - **Full** : 18 km/30 km x 10 km

- Each domain sampled at 1km along track -> data as vectors and not images



B-SNG detector noise

- Using nighttime SW images (frame ‘A’)
- About ε ~ 0.8 W/m²/sr
  -> ε ~ 0.75 W/m²/sr det. noise
  -> ε ~ 0.30 W/m²/sr cal. noise

→ significant detector noise that has also systematic effect via the calibration

- Noise reduction in integration domains:
  - Standard domain (10x10km, i.e. 10/16 x 9 pix):

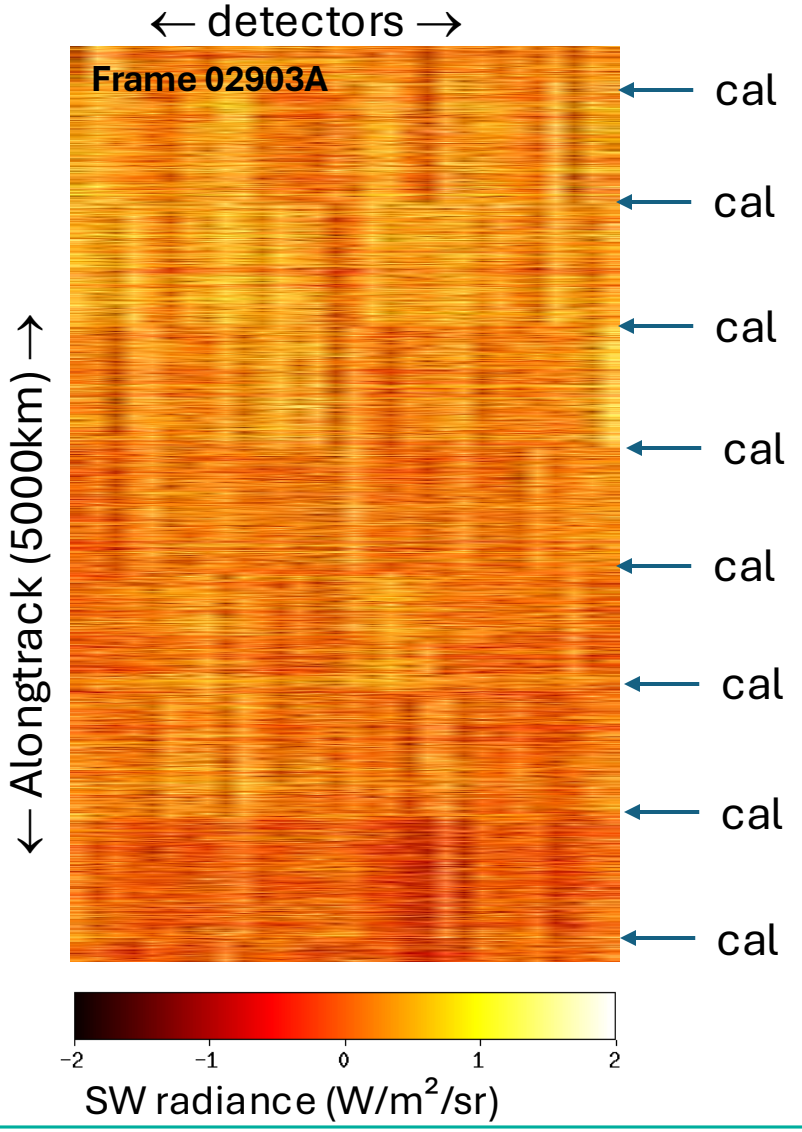
$$\varepsilon = sqrt(\ (\frac{0.75}{\sqrt{90}})^2 + (\frac{0.30}{\sqrt{10}})^2) = 0.12 \text{ W/m²/sr (aft/fore)}$$

$$\varepsilon = sqrt\left((\frac{0.75}{\sqrt{154}})^2 + (\frac{0.30}{\sqrt{16}})^2\right) = 0.10 \text{ W/m²/sr} \quad \text{(nadir)}$$

  - Assessment domain (21x5km, i.e. 5/8 x 19 pix)

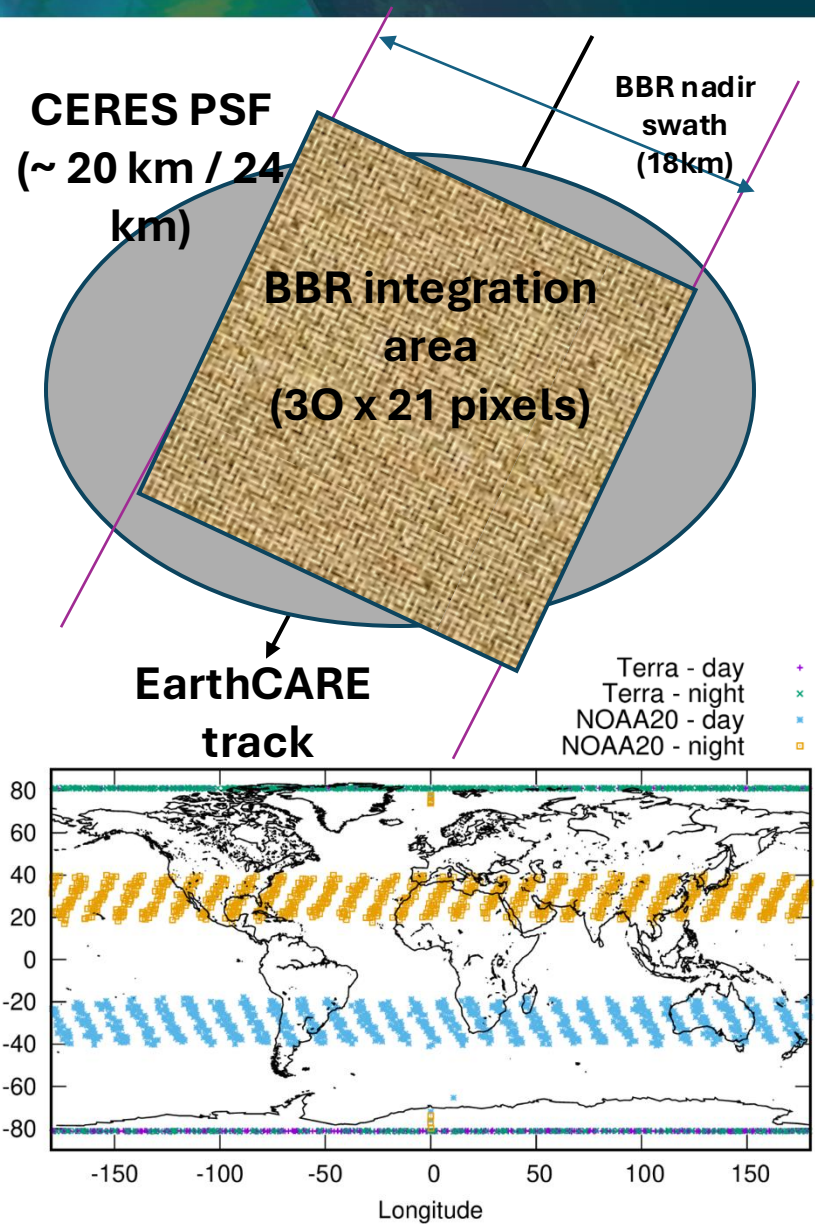
$$\varepsilon = sqrt((\frac{0.75}{\sqrt{95}})^2 + (\frac{0.30}{\sqrt{5}})^2) = 0.15 \text{ W/m²/sr (aft/fore)}$$

$$\varepsilon = sqrt((\frac{0.75}{\sqrt{152}})^2 + (\frac{0.30}{\sqrt{8}})^2) = 0.12 \text{ W/m²/sr} \quad \text{(nadir)}$$

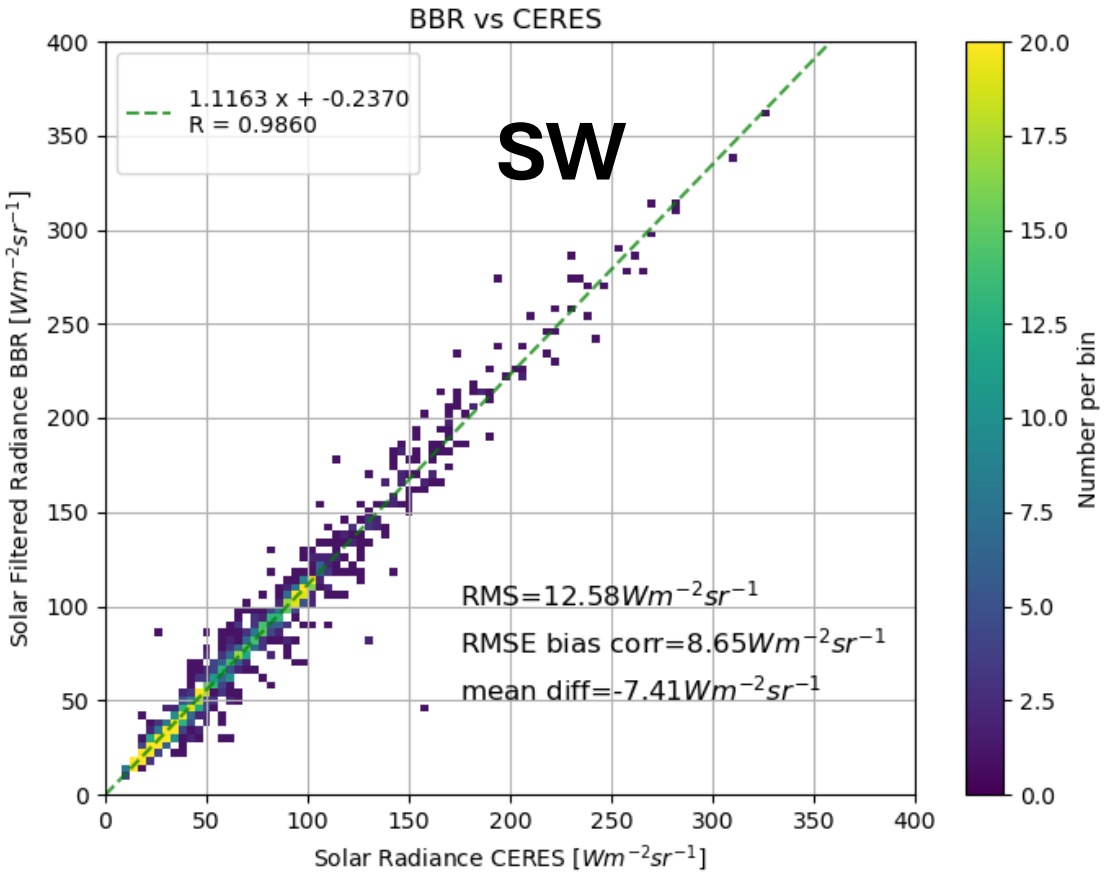


B-SNG Comparison with CERES FLASHFlux - method

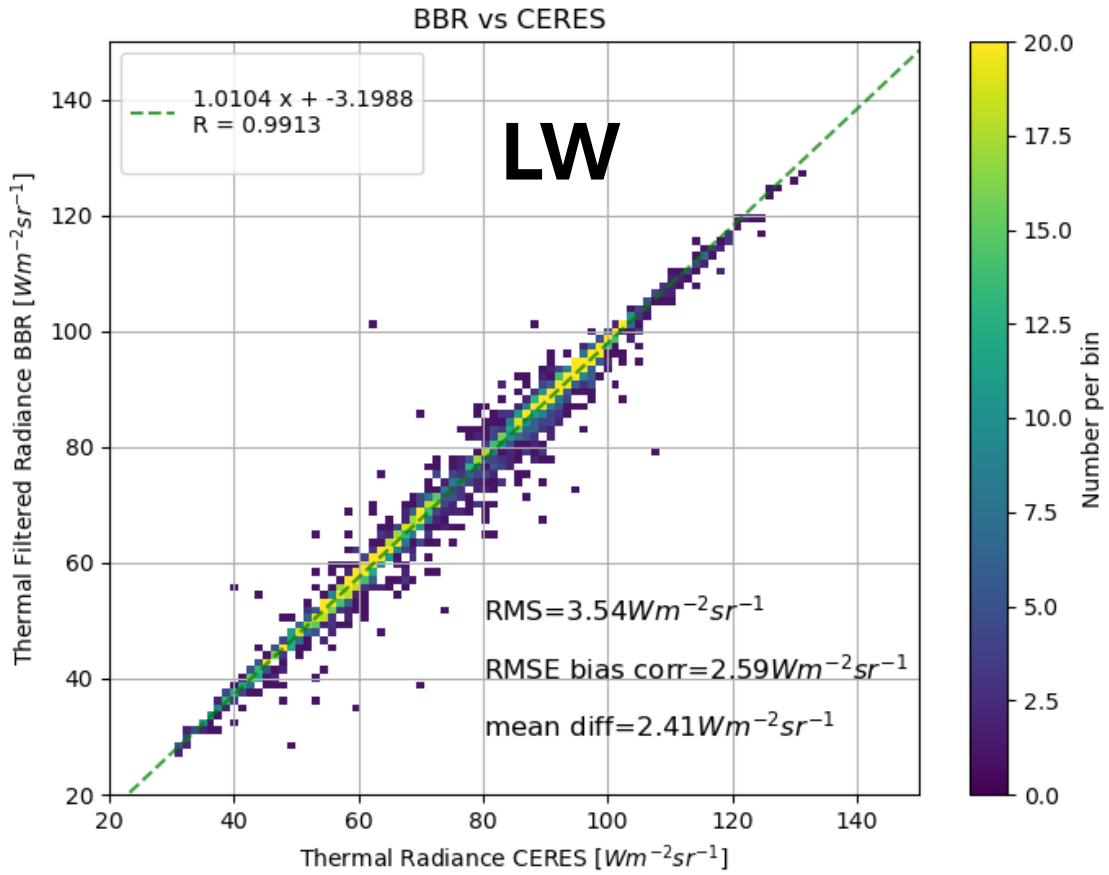
- CERES : Cloud and Earth Radiant Energy System
- Level 2 SSF (Single Scanner Footprint) product
- Use FLASHFlux (Fast Longwave And SHortwave Flux) for near real time monitoring
- FLASHFlux from across-track instruments on:
  - FM1 on Terra (until Feb. 17 2025)
  - FM6 on NOAA20 (until present – May 8 2025)
- CERES PSF of ~20 km (Terra, Aqua) or ~ 24 km (SNPP, NOAA20) is larger than the BBR swath (~18km for nadir)
- B-SNG integration area : 30 (across track) x 21 (along-track)
- Collocation criteria
  - Time difference < 300 seconds
  - distance between PSF centers < 3km
  - Angle between viewing directions < 3°
- Dates : 10 Aug. 2024 – 08 May 2025



B-SNG Comparison with CERES FLASHflux – First results using the current “baseline” AD (version)



SW brighter ~9%



LW lower ~ 3% (~2.4 W/m²/sr)

BBR Level 1 Evolution

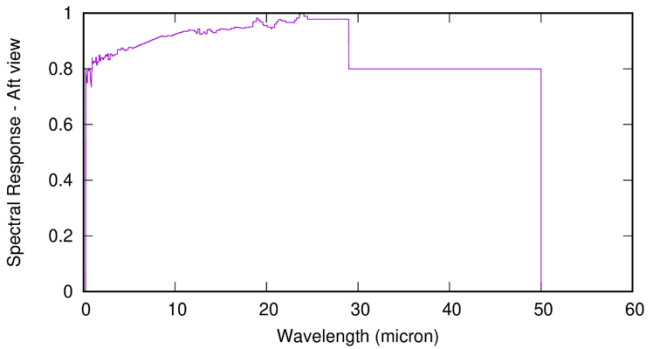
Investigations based on commissioning data :

1. Revisit the detectors' B values to reduce "stripping" between the 30 detectors

2. Revisit the ground characterization of the SW gain ('B' values):
   - The ground SW calibration was done using a reference laser (λ=0.532 µm)
   - The obtained gain G_{laser} (at λ=0.532 µm) was converted in (broadband) SW gain G_{SW} using an incorrect SR.

$$G^{s}_{SW} = \frac{G_{laser}}{r_{SW}(\lambda_{laser})} \frac{\int r_{SW}(\lambda).L_{Planck}(\lambda,5800).d\lambda}{\int L_{Planck}(\lambda,5800).d\lambda}$$

3. Revisit the far-IR spectral response used in the L1 processing
   - Was (incorrectly) set to 0.0 for λ > 50µm
   - To be extended up to λ=500µm

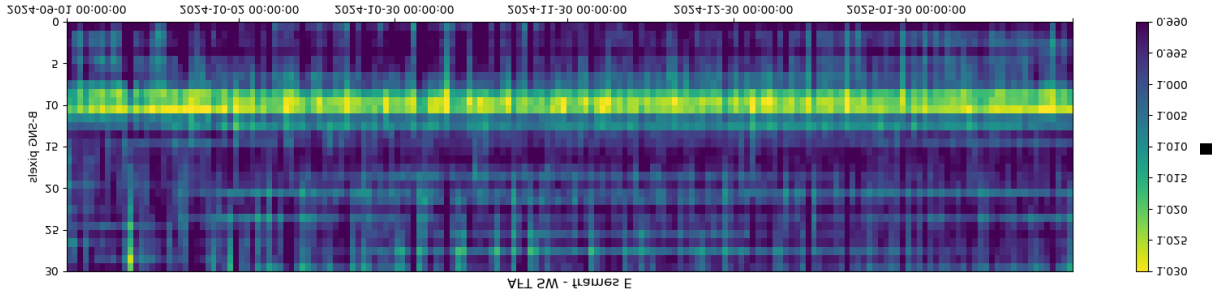


-> Updated CCDB ("Calibration and Characterization Data Base") ready to go to operation and reprocessing of the full archive -> Baseline (version) will change from "AD" to "BA"

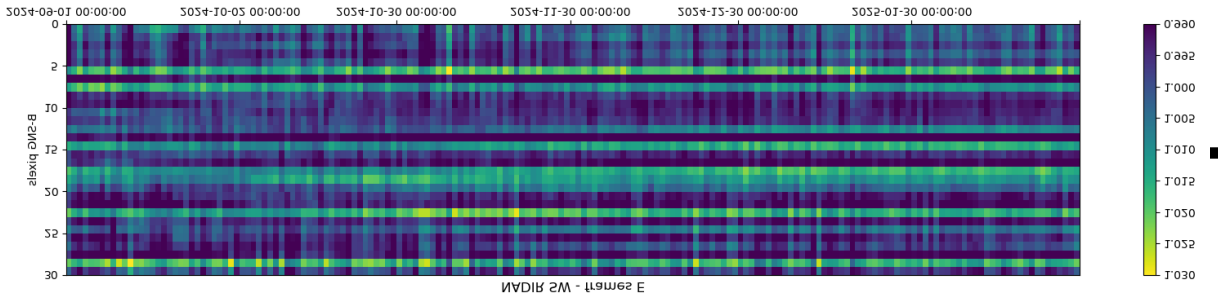
BBR L1 Evolution : Striping reduction in baseline “BA” wrt “AD”

Current baseline “AD”

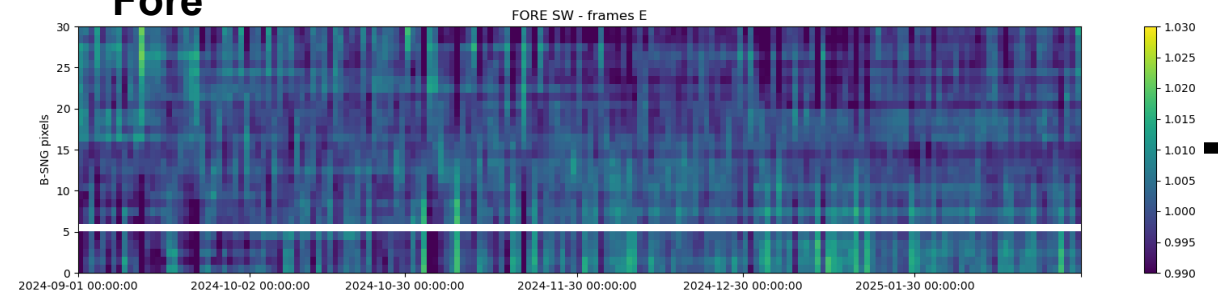
Aft



Nadir

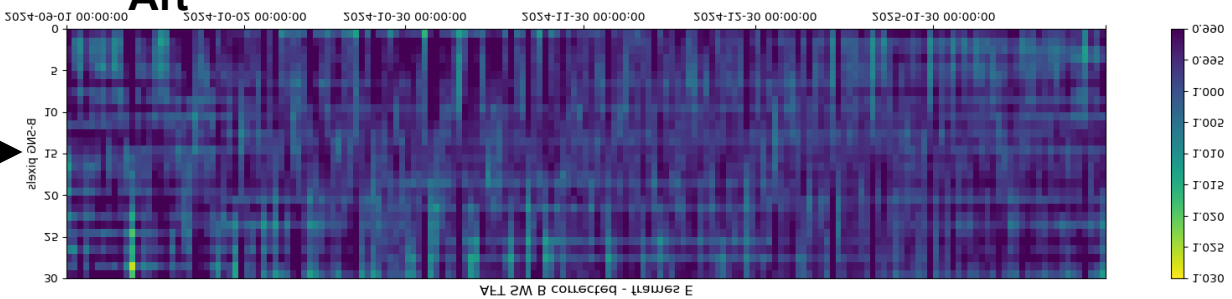


Fore

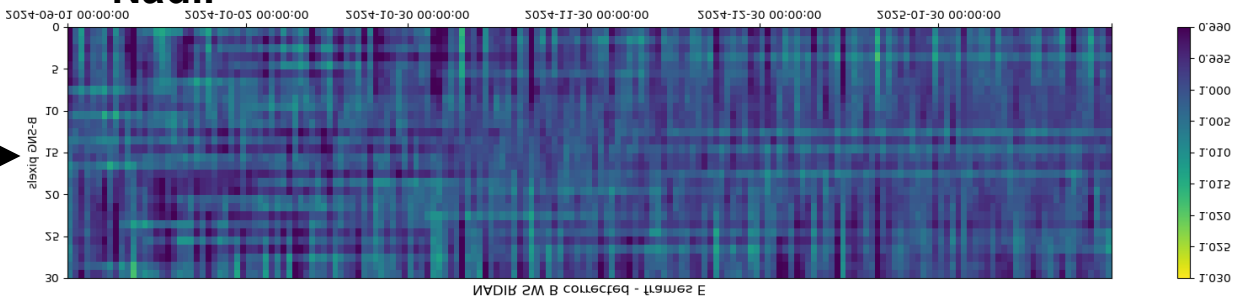


Next baseline “BA”

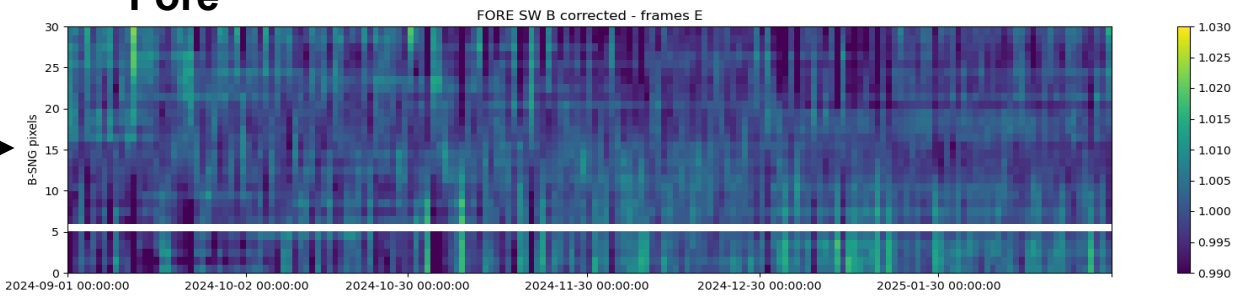
Aft



Nadir

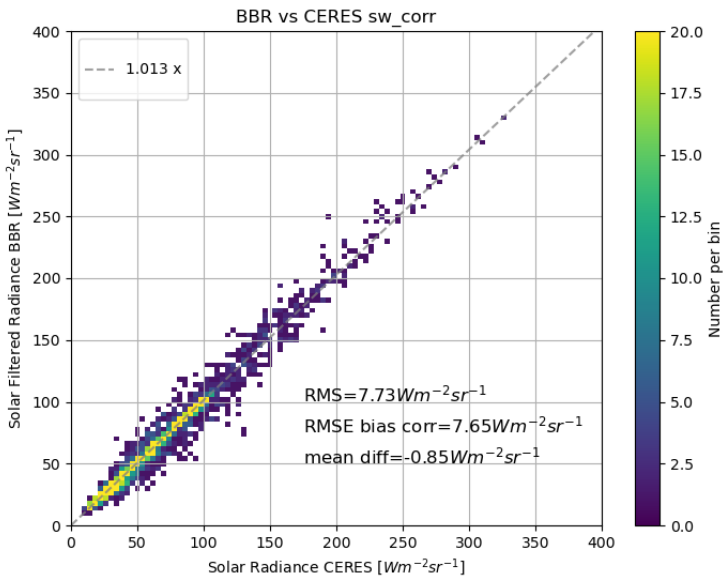


Fore



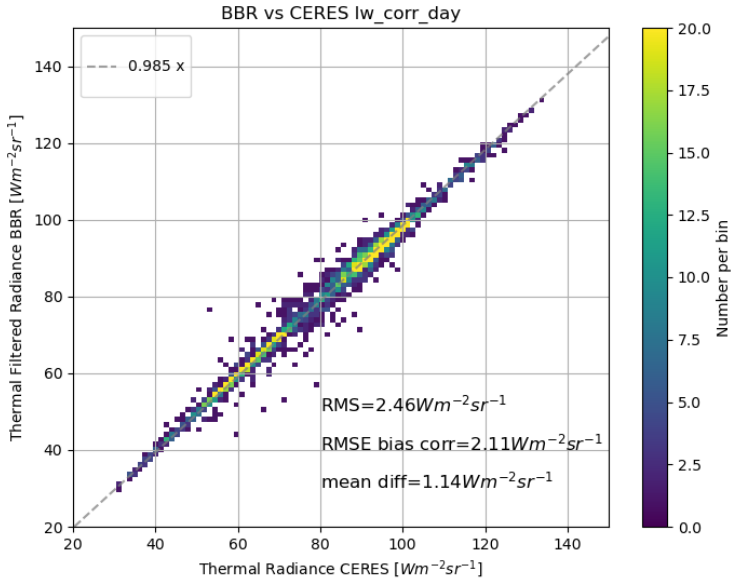
Future Baseline “BA” : (expected) BBR – CERES matching

Shortwave (day)



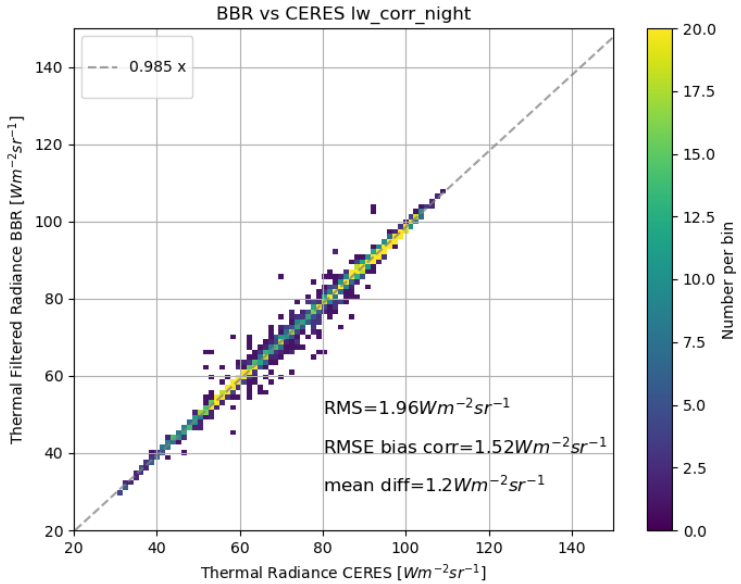
best fits day: $L_{BBR} = 1.013\ L_{CERES}$

Longwave (day)



best fits day: $L_{BBR} = 0.985\ L_{CERES}$

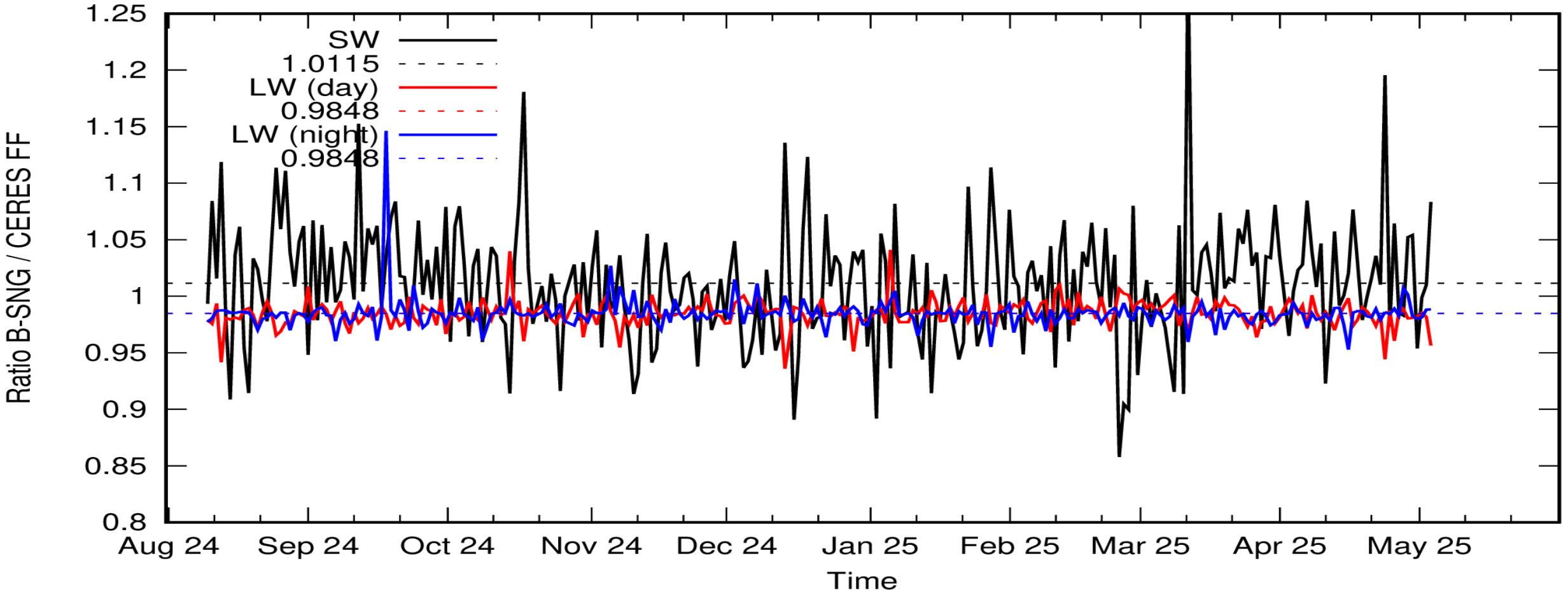
Longwave (night)



best fit night: $L_{BBR} = 0.985\ L_{CERES}$

→ **Better agreement with CERES.**
→ **LW lower by ~1.5% (similar to GERB/CERES ratio), no more visible scene type dependency.**

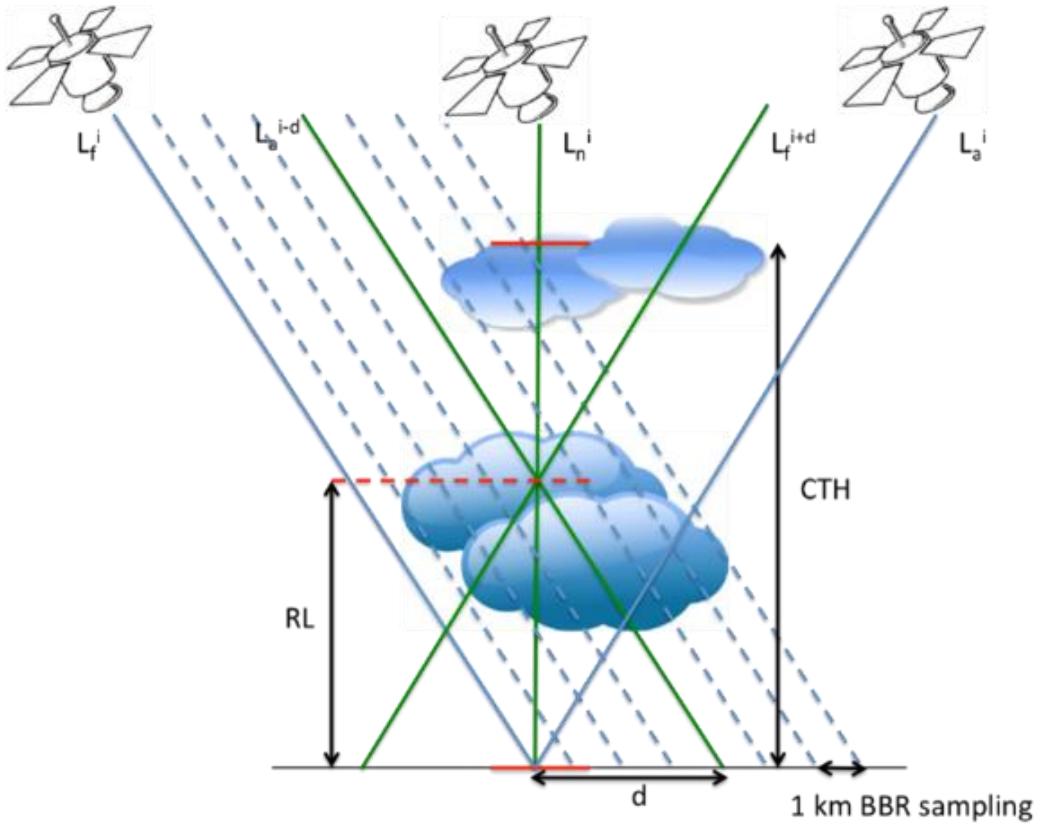
Temporal Stability – BBR versus FM6/NOAA20 – Daily ratio



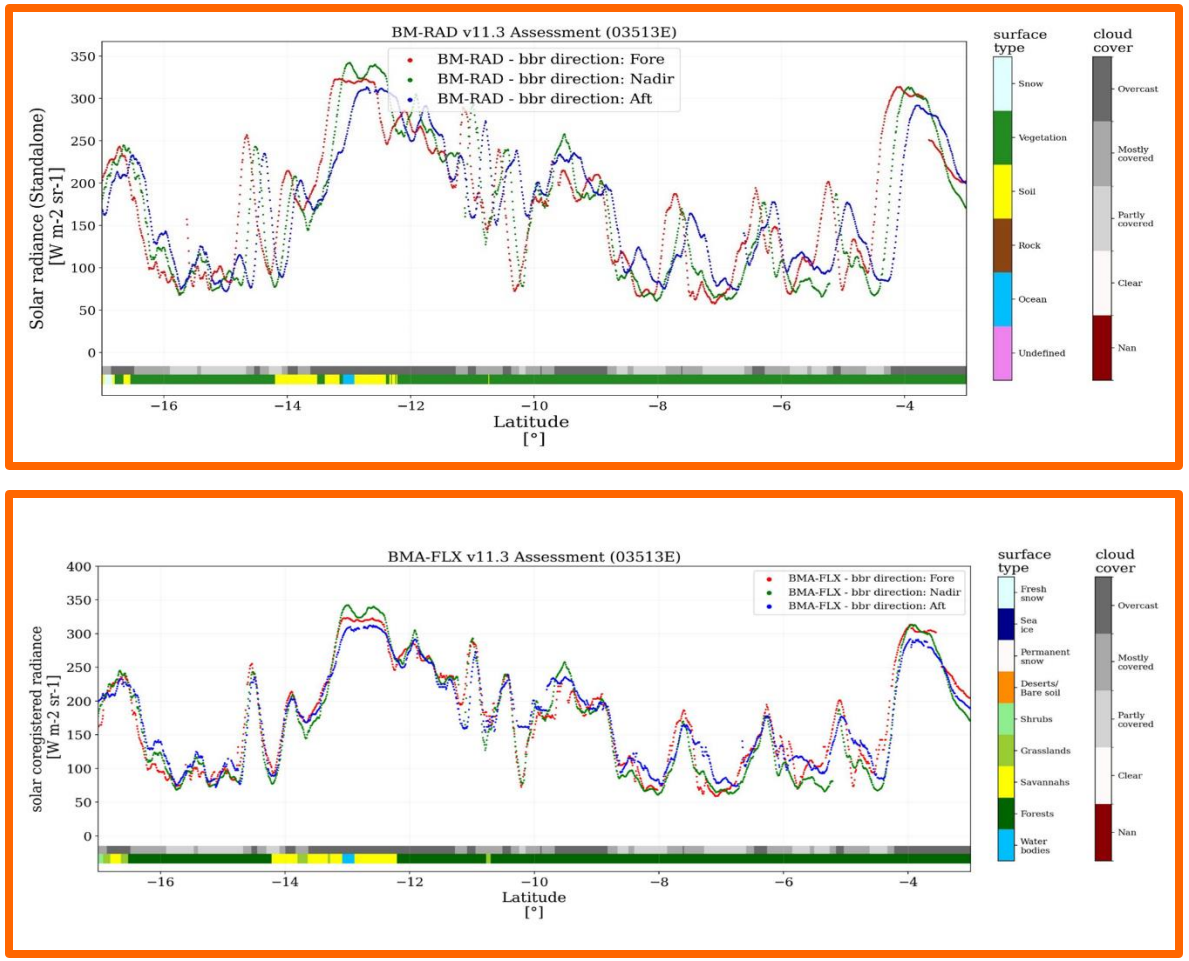
→ **No evidence of temporal degradation so far.**

BBR Level 2 : BMA_FLX (TOA instantaneous SW/LW fluxes)

The 3 views are co-registered at a reference level (top of cloud) that can be different for SW and LW



Using the reference level improve the consistency of the fluxes from the 3 views.



BBR – CERES flux comparison – shortwave (baseline “BA”)

SW flux ratio wrt CERES FF:

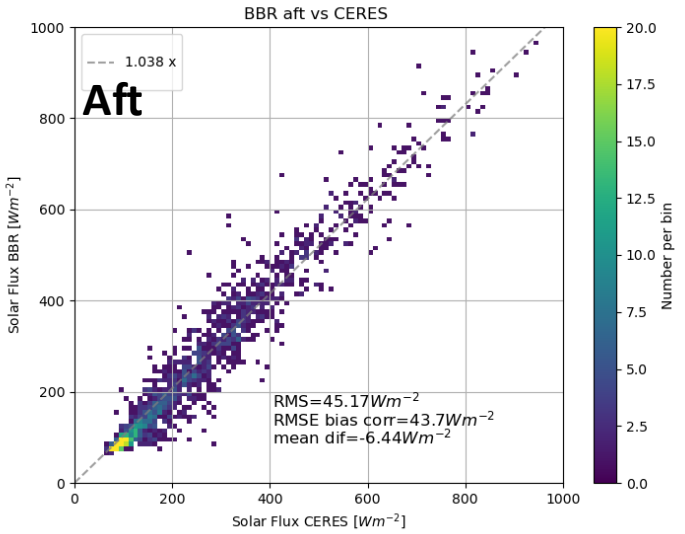
Aft : BBR = 1.038 CERES

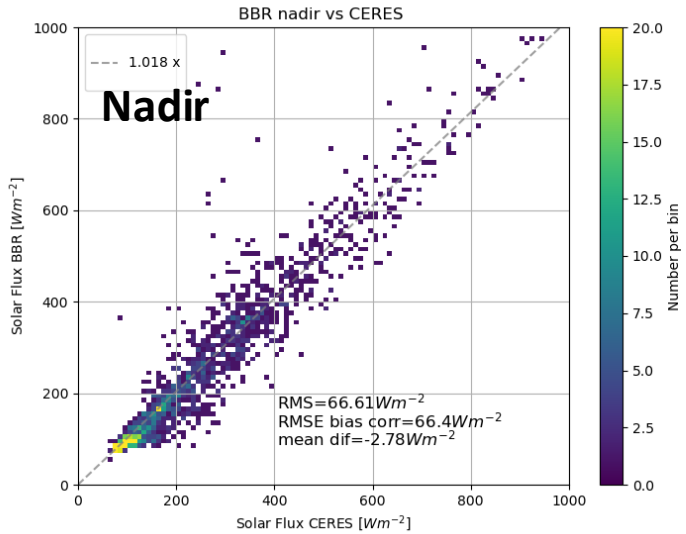
Nadir: BBR = 1.018 CERES

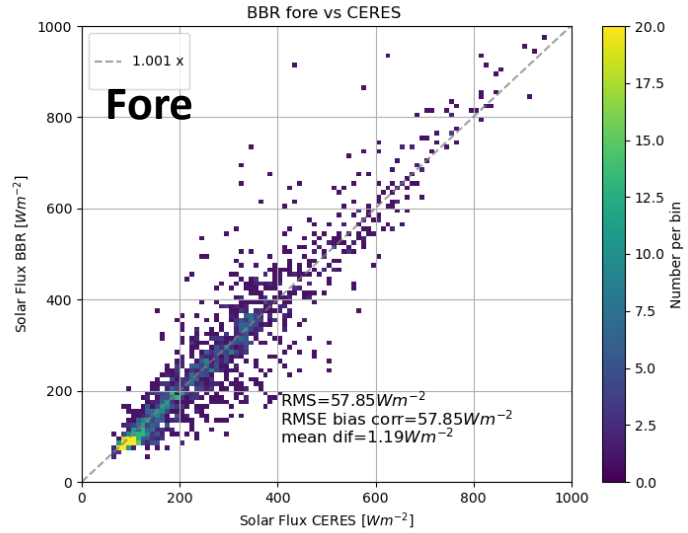
Fore : BBR = 1.001 CERES

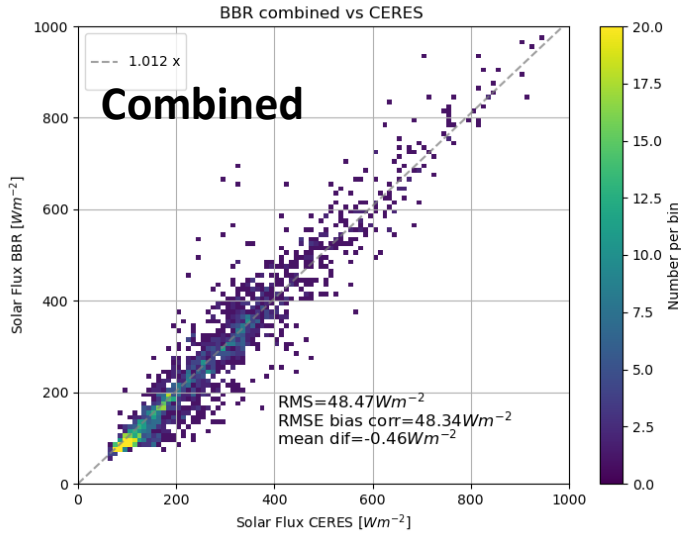
Combined: BBR = 1.012 CERES

Note : SW gain corrected to mimic future baseline “BA”









BBR – CERES flux comparison – Longwave (baseline “AD”)

LW flux ratio wrt CERES FF:

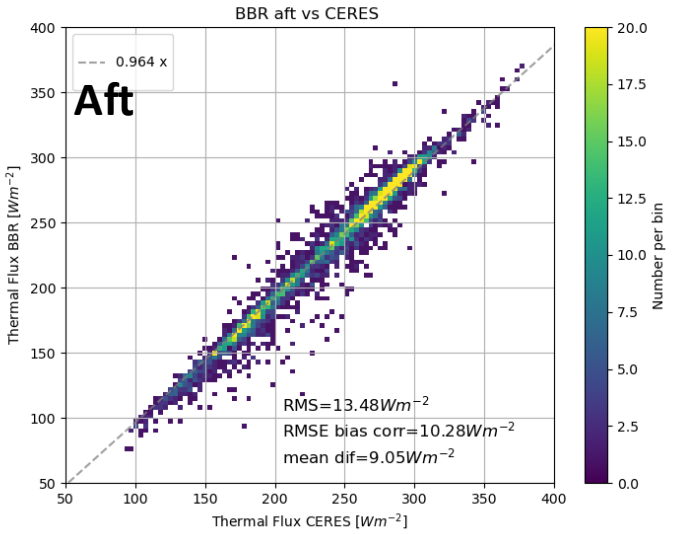
Aft : BBR = 0.964 CERES

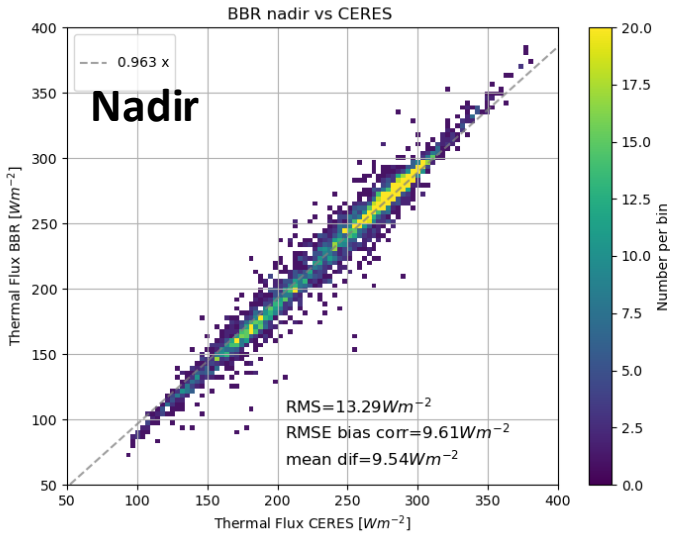
Nadir: BBR = 0.963 CERES

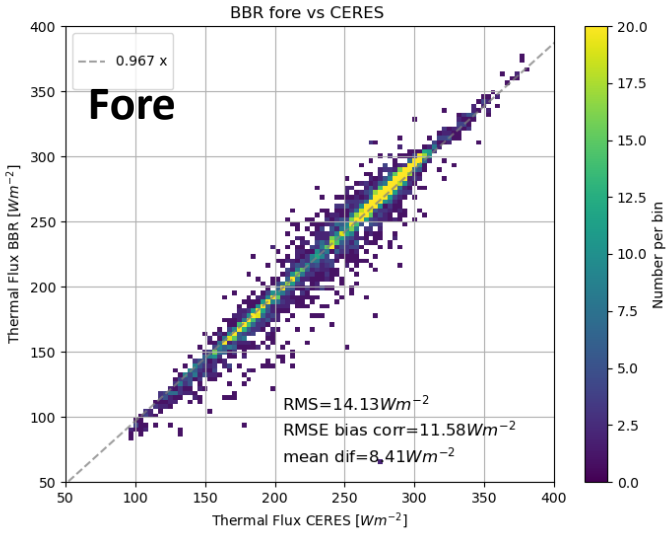
Fore : BBR = 0.967 CERES

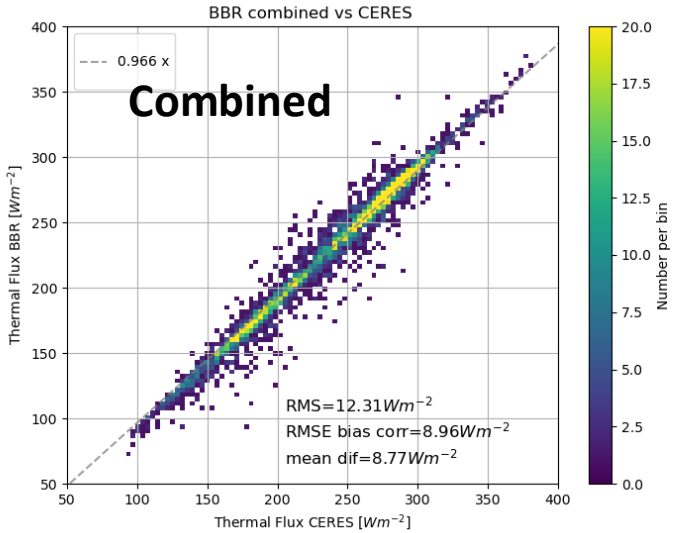
Combined: BBR = 0.966 CERES

Note : factor will increase to ~0.985 in baseline “BA”.









Summary

- **EarthCARE** is quite successful so far, all instrument are working fine and data are being progressively released to the community.
- The **BBR** is overall of good quality and excellent availability (useful record start ~ July 26th 2024).
- The **BBR L1 processing** will be upgraded soon from baseline “AD” to baseline “BA”. Will improve the consistency in radiometric level with CERES.
- The BBR radiance **comparison with CERES** is currently only possible for the nadir view.
- The **BMA_FLX flux comparison with CERES** can be done for the 3 views. Results are consistent between the views within +/- 2% for SW and +/- 0.2% for LW.
- Not shown : it is also possible to compare statistically the aft and fore radiances (with criteria on relative sun azimuth angle ~90° for SW)-> no significant difference between aft and fore radiances.