Meteosat MVIRI/SEVIRI TOA radiation data records within the Climate Monitoring SAF

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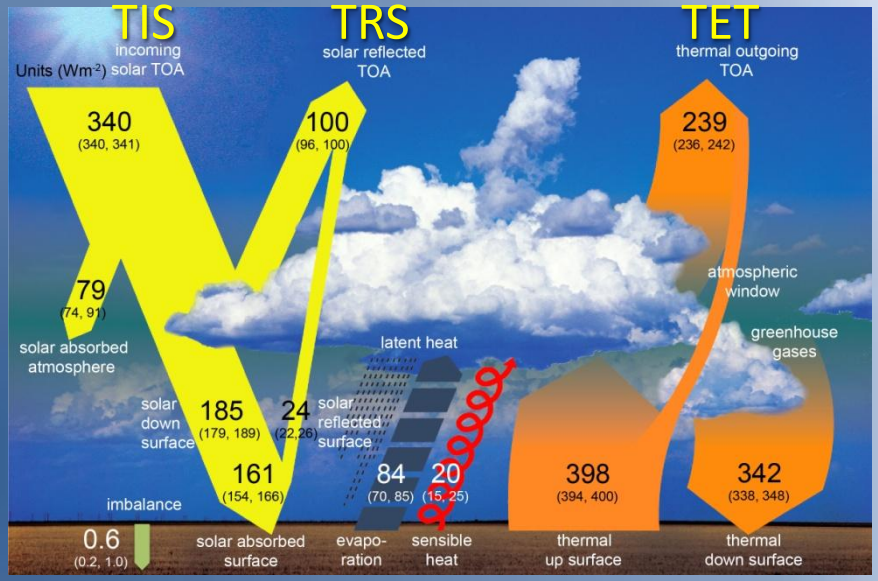
CM SAF Climate Monitoring

Introduction
TOA radiation in CM SAF

- Operational GERB EDR product (since 2004)
- GERB/SEVIRI dataset ed01
- Meteosat (MVIRI/SEVIRI) datasets ed01
- GERB/SEVIRI dataset ed02
- TOA radiation in CLARA-A3 (AVHRR)



Wild et al., 2013

- Generation of a TCDR from Meteosat instruments covering more than 30 years
- An unprecedented temporal (30min/15min) and spatial (2.5km/3km) resolution (compared to other ERB products)
- A better knowledge of the diurnal cycle and the small-scale spatial variations of radiation

CM SAF identifier	Content
CM-23311	TOA Reflected Solar radiative flux All Sky (TRS_AS)
CM-23341	TOA Emitted Thermal radiative flux All Sky (TET_AS)

Main products features

Covered period	**32 years** → from 1 February 1983 to 31 January 2015
Output quantities	TRS and TET fluxes in **all-sky** conditions →TIS provided as ancillary field of the TRS product
Temporal characteristics	Fluxes provided as **Daily Mean (DM)**, **Monthly Mean (MM)** and **Monthly Mean Diurnal Cycle (MMDC, 24 hourly intervals)**
Spatial resolution	Data records provided on a **regular grid** with a spatial resolution of (**0.05°**)², i.e., about (5.5 km)² at sub-satellite point
Format	**NetCDF** file format following the CF convention

User requirements

Stability requirements for CM-23311 and CM-23341

Products	Threshold	Target	Optimal
TRS all sky MM	4 W/m²/dec	0.6 W/m²/dec	0.3 W/m²/dec
TET all sky MM	4 W/m²/dec	0.6 W/m²/dec	0.3 W/m²/dec

- Maximum acceptable change (max-min) of the systematic error over a period of 10 years
- Primarily caused by switches of instruments and instrumental drift
- Only defined for the MM products but also representative of the DM and MMDC products
- Should be met over most of the scene types

Accuracy requirements for CM-23311 and CM-23341

Products		Threshold	Target	Optimal	CM-113 and CM-115 accuracy
TRS CM-23311	**MM**	8 W/m²	4 W/m²	2 W/m²	3.0 W/m²
	DM	16W/m²	8 W/m²	4 W/m²	5.5 W/m²
	MMDC	16W/m²	8 W/m²	4 W/m²	12.8W/m²
TET CM-23341	**MM**	4 W/m²	2 W/m²	1 W/m²	2.0 W/m²
	DM	8 W/m²	4 W/m²	2 W/m²	3.6 W/m²
	MMDC	8 W/m²	4 W/m²	2 W/m²	3.1 W/m²

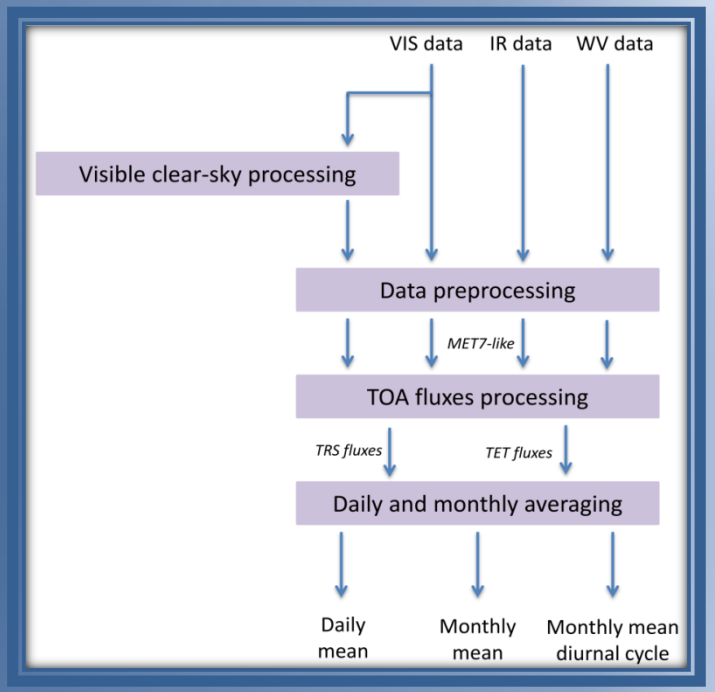
Requirements referring to error:

- at 1 standard deviation (RMS error)
- at 1° x 1° scale
- taking only VZA<60°
- does not include error (bias) due to the absolute calibration

Processing overview

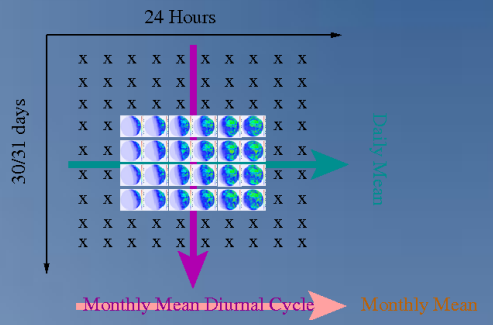
- **Visible clear-sky processing**:
  - Generates the clear-sky VIS data
  - Cloud effect filtered by image processing techniques (based on a series of 61 days of input VIS images)

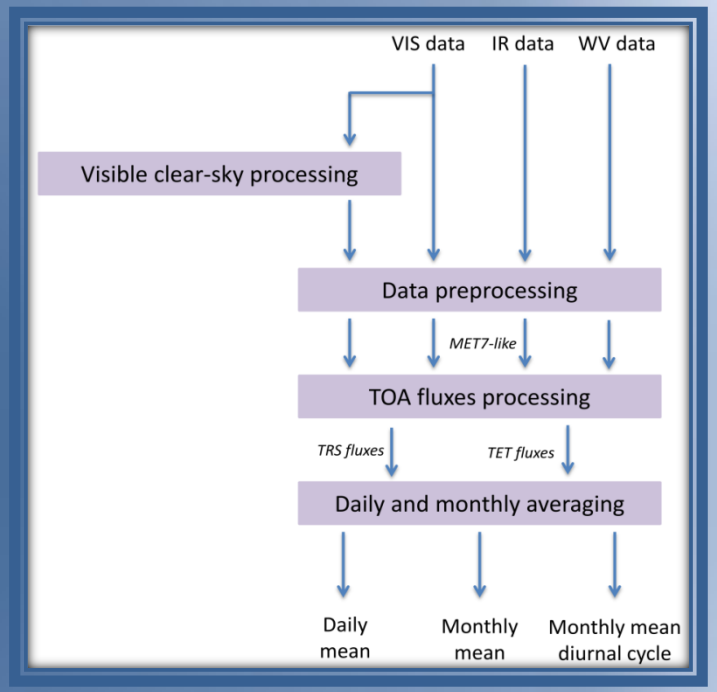
- **Data preprocessing:**
  - Calibration & ageing correction
  - Stripes' interpolation
  - Conversion to "MET7-like" using theoretical regressions from NB channels



Instrument	TRS	TET
MVIRI	SEVIRI Solar Channel Calibration (Govaerts et al., 2004)	MFG-2 and -3 : operational calibration MFG-4 to -7 : GSICS/EUMETSAT recalibration using HIRS (R. Stöckli and A. Tetzlaff, pers. comm.)
SEVIRI	Meirink et al. (2013)	Operational calibration

- **TOA fluxes processing:**
  - Scene identification (daytime only; Ipe, 2011 & Ipe et al., 2010, 2004)
  - Empirical NB to BB regressions (GERB used "off-line")
  - Instantaneous fluxes computation:
    - TRS: using CERES TRMM angular dependency models (Loeb et al., 2003)
    - TET: using theoretical models (Clerbaux et al., 2003)
- **Daily and monthly averaging:**
  - Averaging of the instantaneous fluxes in hourly boxes from which the **DM**, **MM** and **MMDC** are estimated





- Maximum **3 hours** of successive missing data in the daily averaging (otherwise DM not issued)
- Minimum **15 days** required in the monthly averaging (MM and MMDC)
- Seasonal change in insolation taken into account in the monthly averaging
- Regridding onto a regular grid at 0.05° x 0.05°

Validation methodology

No "Ground Truth" observations for the TOA fluxes

- intercomparison with other satellite-based data (polar satellites observations are preferred)

Source	Version	Variable	Temporal resolution	Spatial resolution	Period
CERES EBAF	2.8	TRS TET	MM	1° x 1°	March 2000 onward
CERES SYN1deg-Day	3A	TRS TET	DM	1° x 1°	March 2000 onward
CERES SYN1deg-M3Hour	3A	TRS TET	MMDC in 3-hourly intervals	1° x 1°	March 2000 onward
HIRS OLR CDR - Monthly	2.7	TET	MM	2.5° x 2.5°	1979 onward
HIRS OLR CDR - Daily	1.2	TET	DM	1° x 1°	Jan. 1979 to Dec. 2013
Univ. Reading ERBS WFOV-CERES (DEEP-C)	2	TRS TET	MM	0.7° x 0.7°	Jan. 1985 to May 2015
ISCCP FD	-	TRS TET	MM	2.5° x 2.5°	July 1983 to Dec. 2004

Three sources of error:

- Temporal stability of the data records
  - Evaluated by computing time series of overall bias between CM SAF and reference products
- Accuracy (processing error)
  - Quantified by computing the RMS against CERES
  - CERES considered as the best reference, especially for the MM and MMDC products
  - cover the area 50°S-50°N and 50°W – 50°E (approx. VZA<60°).
- Effect of missing input data (not shown here)
  - Due to missing instantaneous fluxes for the DM (interpolation) and missing days in the MM and MMDC

Validation results
Stability
Monthly mean products

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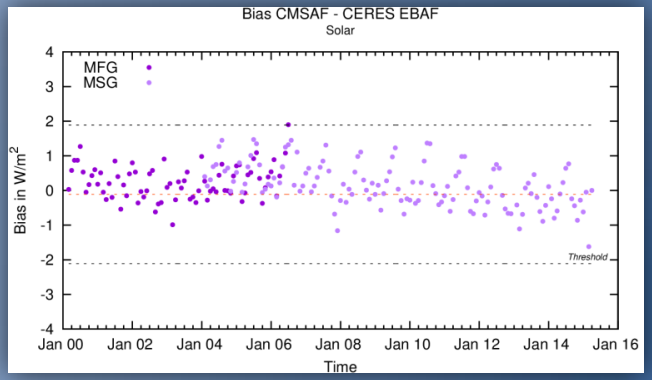
RMI

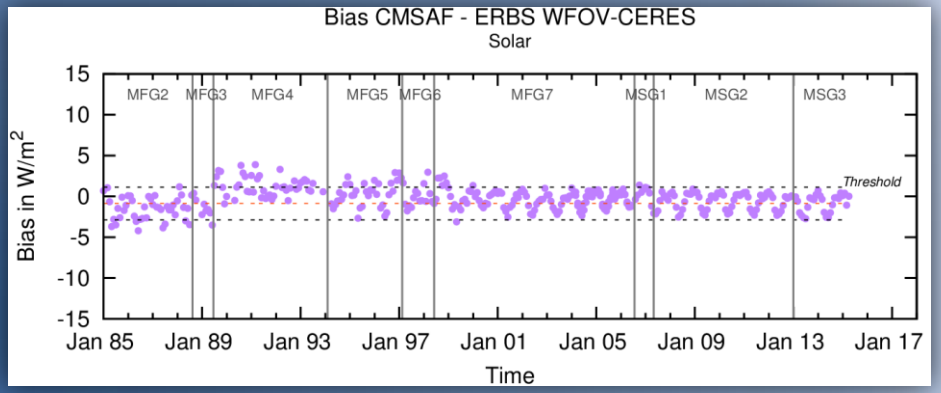
MVIRI/SEVIRI TOA radiation data records

RMIB

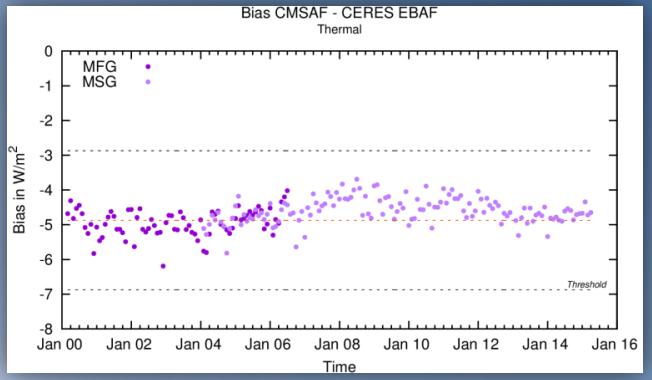
Wrt CERES EBAF — TRS



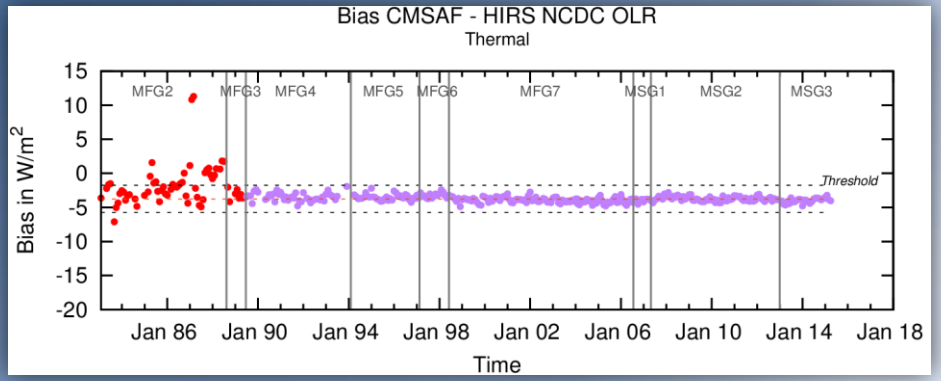
Wrt ERBS WFOV-CERES — TRS



Wrt CERES EBAF — TET



Wrt HIRS NCDC OLR – Monthly — TET



RMI

MVIRI/SEVIRI TOA radiation data records

RMIB

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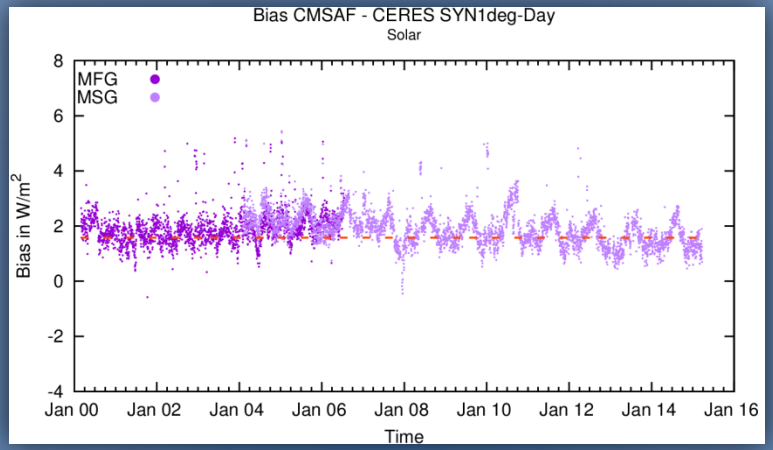
Stability
Daily mean products

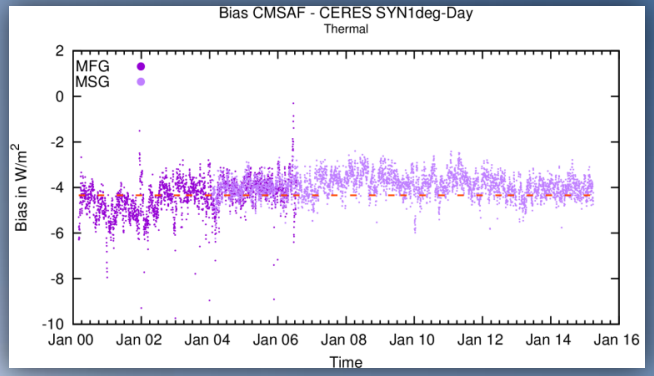
TRS

Wrt CERES SYN1deg-Day

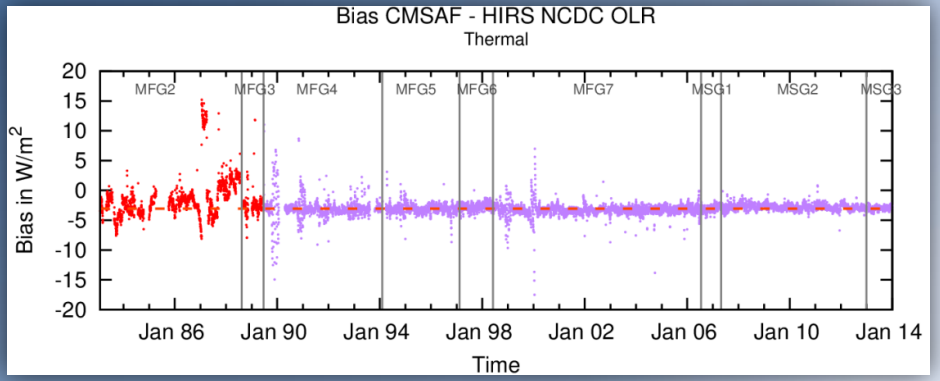


TET

Wrt CERES SYN1deg-Day



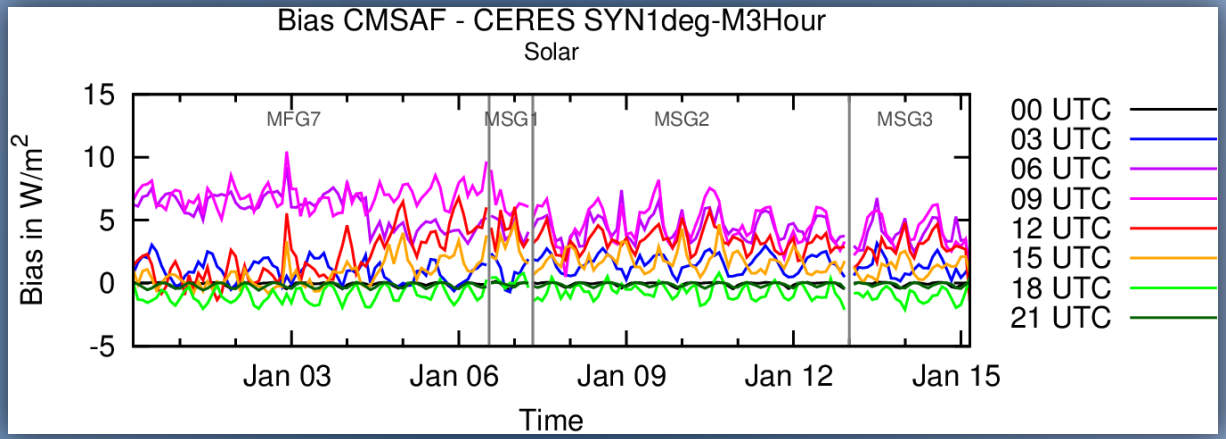
Wrt HIRS NCDC OLR – Daily



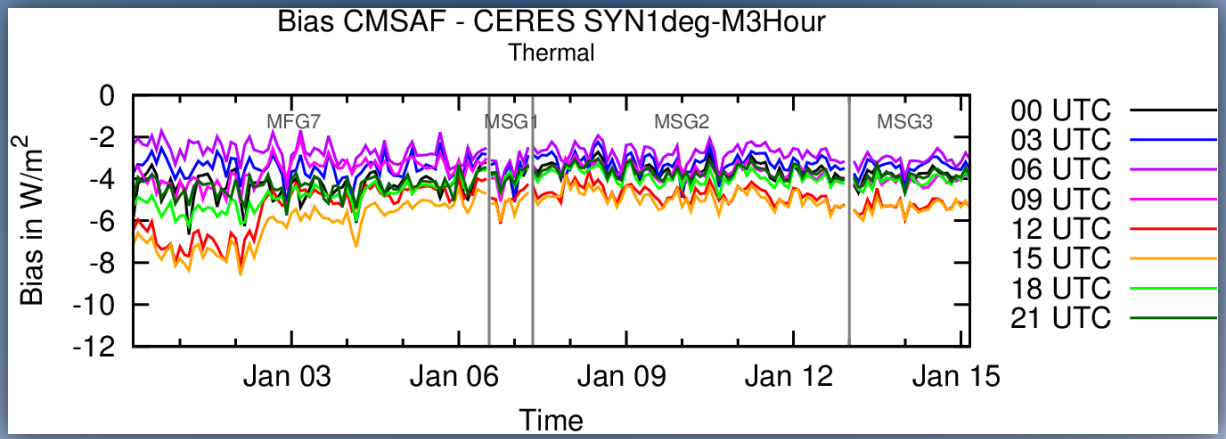
Stability
Monthly mean diurnal cycle products

Wrt CERES SYN1deg-M3Hour

TRS



TET

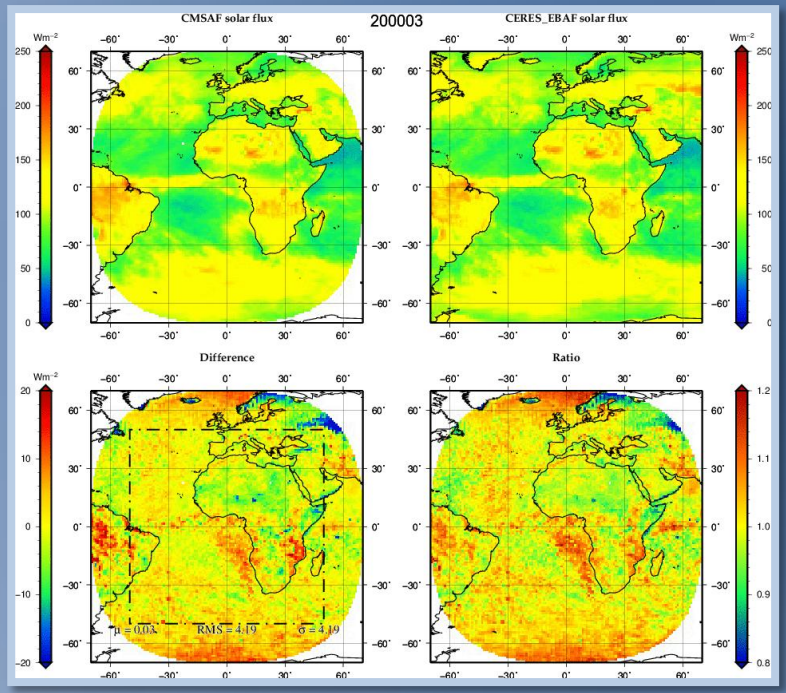


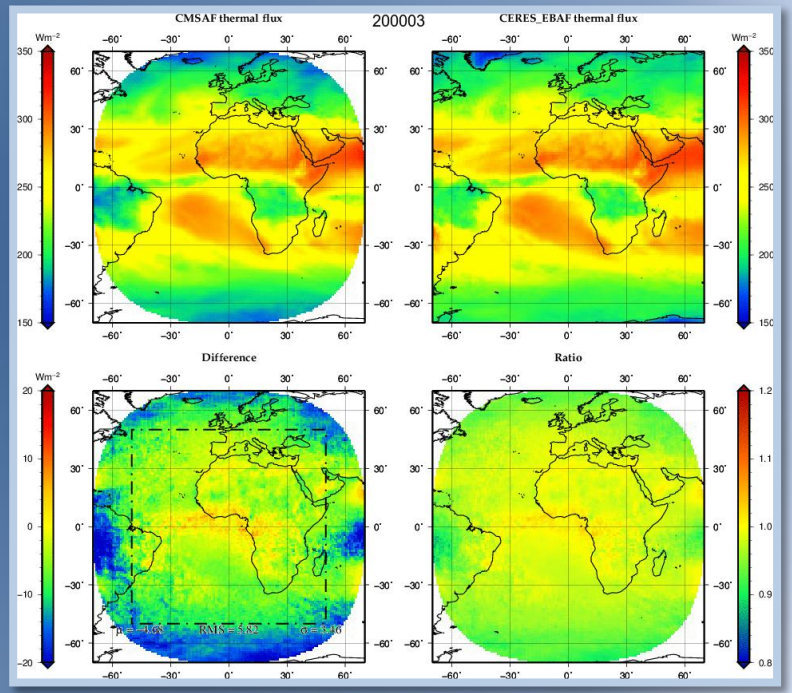
Regional comparison
Monthly mean products

MVIRI/SEVIRI TOA radiation data records

RMIB

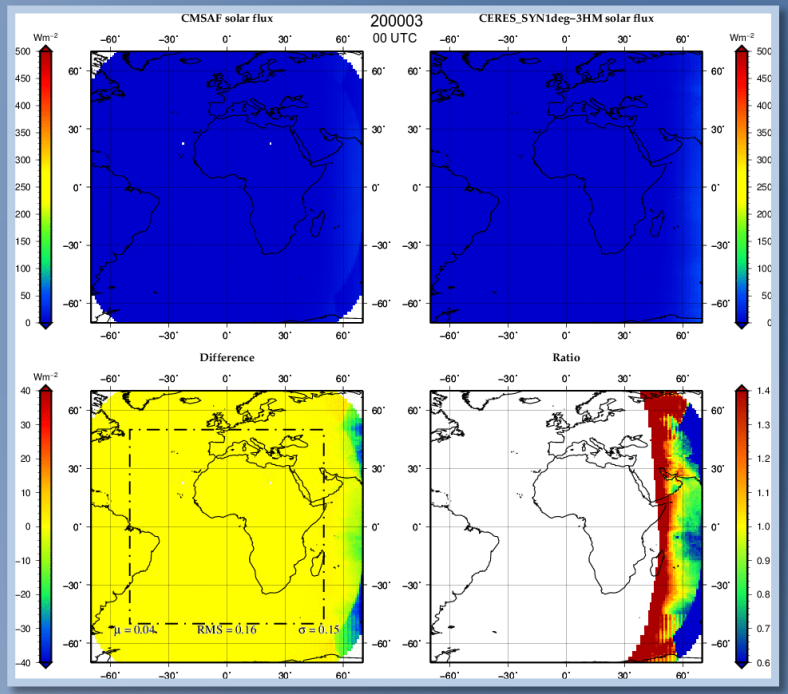
TRS Wrt CERES EBAF **TET**

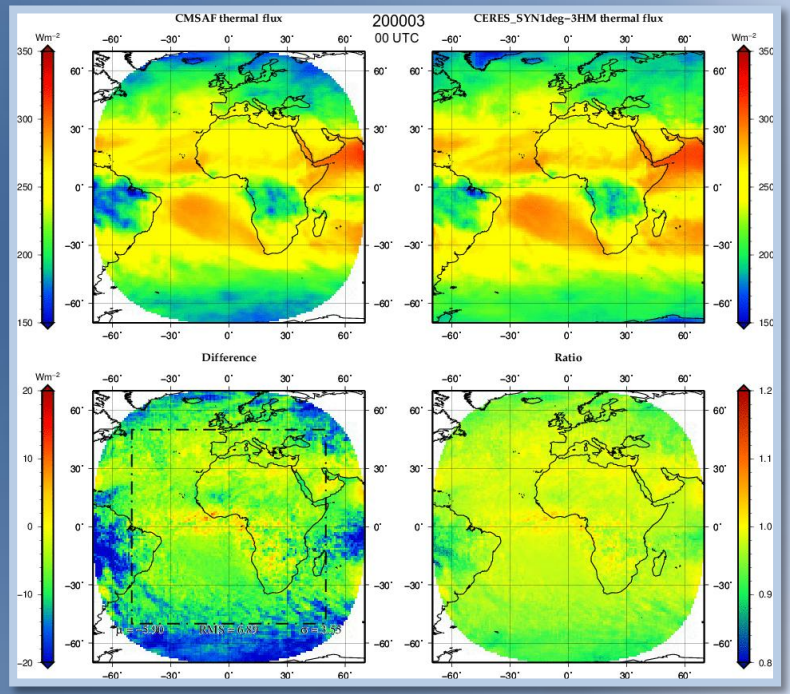




Regional comparison
Monthly mean diurnal cycle products

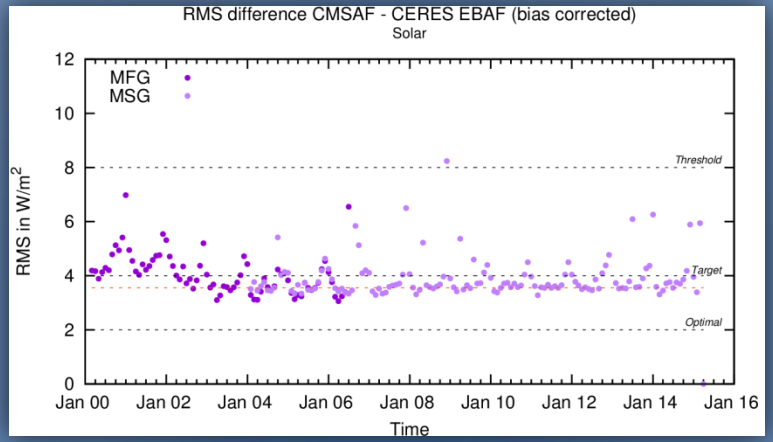
TRS Wrt CERES SYN1deg-M3Hour **TET**



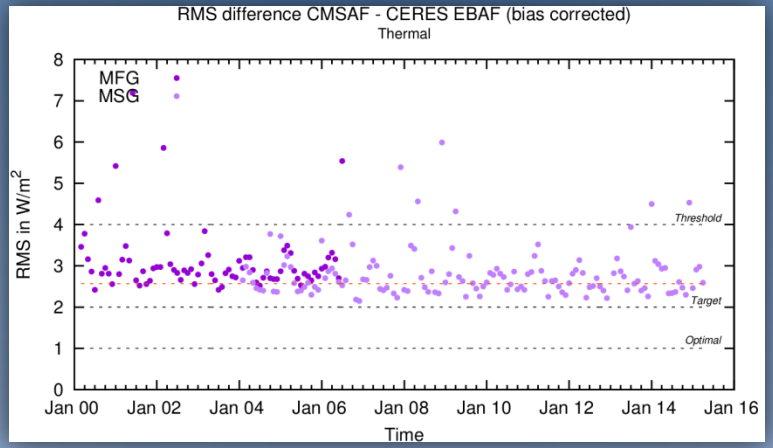


Accuracy
Monthly mean products

TRS Wrt CERES EBAF

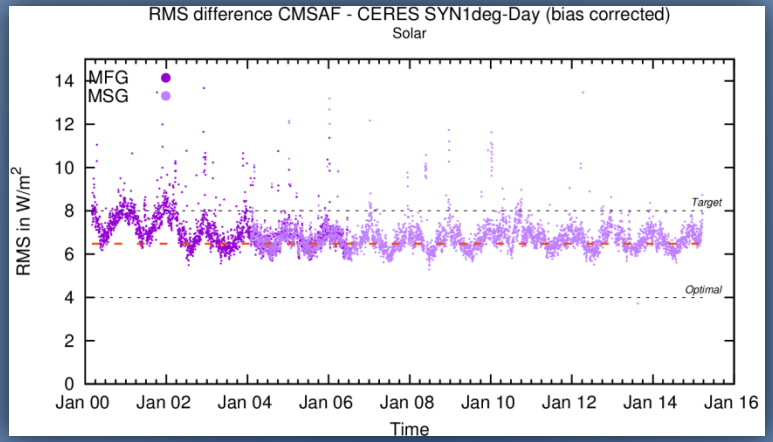


TET Wrt CERES EBAF

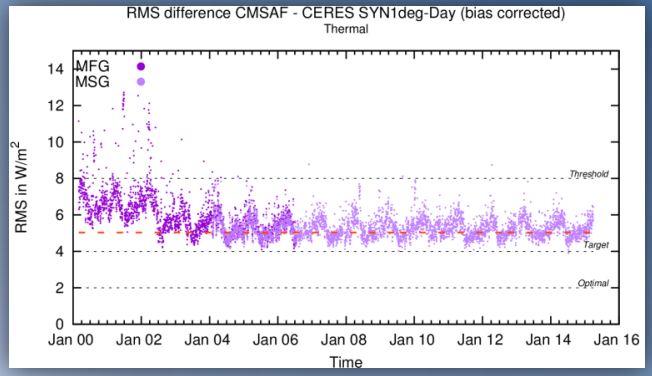


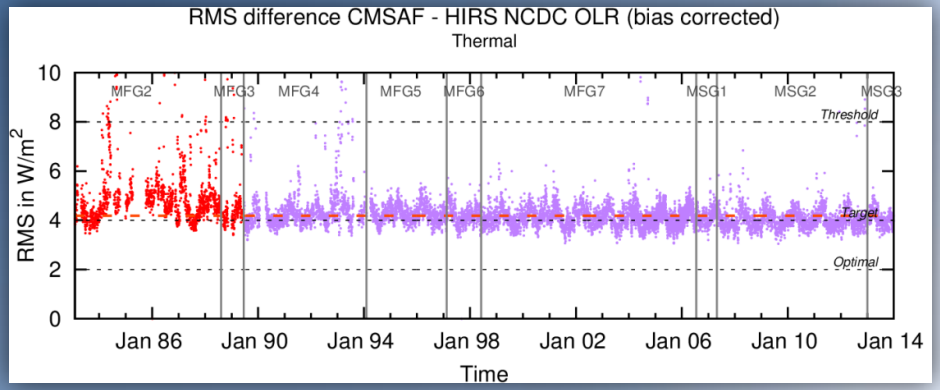
Accuracy
Daily mean products

TRS Wrt CERES SYN1deg-Day



Wrt CERES SYN1deg-Day **TET** Wrt HIRS NCDC OLR – Daily

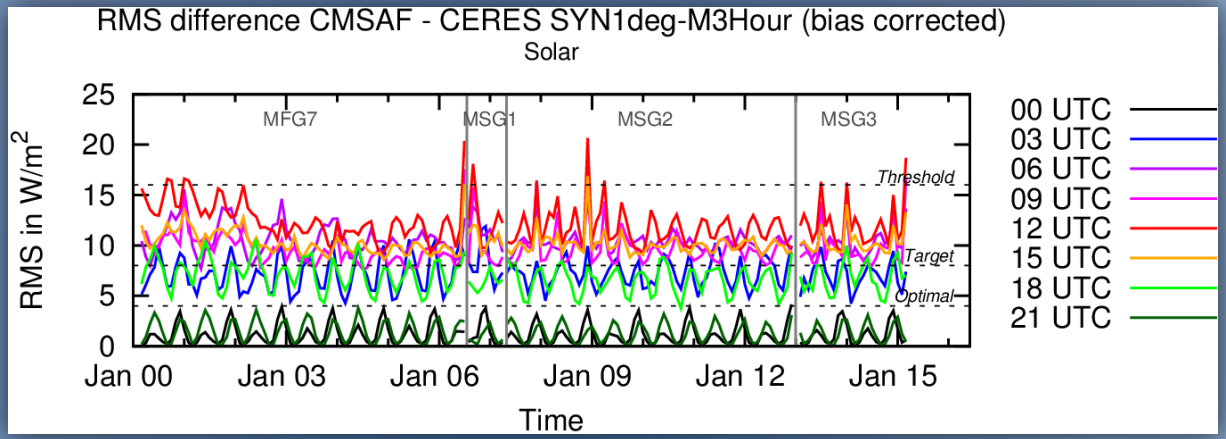




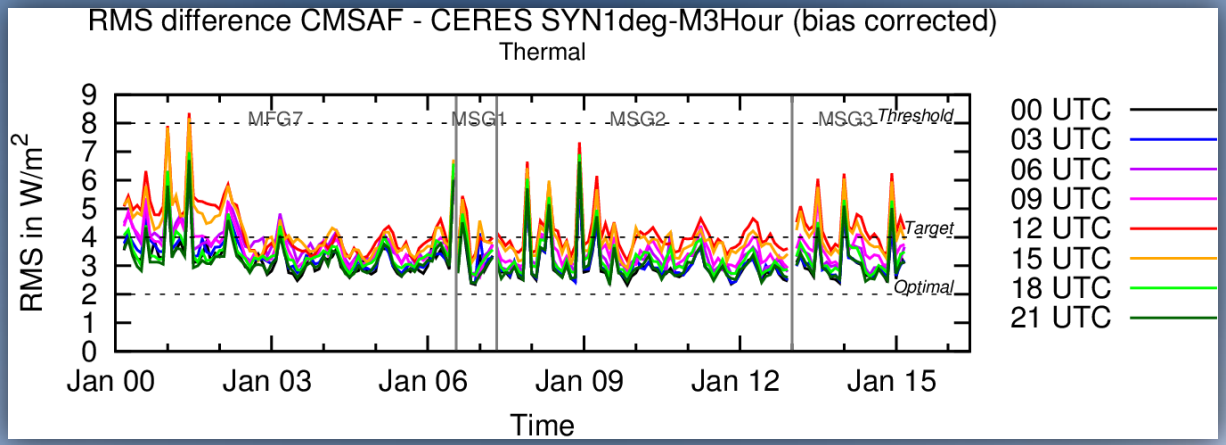
Accuracy
Monthly mean diurnal cycle products

Wrt CERES SYN1deg-M3Hour

TRS



TET



Summary of the errors

Error sources	MM		DM		MMDC	
	TRS	TET	TRS	TET	TRS (midday) (3)	TET
Stability error	Stability of all the products better than 4 W/m² (max-min) except for the TET during a given period in 1987 (MFG2) (4)					
Processing error (at 1 std. dev.)	3.6 W/m²	2.6 W/m²	6.5 W/m²	4.2 W/m²	11.0W/m²	3.5 W/m²
Additional error due to missing input data (1)(2)	0.3 W/m²/day	0.2 W/m²/day	0.5 W/m²	0.3 W/m²	0.7 W/m²/day	0.3 W/m²/day

Remarks

(1) The reported errors due to missing data do not affect the products without missing data. For the DM products, the missing data error is the 0.9 percentile of the error over days affected by missing repeat cycles of image acquisition.

(2) The missing data error must be added to the processing error (not a root mean summation of these errors).

(3) The reported errors for the MMDC of the TRS are estimated for the time intervals with the highest illumination of the Meteosat FOV (e.g. [11-12] and [12-13] UTC).

(4) Those months are January, February and March 1987.

Conclusion

- Validation mainly performed by intercomparison with the CERES products from 2000 onward
- Quality of the early part of the data records verified against other data records (e.g. HIRS OLR CDR - Daily/Monthly, ERBS WFOV-CERES)
- **In terms of accuracy**, validation indicates that:
  - threshold requirements are fulfilled
  - target requirements are fulfilled for most of the products and periods
- **In terms of stability**, validation indicates that:
  - optimal and target requirements far from being achieved
  - threshold requirements are however fulfilled for most of the products and periods
  - systematic error shows a relatively good stability in time, without sharp transitions between satellites and generations of instruments
  - no instrumental drift (i.e. ageing effect) is apparent

Data access and documentation

- Data ordering via the Web User Interface through the CM SAF homepage : www.cmsaf.eu

CM SAF identifier	Content
CM-23311	TOA Reflected Solar radiative flux All Sky (TRS_AS)
CM-23341	TOA Emitted Thermal radiative flux All Sky (TET_AS)

- Algorithm Theoretical Basis Document, version 1.3 : SAF/CM/RMIB/ATBD/MET_TOA
- Dataset Generation Capability Description Document, version 1.1 : SAF/CM/RMIB/DGCDD/MET_TOA
- Product User Manual, version 1.1 : SAF/CM/RMIB/PUM/MET_TOA
- Scientific Validation Report, version 1.1 : SAF/CM/RMIB/VAL/MET_TOA

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Thank you for your attention !

References

- Ipe, A., Bertrand, C., Clerbaux, N., Dewitte, S., & Gonzalez, L. (2003). Pixel-scale composite top- of-the-atmosphere clear-sky reflectances for Meteosat-7 visible data. Journal Geophysical Research, 108, 4612.
- Ipe, A., Bertrand, C., Clerbaux, N., Dewitte, S., & Gonzalez, L. (2004). Validation and homogenization of cloud optical depth and cloud fraction retrievals for GERB/SEVIRI scene identification using Meteosat-7 data. Atmospheric Research, 72(1), 17-37.
- Ipe, A., Gonzalez, L., Bertrand, C., Baudrez, E., Clerbaux, N., Decoster, I., Dewitte, S., Nevens, S., & Velazquez Blazquez, A. (2010). Cloud detection using IR SEVIRI channels for GERB. Remote Sens. Environ., submitted, 2010.
- Ipe, A. (2011). Cloud properties retrieval for climate studies from geostationary orbit. PhD thesis at Vrije Universiteit Brussel. Available via http://gerb.oma.be
- Loeb, N. G., Manalo-Smith, N., Kato, S., Miller, W. F., Gupta, S. K., Minnis, P., & Wielicki, B. A. (2003). Angular distribution models for top-of-atmosphere radiative flux estimation from the Clouds and the Earth's Radiant Energy System instrument on the Tropical Rainfall Measuring Mission satellite. Part I: Methodology. Journal of applied meteorology, 42(2), 240-265.
- Clerbaux, N., Dewitte, S., Gonzalez, L., Bertand, C., Nicula, B. & Ipe, A. (2003a). Outgoing Longwave Flux Estimation: Improvement of Angular Modelling Using Spectral Information. Remote Sensing of Environment, 85, 389-395.
- Clerbaux, N. (2008). Processing of Geostationary Satellite Observations for Earth Radiation Budget Studies. PhD thesis at Vrije Universiteit Brussel Available via http://gerb.oma.be
- Govaerts, Y. M., Clerici, M., & Clerbaux, N. (2004). Operational calibration of the Meteosat radiometer VIS band. IEEE Transactions on Geoscience and remote sensing, 42, 1900-1914.
- Govaerts, Y. M., Clerici, M., & Clerbaux, N. (2004). Operational calibration of the Meteosat radiometer VIS band. IEEE Transactions on Geoscience and remote sensing, 42, 1900-1914.
- Meirink, J.F., Roebeling, R.A., & Stammes, P. (2013). Inter-calibration of polar imager solar channels using SEVIRI. Atmospheric Measurement Techniques, 6, 2495-2508.