Evaluation of the GERB-4 dataset (Jan. 2018 – Feb. 2023)

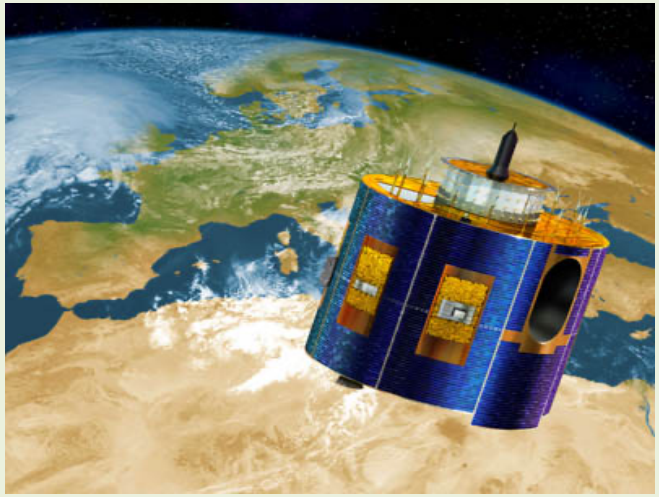
CERES Science Team Meeting
NASA GISS
Oct. 17th 2023

***Nicolas Clerbaux**, Edward Baudrez, Christine Aebi, Pierre de Buyl*
Jacqui Russell, Helen Brindley

Royal Meteorological Institute of Belgium (RMIB)
Imperial College London (ICL)

Content

- Introduction to GERB
  - Instrument and Mission
  - Products
  - Operations overview
  - Some examples of applications
- The GERB-4 dataset
  - Version V011
  - Level 1.5 evaluation
  - Level 2 evaluation
  - Level 3 evaluation
  - SW channel calibration discussion
- Summary

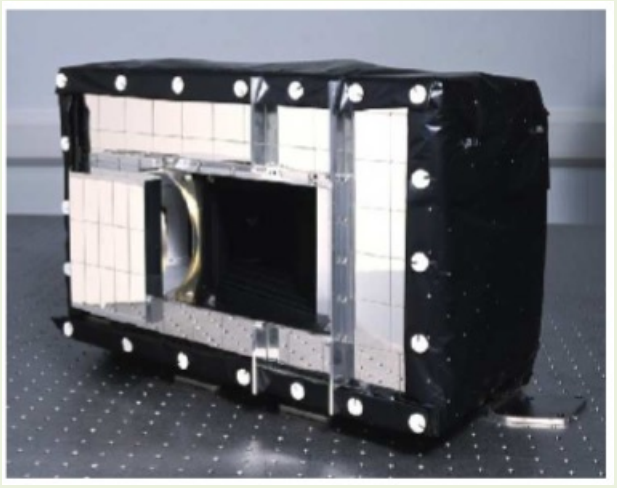


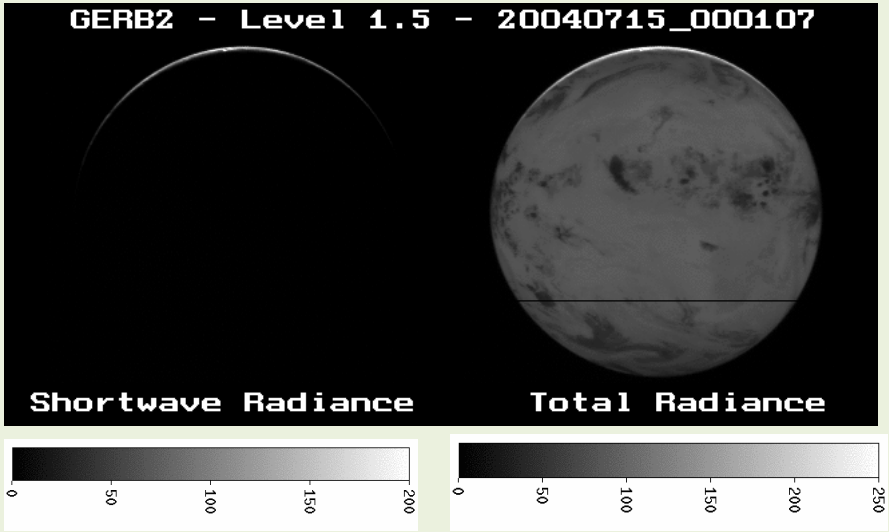
GERB instrument on the MSG satellite

Launch of MSG4 from Kourou (15th July 2015)

The GERB mission and instrument

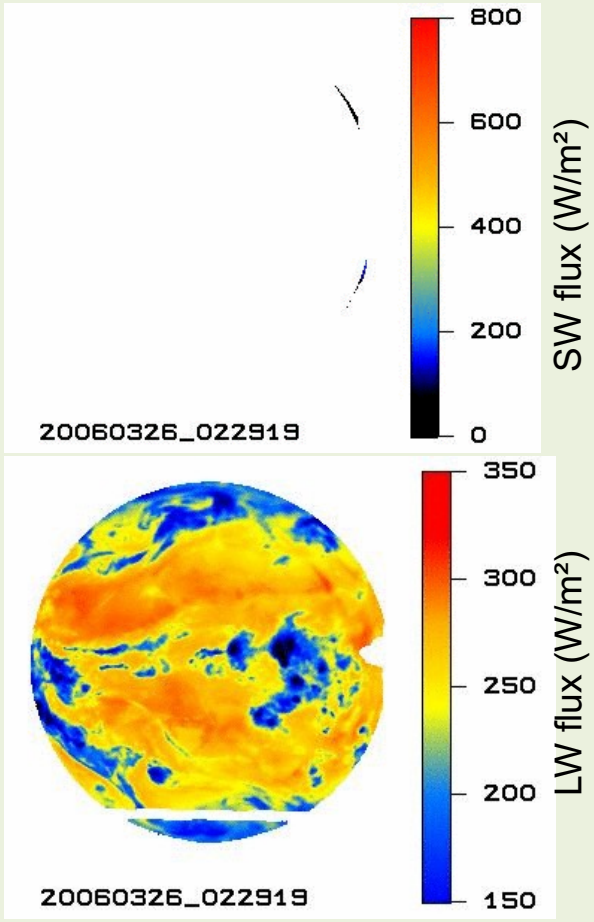
- GERB = Geostationary Earth Radiation Budget
- Onboard the European's Meteosat Second Generation (MSG) satellites
- Operational since Feb. 2004
- Broadband observations with TW and SW channels
- Optics : 5 mirrors (silver coating), incl. 1 rotating De-Spin Mirror (DSM)
- Repeat cycle ~6 minutes (one TW + one SW images)
- Main scientific objectives : observe the diurnal cycle of TOA radiation and rapidly evolving phenomena.





The GERB products

Level	GERB Products	Time res.	Spatial resolution	Content	Covered periods (0°)
L1.5	**NANRG** : Not Averaged Not Rectified Geolocated	6’	~45km	Filtered radiances (SW, TW) geolocation (lat, lon)	GERB2 2004 – 2007 (ED01 released) GERB1 : 2007 – 2012 (ED01 released) GERB3 2015-2018 (V006 development) GERB4 2018-2023 (V011 pre-release)
L2	**ARG** : Averaged Rectified Geolocated	18’	~45km	Unfiltered solar and thermal radiances Unfiltered solar and thermal fluxes at TOA Basic scene identification (surface, cloudiness, aerosols).	
	BARG : Binned Averaged Rectified Geolocated	15’	~45km		
	HR : High Resolution	15’	9 km		
L3	**Obs4MIPS**	60’	1°x1°	Diurnal cycle of TOA fluxes, limited gap filling with SEVIRI	2007-2012, but only Jan, Feb, May, June, July, Nov, & Dec.
	CM SAF : Climate Monitoring SAF	60’	0.1°x0.1°	Diurnal cycle of TOA fluxes, full gap filling with SEVIRI	Feb. 2004 – Apr. 2015



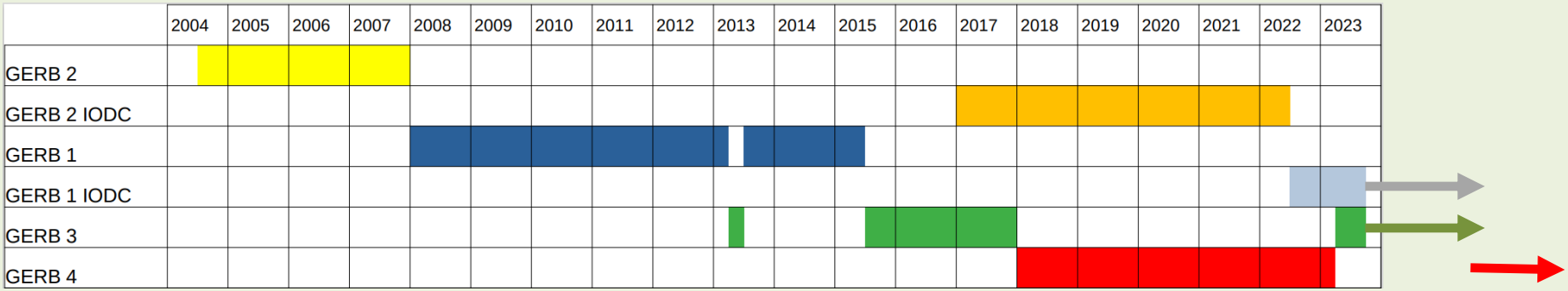
Animations of ARG product

Datasets access via:

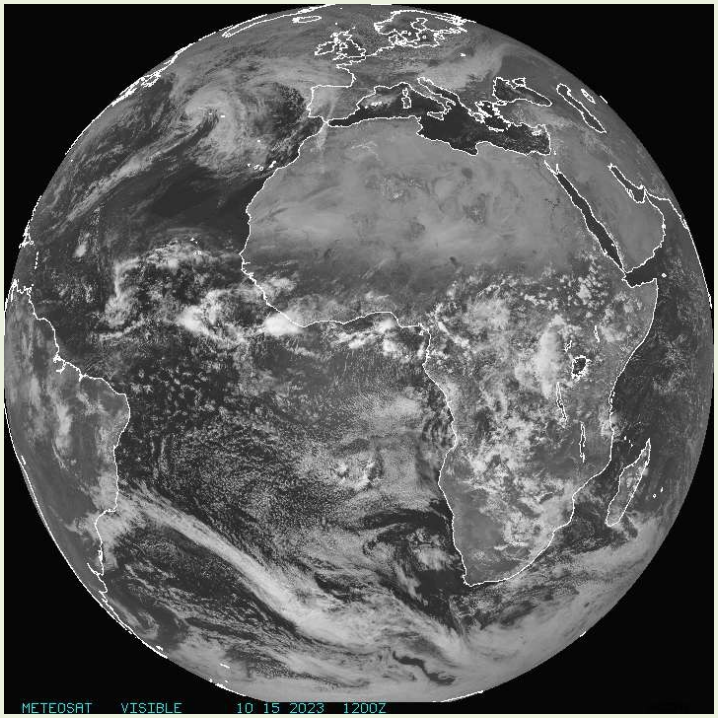
- https://gerb.oma.be
- https://data.ceda.ac.uk/badc/gerb
- https://data.ceda.ac.uk/neodc/obs4MIPS
- https://www.cmsaf.eu

New : GERB data reader for the python package ***satpy.***

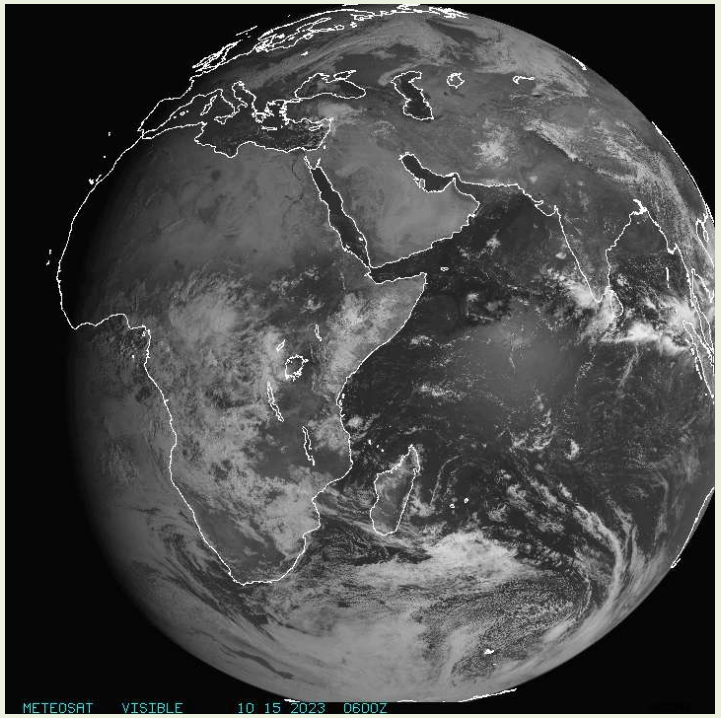
GERB operation overview



0° service (since 2004)



Indian Ocean Data Collection (since 2017)



Meteosat-9 satellite longitude 45°East

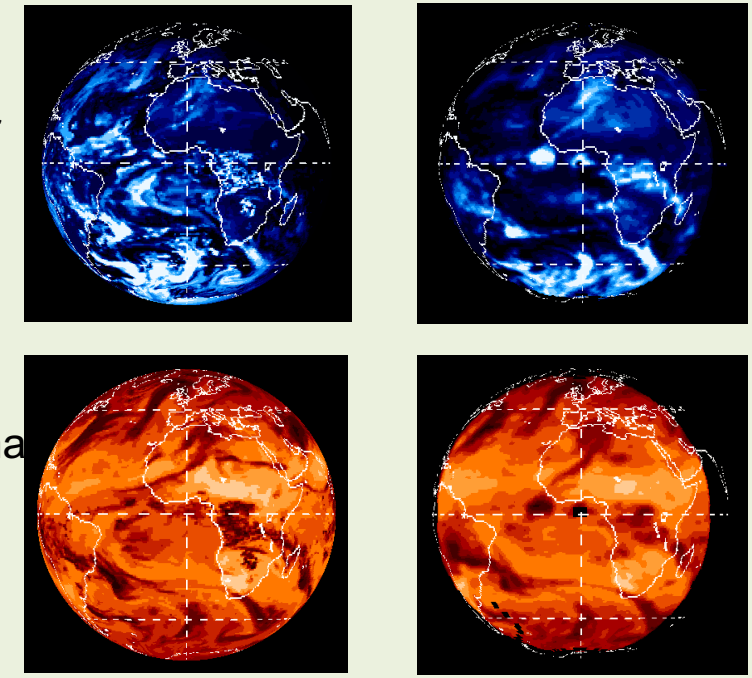
Example of application : model monitoring including in "*near real time*" (GERB timeliness < 4hours)

UK-MO Unified Model

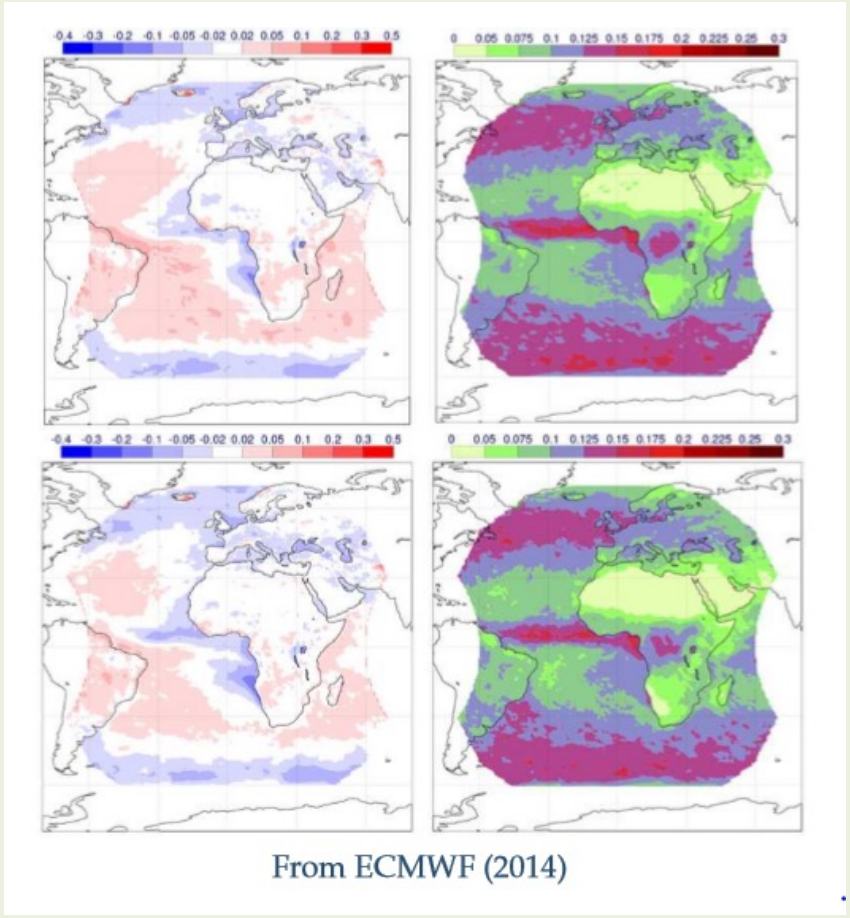
GERB

Solar Flux

Therma Flux



(Courtesy UK Met Office)



From ECMWF (2014)

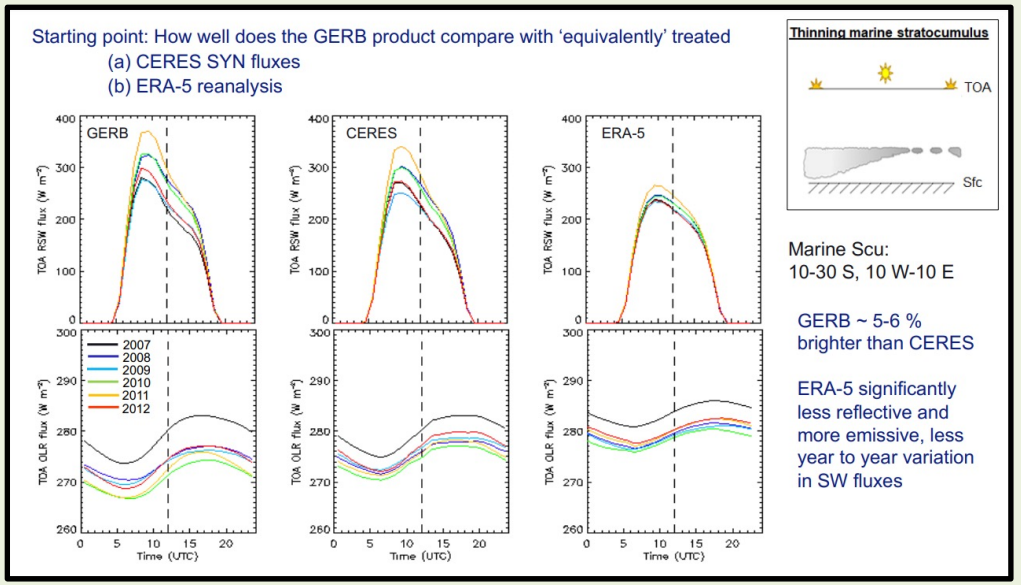
Example of application : Diurnal cycle in reanalysis and in climate models

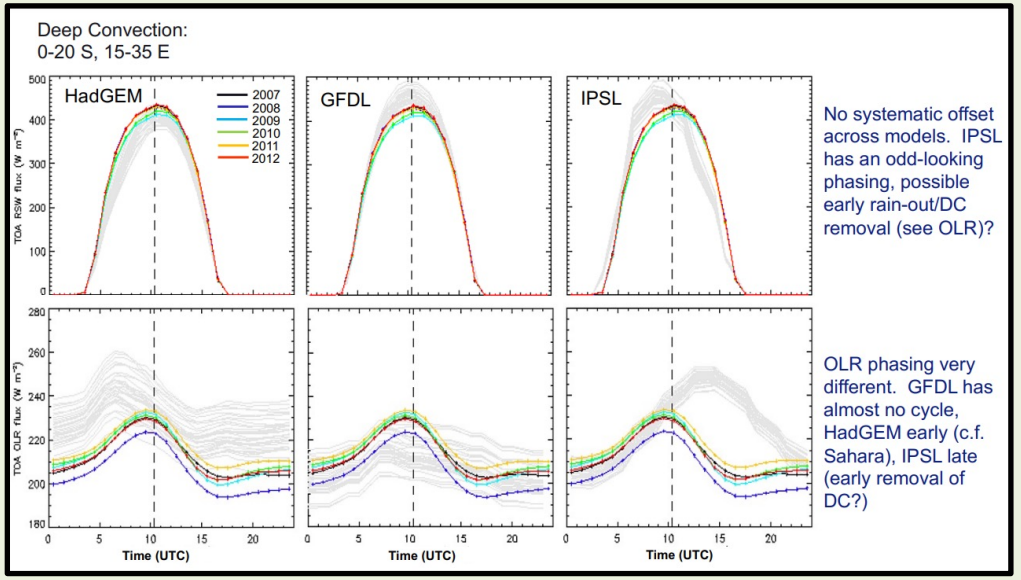
Helen Brindley, ERB Workshop 2022 (MPI-M, Hamburg).

Based on the GERB Level 3 "Obs4MIPs" data

Evaluation of diurnal cycles of OLR and RSF in
- reanalysis (ERA5)
- AMIP6 runs (HadGEM, GFDL, IPSL)

For different regions :
- Deep convection
- Sahara (surface heating)
- Marine stratocumulus (cloud thinning)





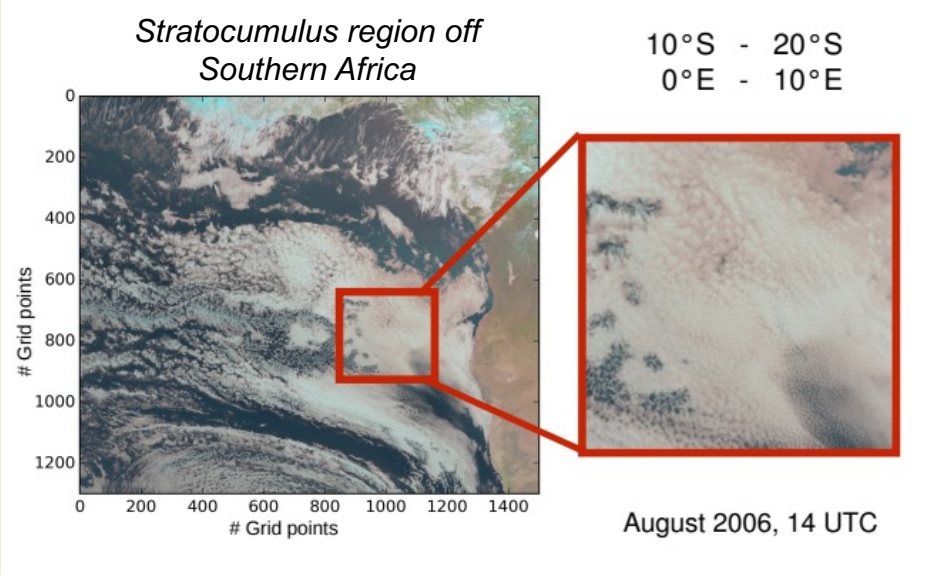
Example of application : Direct radiative effect of above cloud absorbing aerosols

CM SAF Visiting Scientist activities:

- Smoke over Clouds Radiative Effect Assessed with MSG (SCREAM) – Daniel Merk (KNMI)
- Above Cloud Aerosols (ACA) - Christine Aebi.

Scientific questions :

- What is the DRE of the ACA?
- Could this be quantified using NB observations?



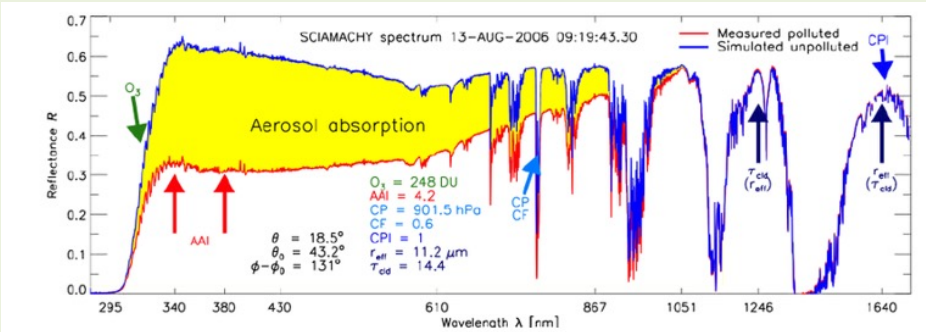


Figure 2: SCIAMACHY reflectance spectrum (red), measured on 13 August 2006, 09:19:43 UTC, and the modelled equivalent unpolluted cloud reflectance spectrum (blue) for this scene. The difference between these two spectra (yellow, labelled 'Aerosol absorption') indicates the irradiance absorbed by the aerosols. At visible wavelengths (0.6 and 0.8 microns) the absorption is significant. At SWIR wavelengths (e.g. 1.2 and 1.6 microns), the cloud retrieval is less affected by absorption due to aerosols.

The GERB-4 dataset

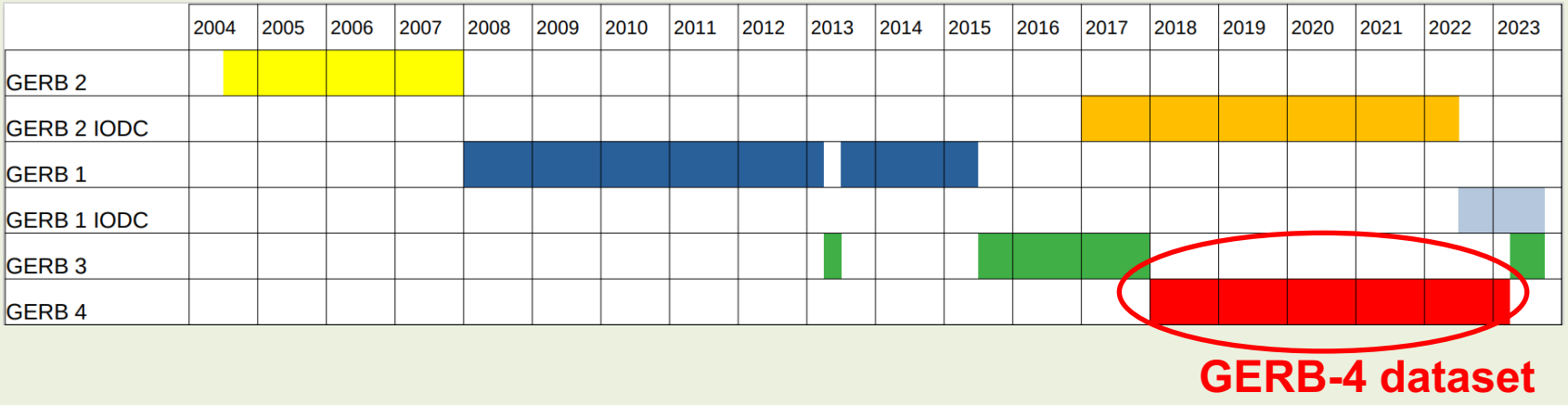
Satellite MSG4 / Meteosat-11

- launched on July 15th 2015
- In-orbit storage until 2018
- Operational at 0° from Feb. 20th 2018 until Feb. 2023.

Regarding GERB, a series of problems had to be fixed, including:

- Incorrect normalization of unfiltering coefficients
- North / South mirror pointing
- Quartz filter vignetting anomaly

Launch of MSG4 from Kourou (15th July 2015)



GERB-4 Level 2 data availability – latest version (V011) – daily summary

2018	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Jan.																															
Feb.																			x	x	x	x	x	x	x	x	x	x			
Mar.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Apr.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x							
May																															
June																															
July																															
Aug.																						x	x	x	x	x	x	x	x	x	x
Sep.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Oct.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					
Nov.																															
Dec.																															

2019	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Jan.																															
Feb.																			x	x	x	x	x	x	x	x	x	x			
Mar.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Apr.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x							
May																															
June																															
July																															
Aug.																						x	x	x	x	x	x	x	x	x	x
Sep.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Oct.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
Nov.																															
Dec.																															

2020	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Jan.																															
Feb.																	x	x	x	x	x	x	x	x	x	x	x	x			
Mar.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Apr.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					
May																															
June																															
July																															
Aug.																			x	x	x	x	x	x	x	x	x	x	x	x	x
Sep.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Oct.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					
Nov.																															
Dec.																															

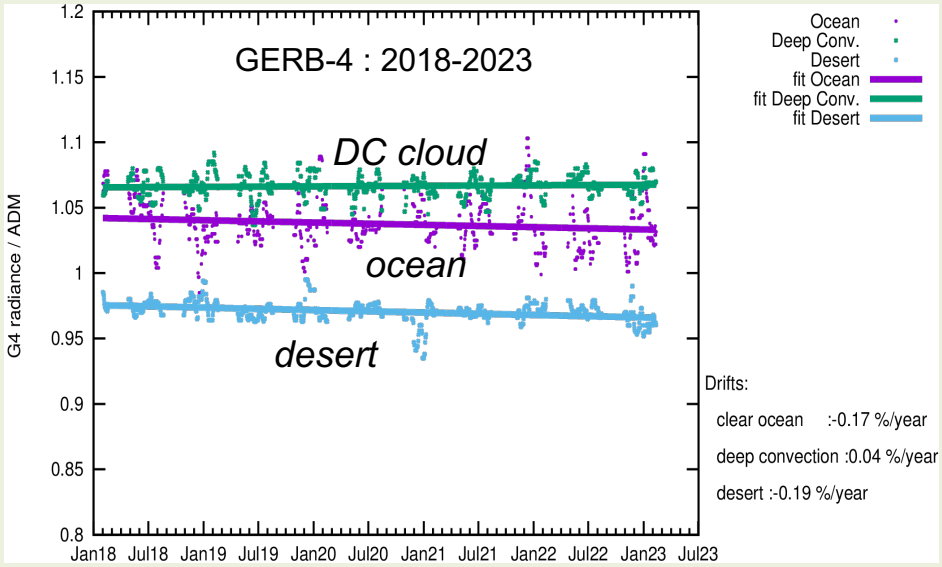
2021	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Jan.																															
Feb.														x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			
Mar.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Apr.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x							
May																															
June																															
July																															
Aug.																															
Sep.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Oct.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					
Nov.																															
Dec.																															

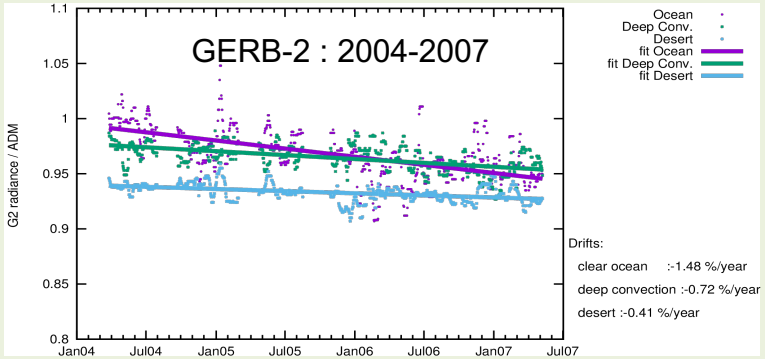
2022	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Jan.																															
Feb.																			x	x	x	x	x	x	x	x	x	x			
Mar.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Apr.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x							
May																															
June																															
July																															
Aug.																															
Sep.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Oct.	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x					
Nov.																															
Dec.																															

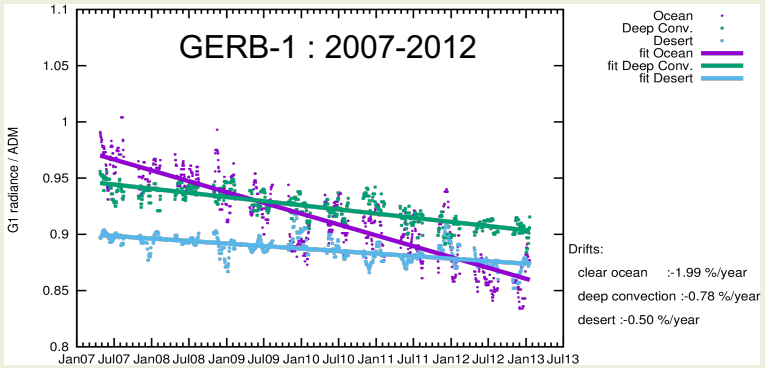
2023	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Jan.																															
Feb.													x	x	x	x	x	x	x	x											

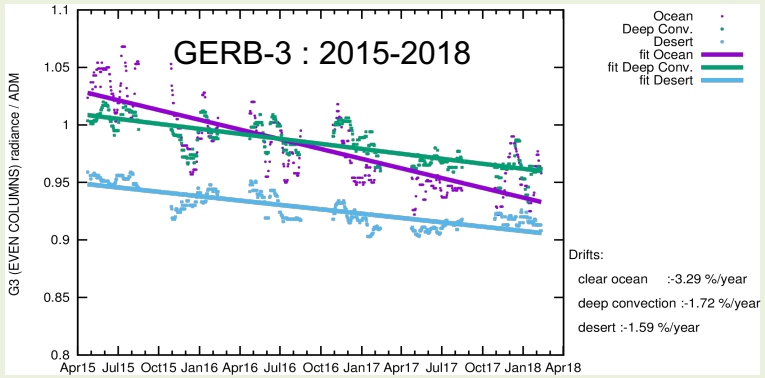
Legend:	
	GERB data most of the day
x	GERB-like data most of the day (GERB 02-07 UTC)
	GERB-like data most of the day
	No data or data gap longer than 4h.

GERB-4 Level 1.5 evaluation – SW radiance stability wrt CERES TRMM radiance models









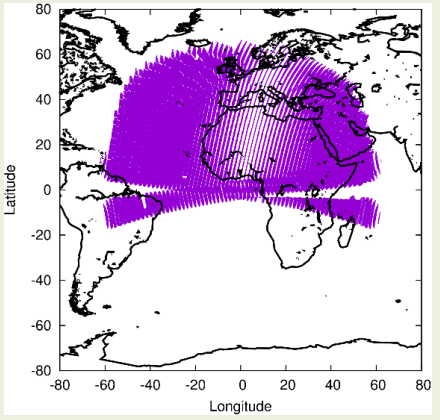
- For deep convective clouds, clear desert, and clear ocean.
- GERB-4 SW radiances are stable over the record (see ↑)
- Not consistent with the previous GERB instruments (see →)

GERB-4 Level 2 evaluation – Exploiting CERES *GERB Campaigns* data (June 2018 to 2022) – CERES TERRA FM2 SSF Edition 4A

Campaign	SW radiance	SW flux	LW radiance day	LW flux day	LW radiance night	LW flux night
June 2018	1.0934	1.1111	0.9733	0.9785	0.9816	0.9883
June 2019	1.0957	1.1134	0.9744	0.9793	0.9827	0.9884
June 2020	1.0971	1.1129	0.9742	0.9804	0.9824	0.9924
June 2021	1.0931	1.1069	0.9740	0.9801	0.9815	0.9920
June 2022	1.0912	1.1067	0.9773	0.9834	0.9840	0.9913
Average +/- std.dev.	1.0941 +/- 0.0021	1.1102 +/-0.0029	0.9746 +/-0.0014	0.9803 +/-0.0017	0.9824 +/-0.0009	0.9905 +/-0.0018

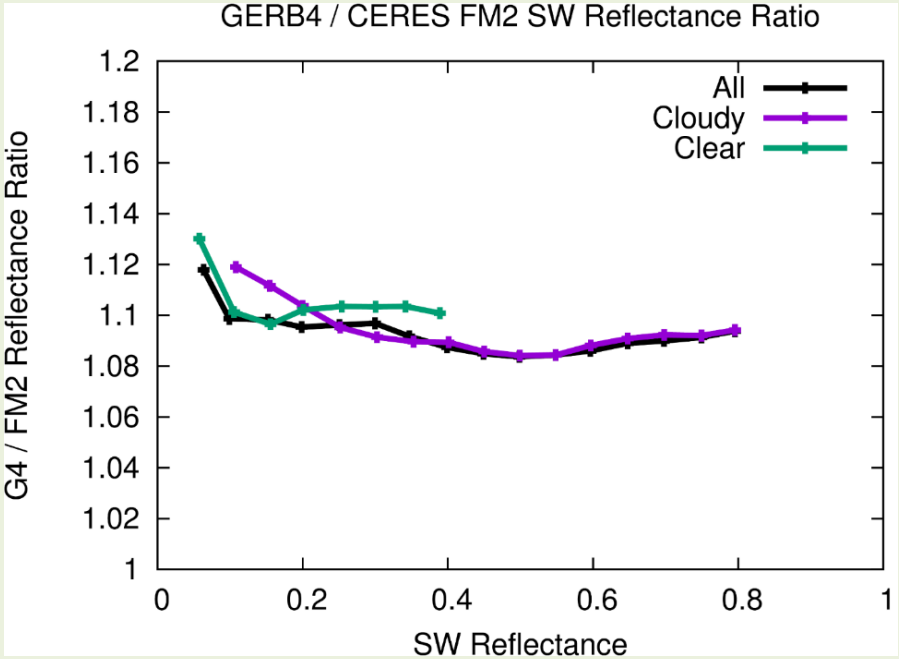
- Lot of coangular obs. mostly in the Northern hemisphere (→)
- GERB-4 SW and LW are stable wrt FM2
- LW ratio similar as for previous GERBs
- SW radiances about 9%-10% brighter than FM2

June 2020 matches

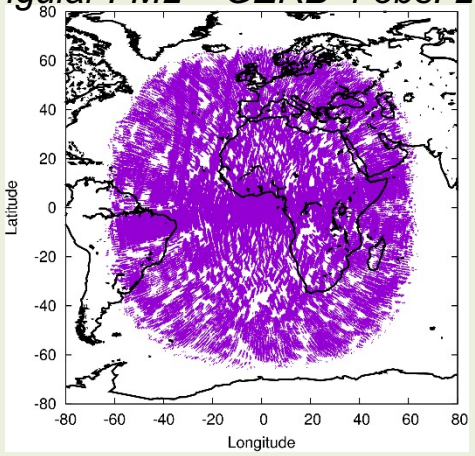


GERB-4 Level 2.0 evaluation – Exploiting FM2 in RAPS mode since Nov. 2021.

- CERES FM2 mostly in RAPS from Nov. 2021 onward (and FM3 from April 2023)
- Coangular obs. cover the full FOV
- Limited variation in SW ratio as a function of scene type / reflectance → Confidence in the SW spectral response

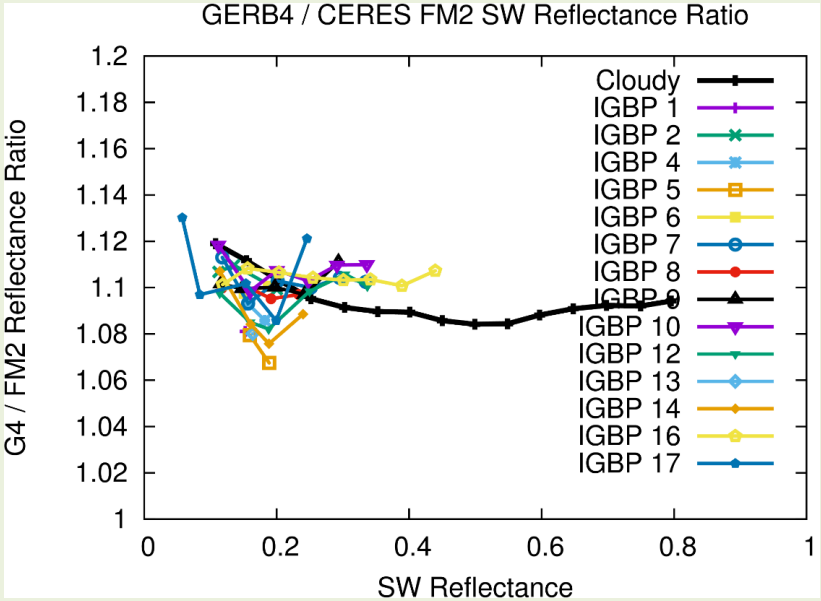


Coangular FM2 – GERB-4 obs. 2022



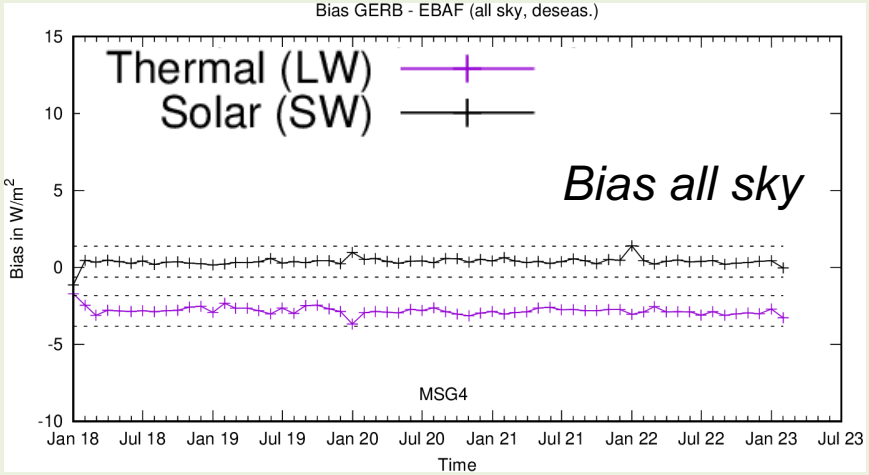
GERB-4 level 2 evaluation – SW radiance ratio according to IGBP surface type (clear sky)

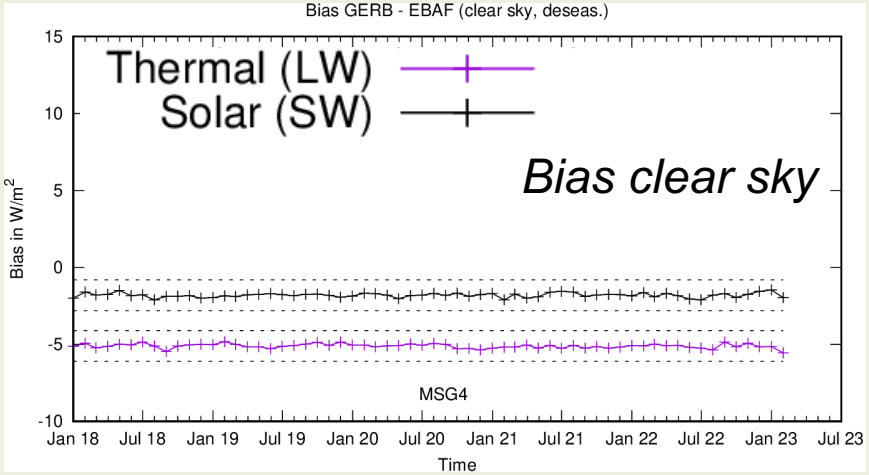
IGBP class		Aver. Reflect.	G4/FM2 SW ratio	N matches
1	Evergreen needleleaf	0.1569	1.0768	53
2	Evergreen broadleaf	0.1195	1.1061	647
3	Deciduous needleleaf	-	-	-
4	Deciduous broadleaf	0.1606	1.0916	248
5	Mixed forest	0.1661	1.0757	119
6	Closed shrublands	0.1592	1.0972	238
7	Open shrublands	0.2473	1.1017	7565
8	Woody savannas	0.1485	1.0996	1689
9	Savannas	0.1612	1.0997	1724
10	Grasslands	0.2218	1.1044	1542
11	Permanent wetlands	0.1630	1.0412	14
12	Croplands	0.1669	1.0853	2319
13	Urban and nuilt-up	0.1688	1.0821	29
14	Cropland	0.1685	1.0828	1223
15	Snow and ice	-	-	-
16	Barren / Sparsely vegetated	0.2870	1.1037	69959
17	Water bodies	0.0600	1.1263	11428

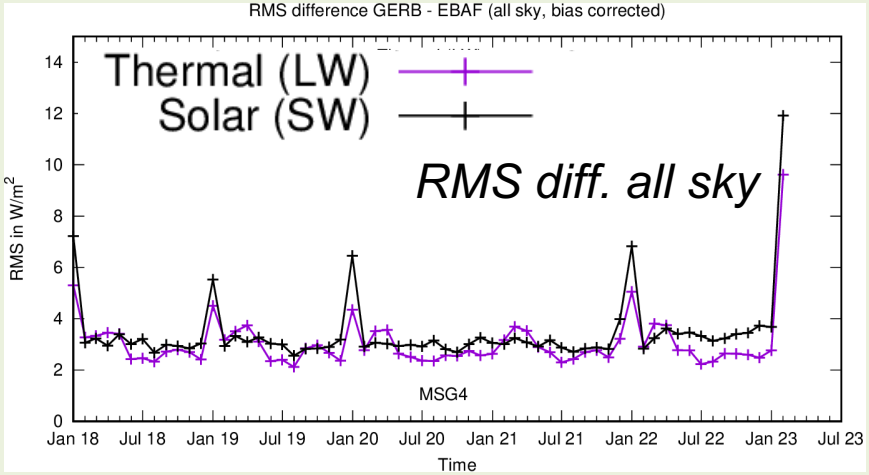


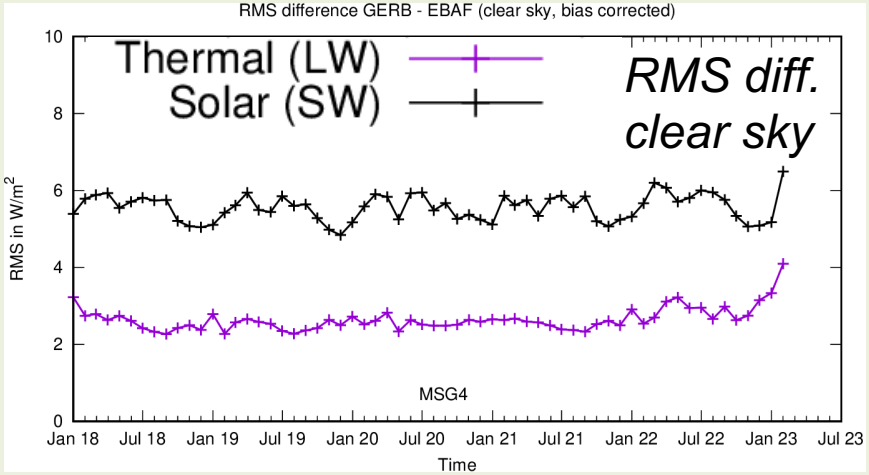
- Limited variation of the GERB/CERES ratio.

GERB-4 level 3 evaluation – Monthly mean comparison with CERES EBAF 4.2 – bias & RMS







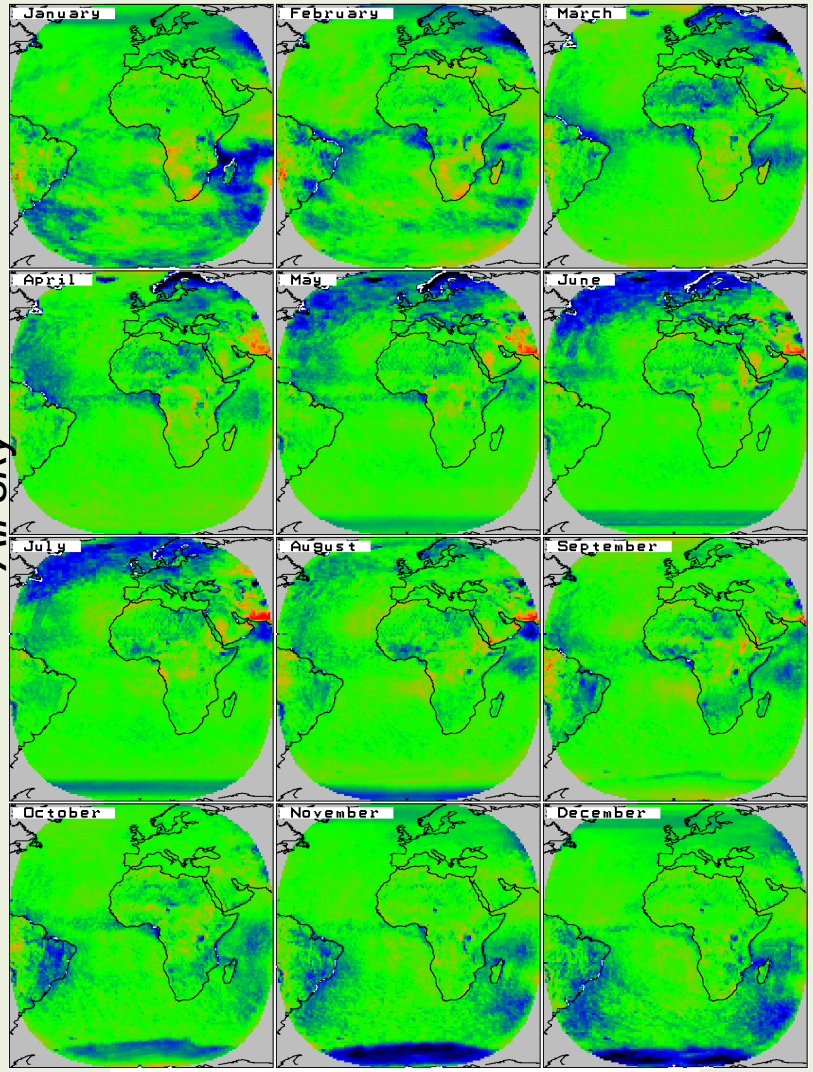


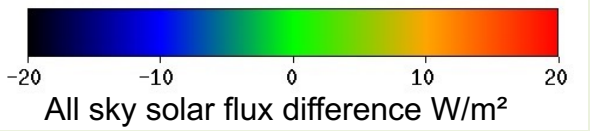
Notes :

- Level 3 using CM SAF recipe (gap filling using SEVIRI)
- Level adjustment : Solar *= 0.91 Thermal *= 1.01

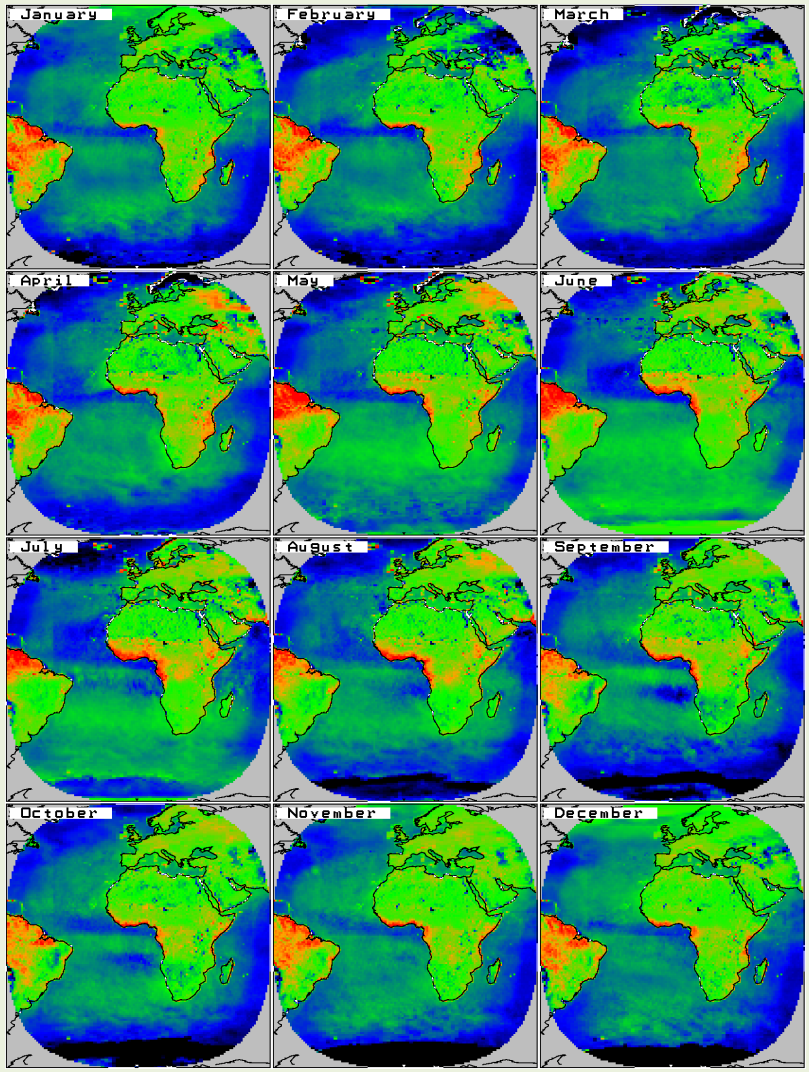
GERB-4 level 3 Evaluation – Monthly Mean comparison with CERES EBAF 4.2 – Calendar month difference – SW flux

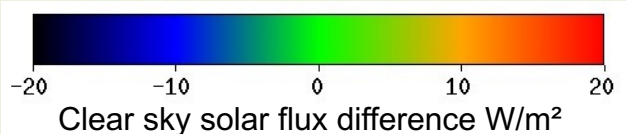
All sky



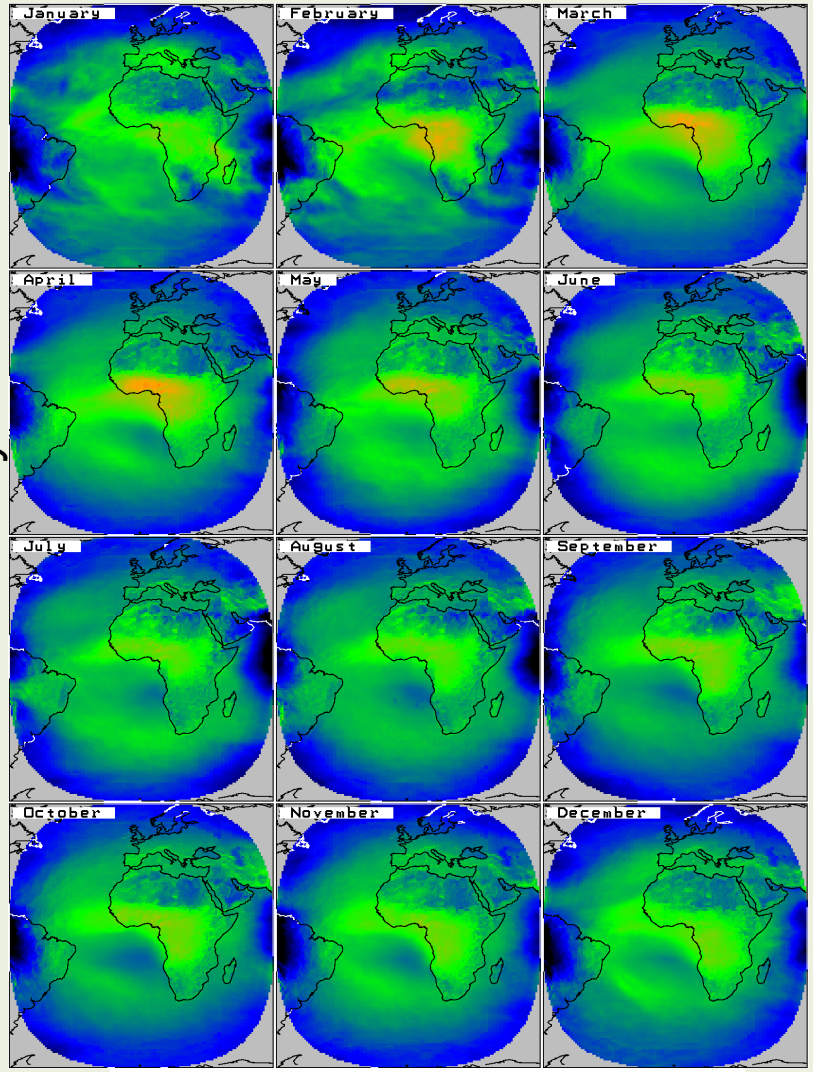


Clear sky

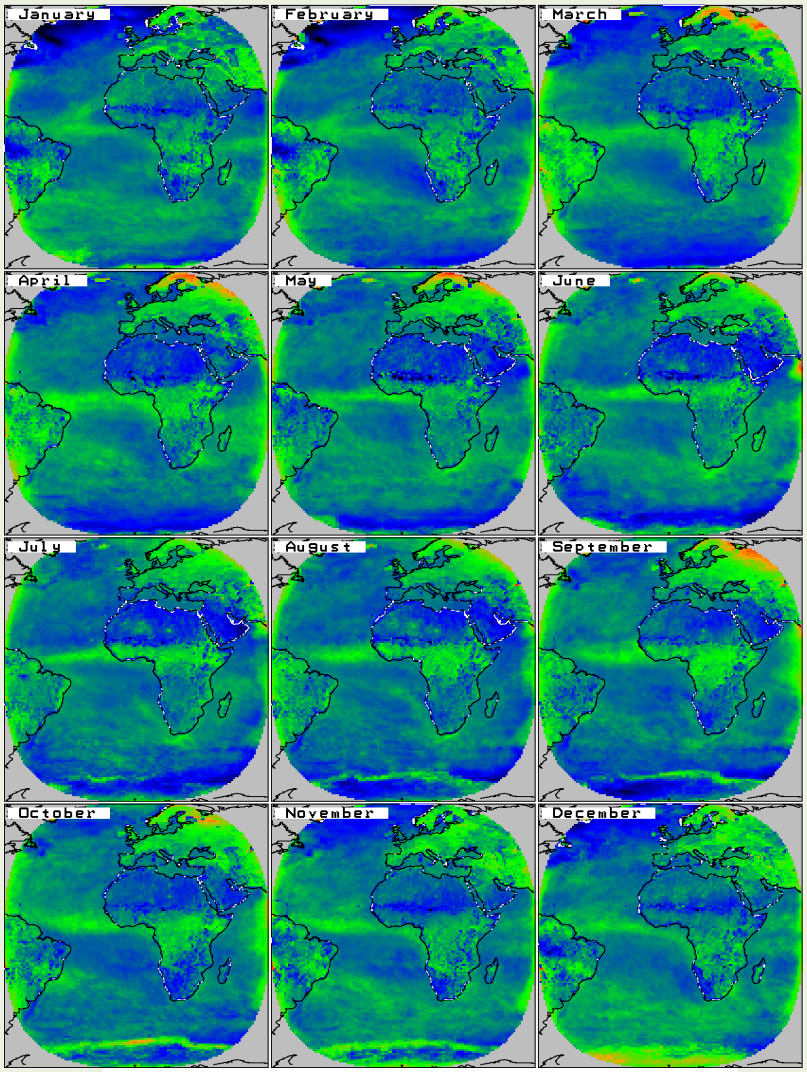




GERB-4 level3 evaluation – Monthly Mean comparison with CERES EBAF 4.2 – Calendar month difference – LW flux

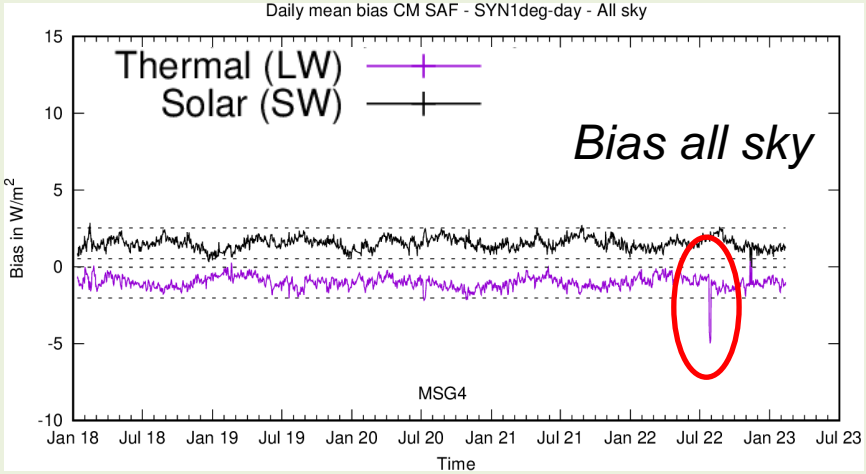


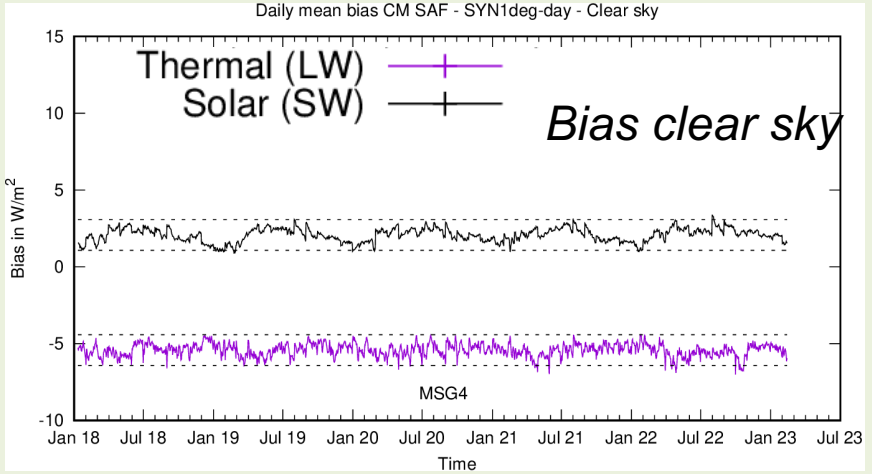
All sky

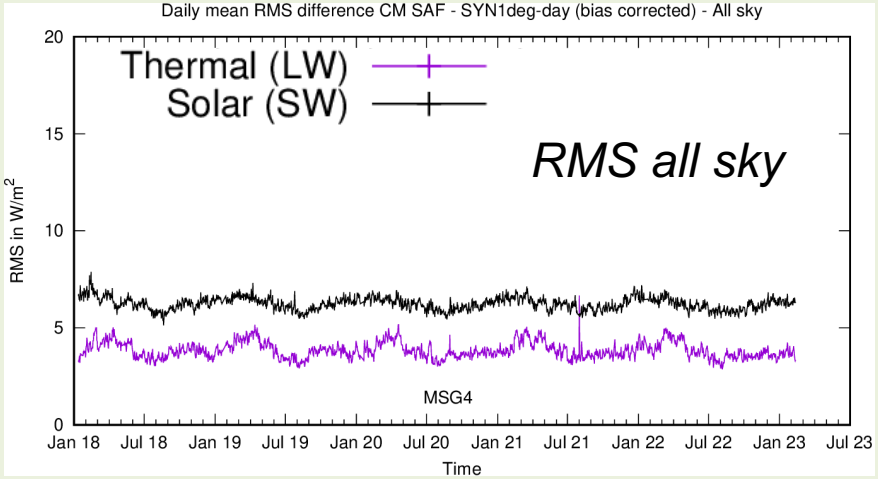


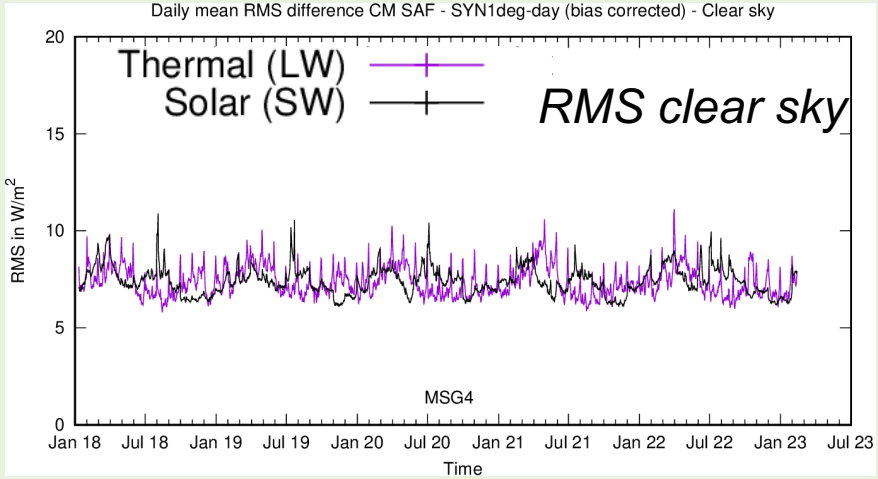
Clear sky

GERB-4 level 3 evaluation – Daily Mean versus SYN1deg-day Ed 4.1 (Terra+Aqua)









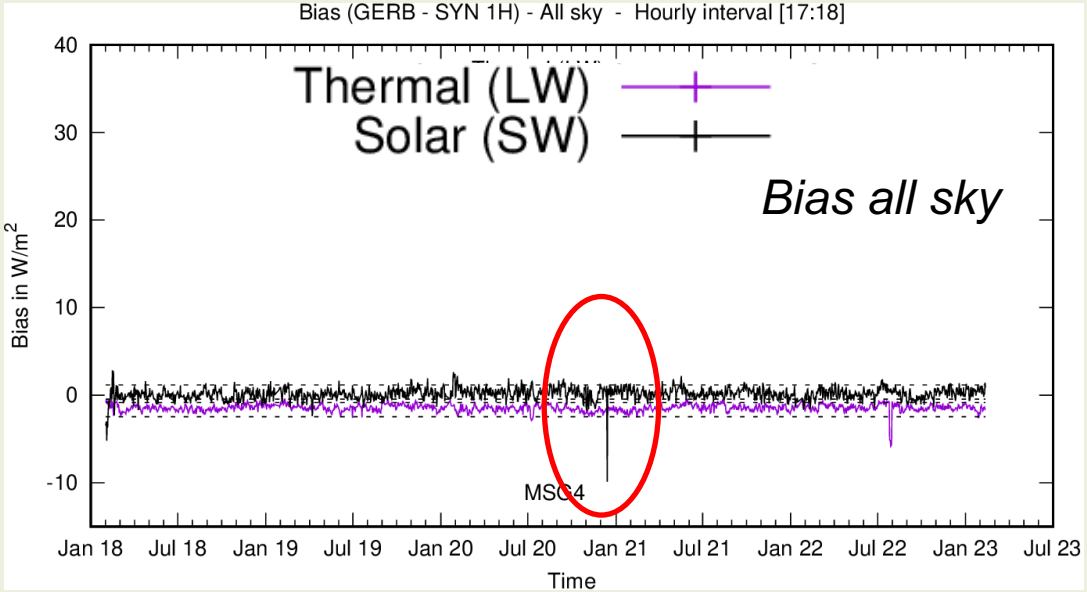
- GERB-4 thermal flux biased 27-31/07/2022 (investigations ongoing)
- More RMS difference in clear sky fluxes at very beginning and very end of each month

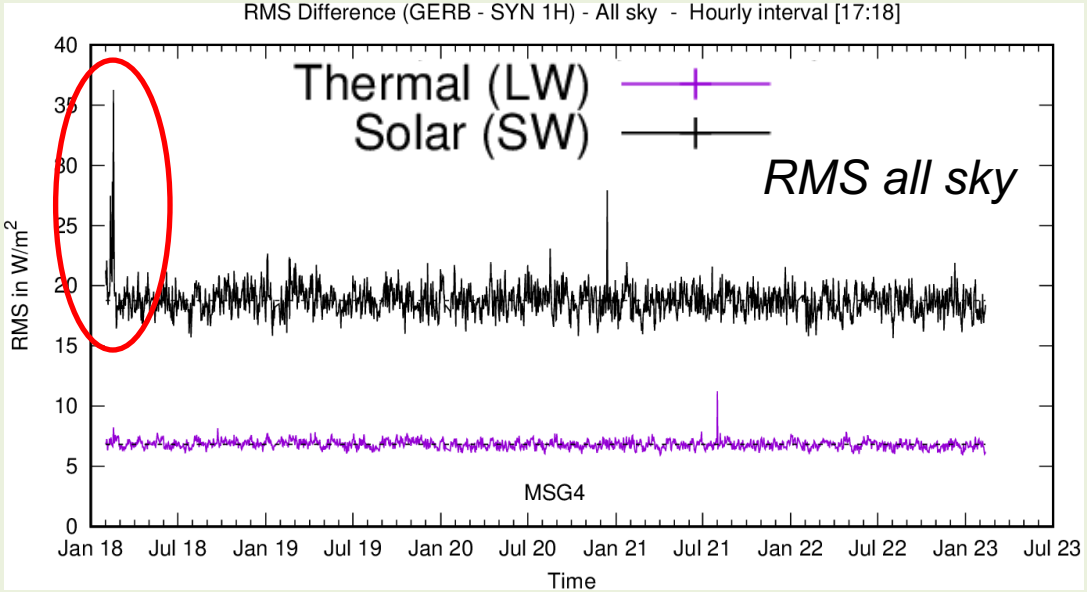
GERB-4 Level 2 evaluation – Hourly mean versus SYN 1deg-hour Ed 4.1

- First time a GERB record is fully compared with CERES SYN 1H data.
- Visual inspection of the GERB products in case of 'spikes'

Example for [17:18] UTC (→)

- Solar eclipse on Dec. 14th 2020 over South America
- More difference before 20th Feb. 2018.

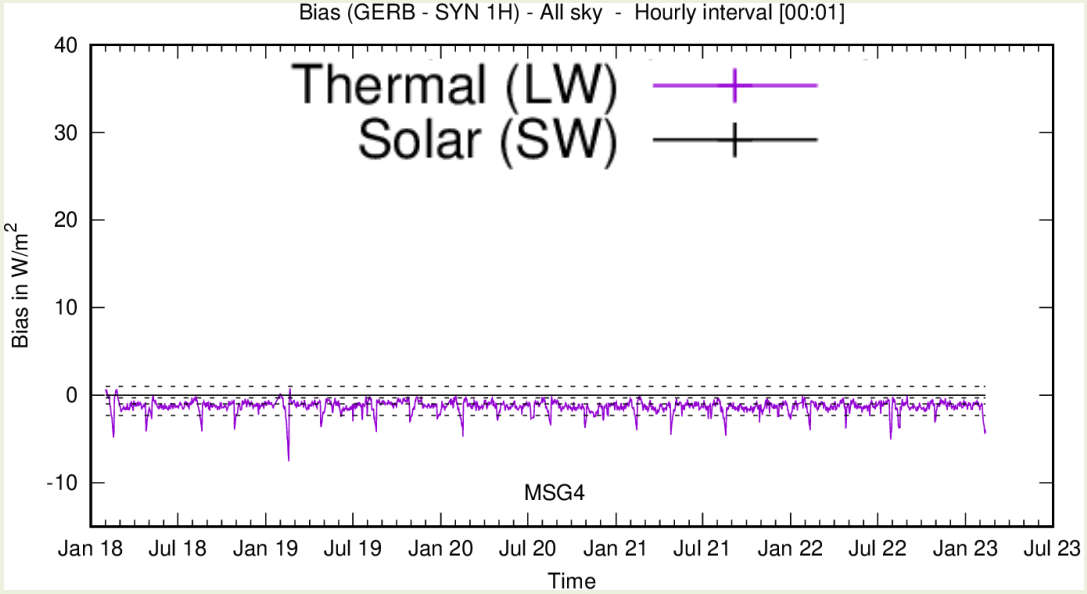


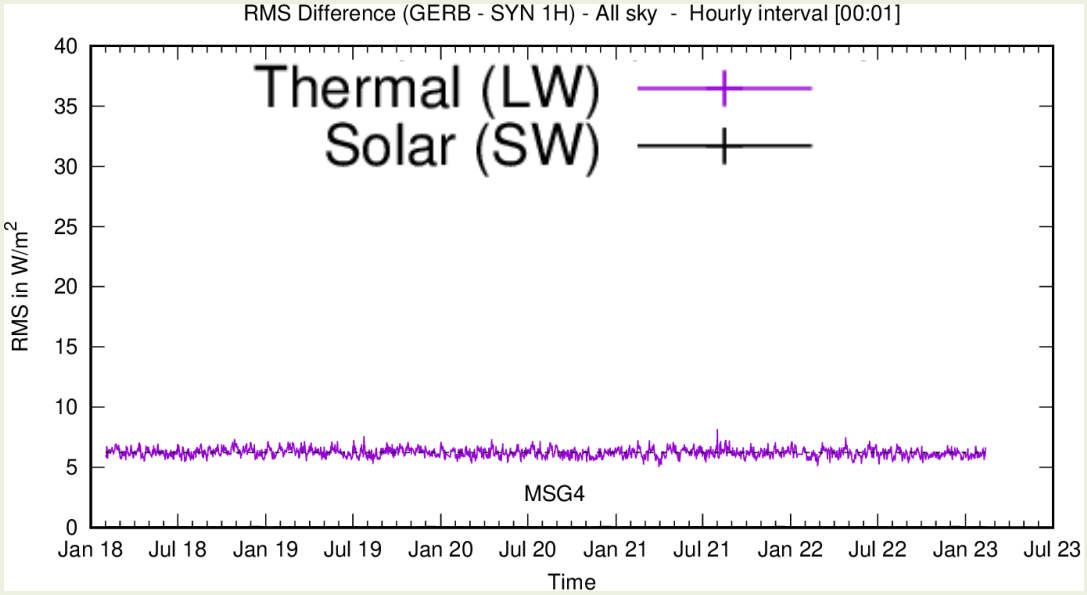


GERB-4 Dataset Evaluation – Hourly Mean versus SYN1deg-hour Ed 4.1

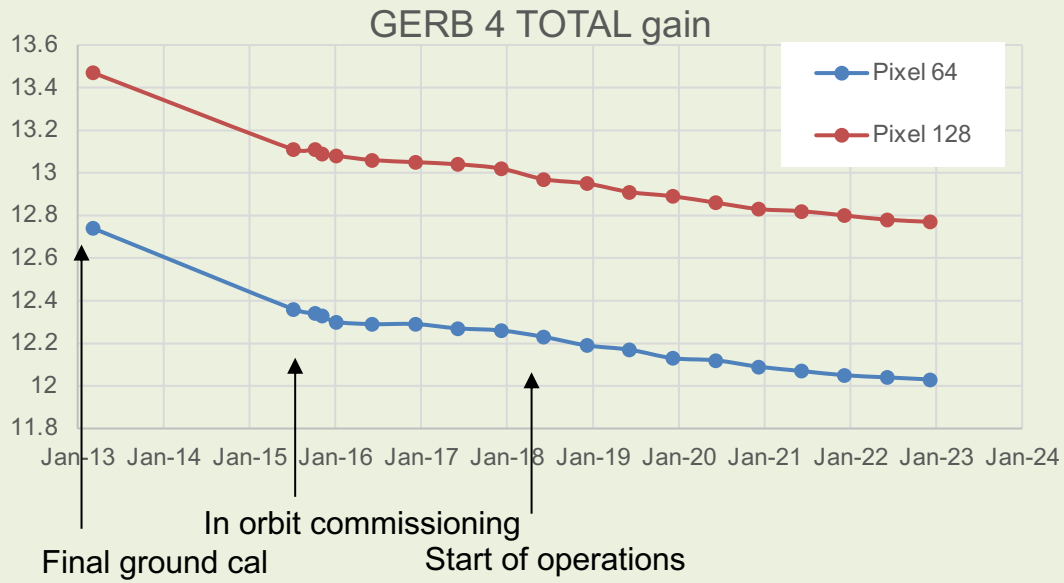
Another example for [00:01] UTC

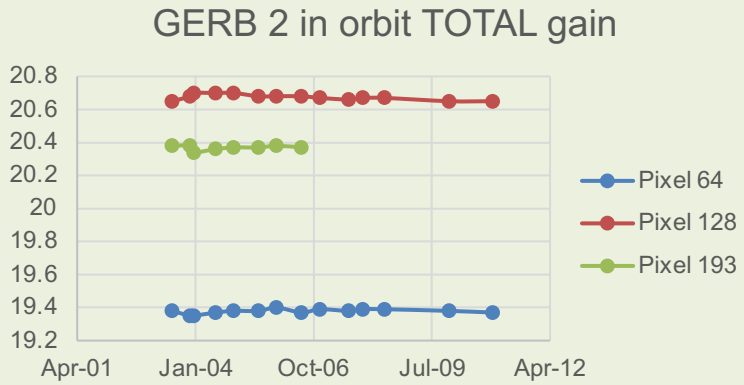
- Some variation of the thermal flux bias just before and after the eclipse seasons
- Probably “Stray-light” contamination

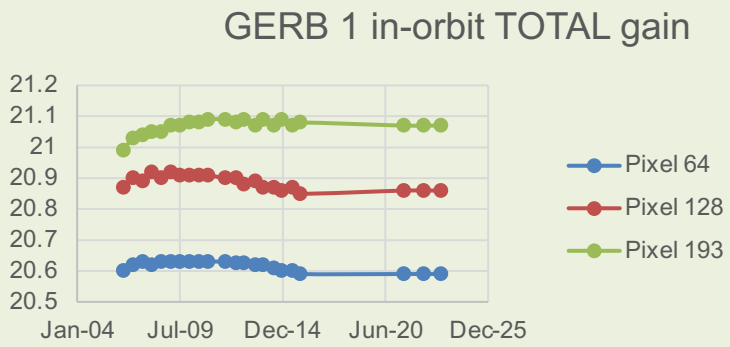


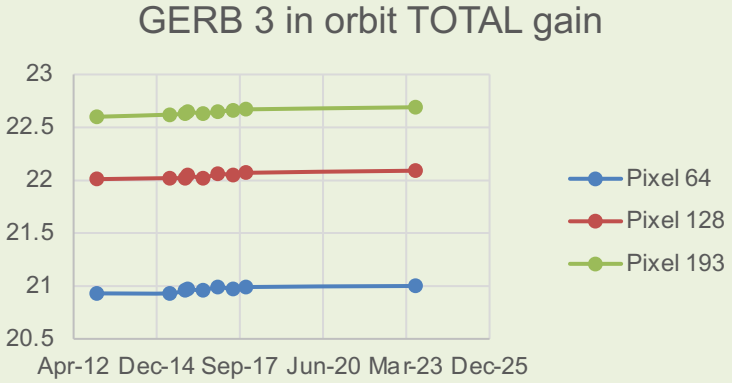


GERB-4 SW Channel Calibration Issue









GERBs 1-3 showed no trends and small changes in calibration of the TOTAL channel gain as measured by the internal black body during in orbit operation. GERB 4 has shown a steady decline during its life. GERB 4 also had a 3.5-4% reduction in TOTAL gain between ground and orbit whereas ground to orbit changes for other instruments were minimal.

We need to be sure these changes are due to electronics rather than LW response change as the latter requiring a change to B.

GERB 4 showed a change in *both* TOTAL and SW gain between ground calibrations in 2009 and 2013 with very little change in B (i.e. gain changes due to ASICs electronic response not spectral degradation. So there is some evidence for and expectation of electronic instability.

GERB 4 TOTAL gain also nearly half that of the other instruments where as the SW gain is similar, and there is indication of a loss of response at the longest (>30μm) wavelengths possibly due to the age of detector for GERB 4. So there is some concern about spectral degradation of the longwave response as well.

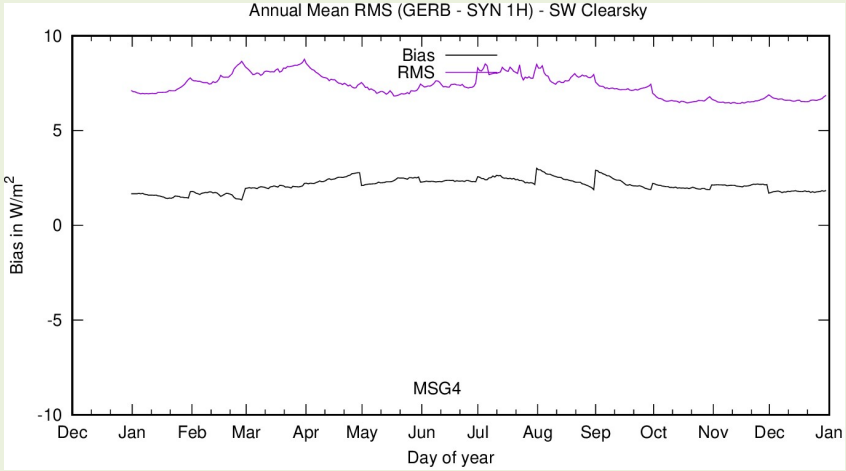
Summary – GERB-4 dataset Status

- GERB-4 dataset overall of good quality and good availability
- The current pre-released version V011 likely to be released as ED01 soon (Q4 2023 or Q1 2024) with user documentation (user guide and Quality Summary).
- Some data still need to be discarded, e.g.: stray-light around midnight, beginning of the record, 27-31 July 2020.
- SW channel too bright -> would need a “user applied” correction (factor of ~ 0.91, final value to be consolidated). This factor seems stable in time.
- More info and access to data via : https://gerb.oma.be

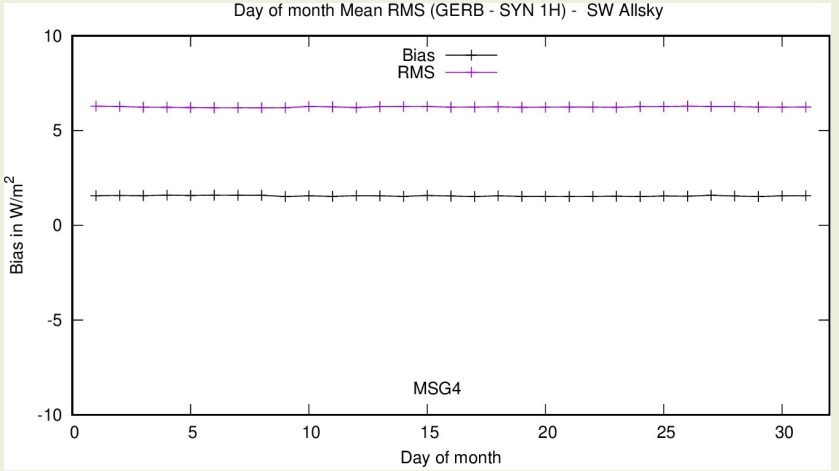
Thank You!

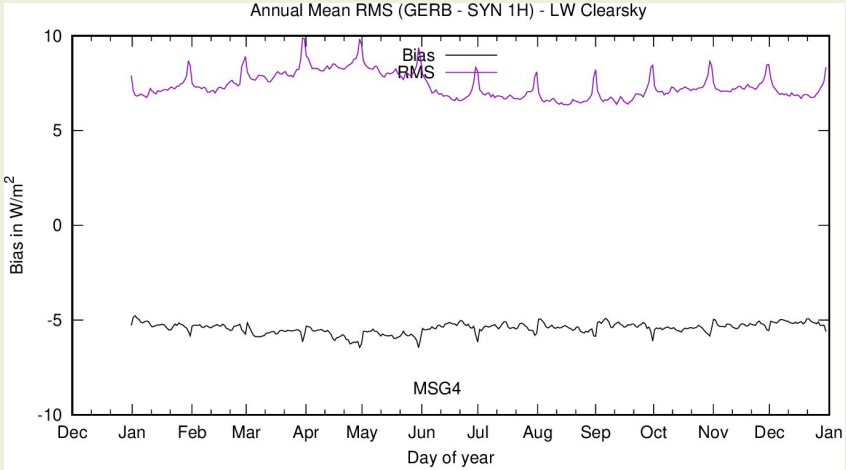
GERB-4 Dataset Evaluation – Daily Mean versus SYN1deg-Day Ed 4.1 (Terra+Aqua)

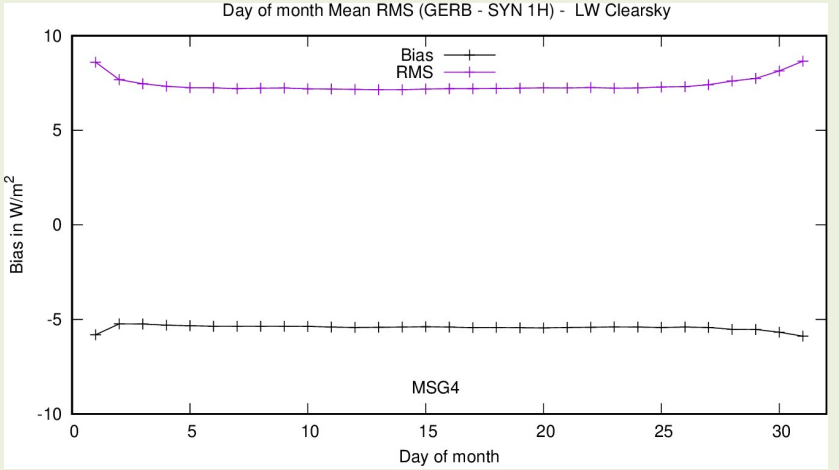
Day of year



Day of month

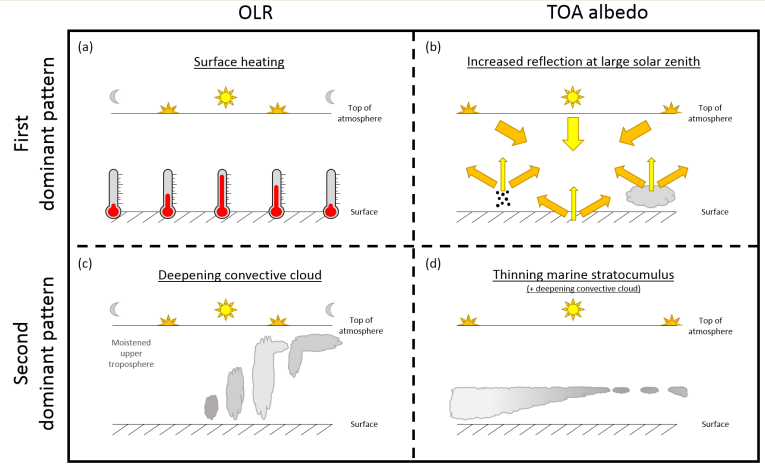


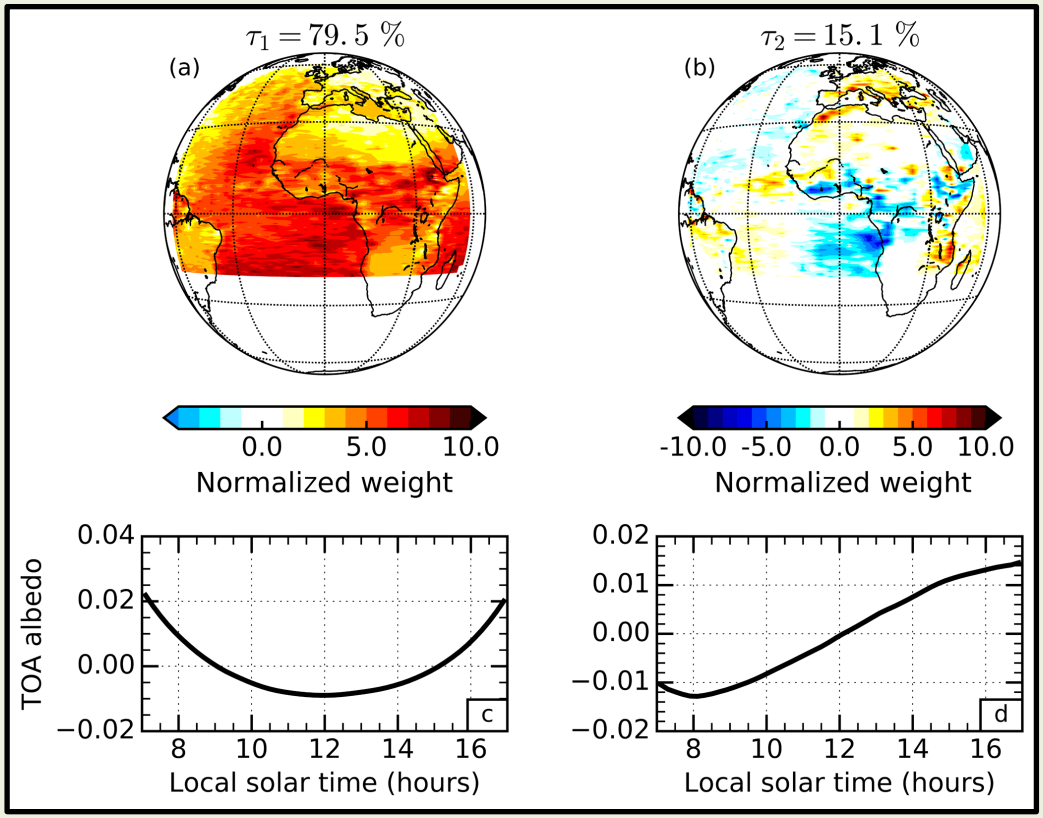




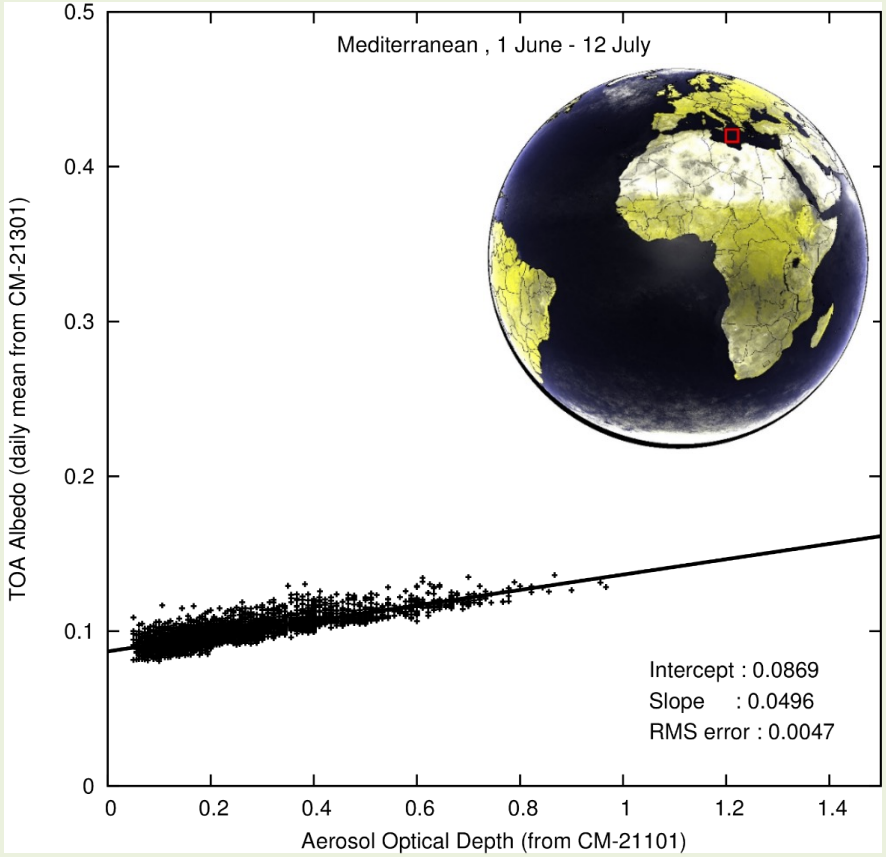
Example of application : principal component analysis of the diurnal cycles of TOA fluxes

Gristey, J. J., Chiu, J. C., Gurney, R. J., Morcrette, C. J., Hill, P. G., Russell, J. E., & Brindley, H. E. (2018). Insights into the diurnal cycle of global Earth outgoing radiation using a numerical weather prediction model. Atmospheric Chemistry and Physics, 18(7), 5129-5145.

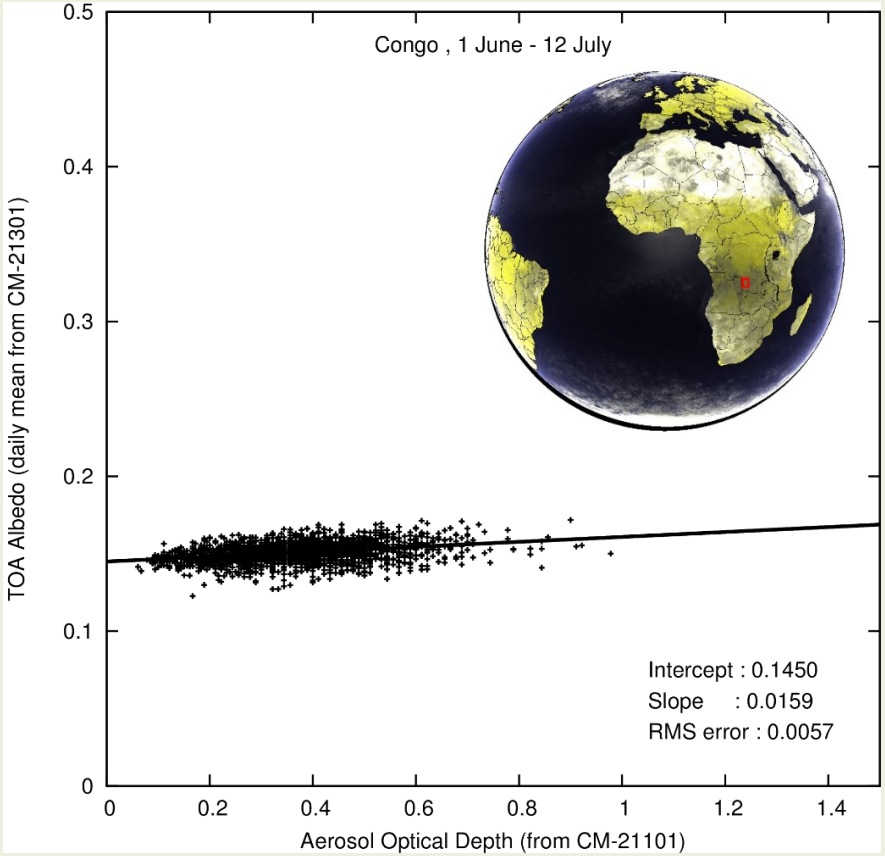




Example of application : combining GERB daily mean TOA albedo with CM SAF AOD dataset



Mediterranean sea (off Libya)



South of RDC (more absorbing aerosols)

GERB-4 Level 2 evaluation – Hourly mean versus SYN 1deg-hour Ed 4.1

- Example for [04:05] UTC
- Beginning of the record -> exclude Jan-Feb 2018