Status of GERB products from 0° and over the Indian Ocean

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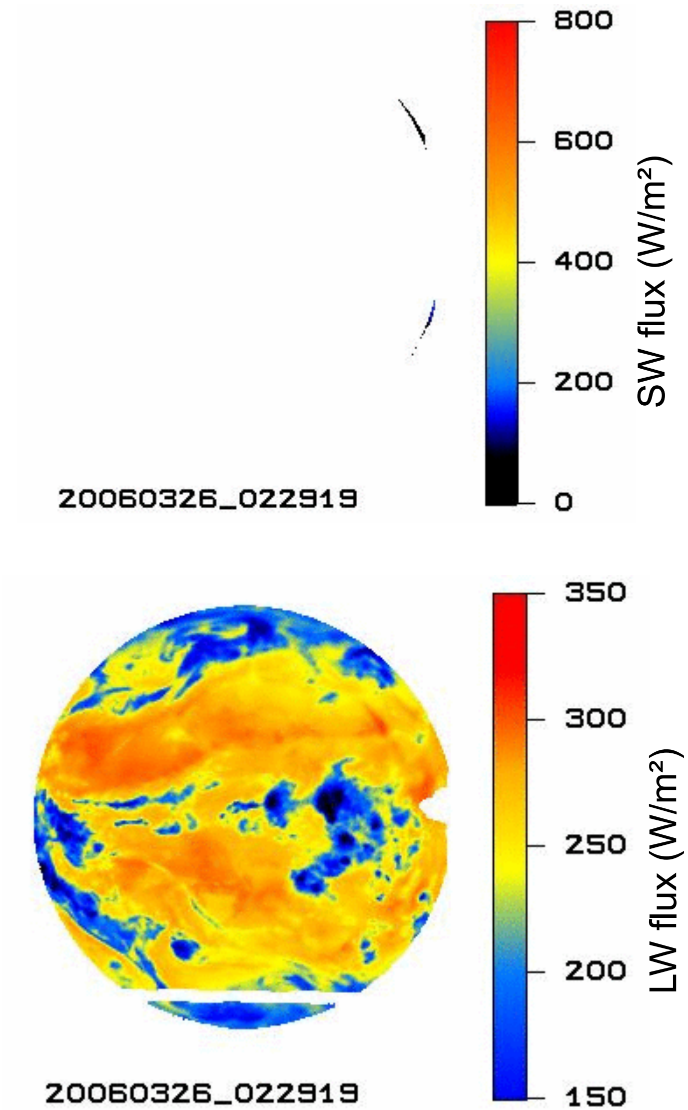
Content 2 parts :

- GERB Status Report
- CM SAF TOA radiation data record (based on GERB)

What is GERB?

- Geostationary Earth Radiation Budget instrument
- On the Meteosat Second Generation satellites (Feb. 2004 – ~Dec. 2022)
- TW channel + quartz filter for SW
- Optics : 5 silver mirrors, incl. 1 rotating De-Spin Mirror (DSM)
- Acquisition cycle ~6 minutes
- Level 2 Products ~15 minutes
- Processing using the Spinning Enhanced Visible and InfraRed Imager (SEVIRI, 12 channels)
- Level 2 products:
  - ARG: Averaged Rectified Geolocated
  - BARG : Bin-Averaged Rectified Geolocated
  - HR : High-Resolution
- Datasets access via https://gerb.oma.be



Animations of ARG product for 26th Mar 2006

GERB Instruments Operation summary

GERB-2 on MSG-1 (Meteosat-8)

- Operational 0° service Feb.2004-Apr. 2007
- In safe mode during 9 years
- Operational 41.5°E service Sept. 2016 onward

GERB-1 on MSG-2 (Meteosat-9)

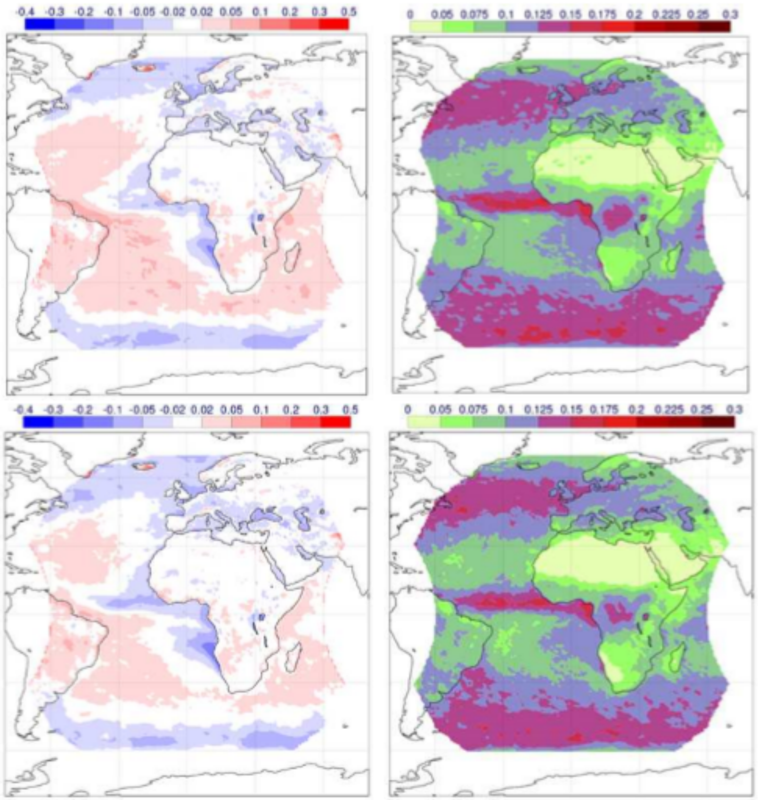
- Operational 0° service May 2007-Dec 2012
- Take over GERB service during the GERB-3 DSM blocking period (but no imager data from the same satellite)
- Mechanism of the DSM not functional

GERB-3 on MSG-3 (Meteosat-10)

- Started operational service on Jan. 2013
- But DSM blocked from Apr 2013 to Feb 2015
- Resume the 0° operational service on Apr 2015

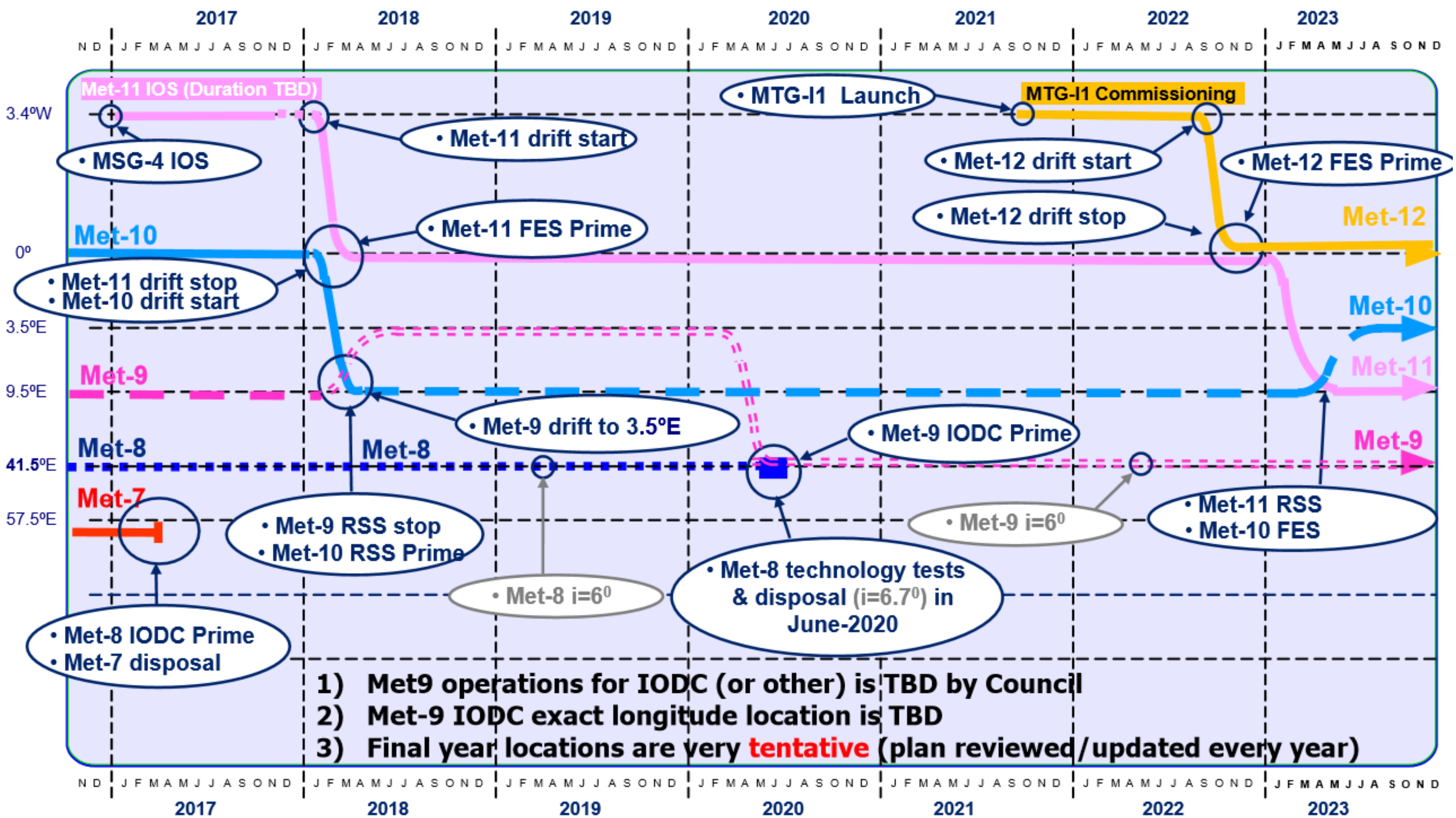
GERB-4 on MSG-4 (Meteosat-11)

- Launched and commissioning okay
- Currently in in-orbit storage
- Will enter operation in Feb. 2018



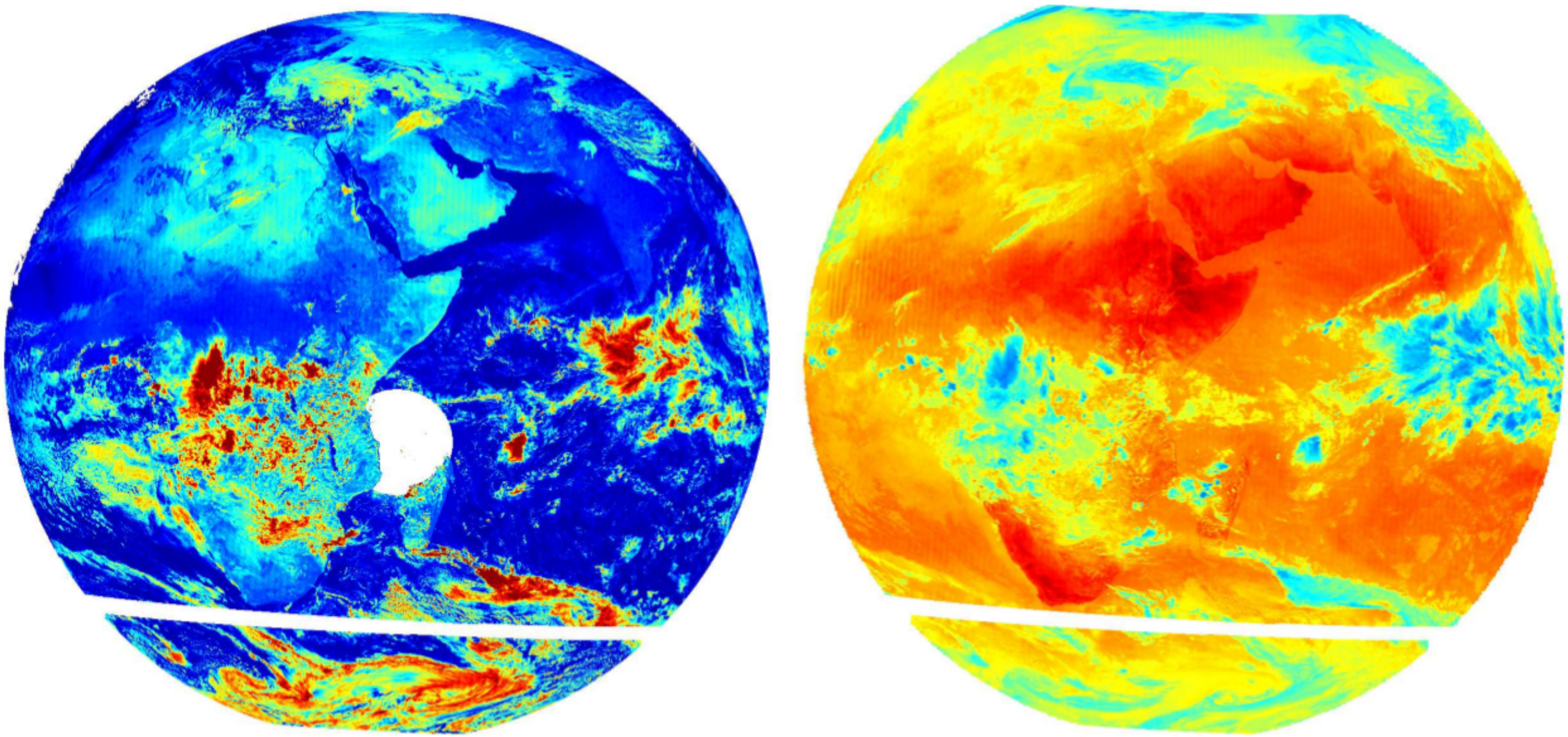
From ECMWF (2014)

EUMETSAT Current Status and Future Operations



GERB-2 over the Indian Ocean

- At 41.5° East
- From Sept. 2016 onward
- GERB Processing has been adapted (ancillary maps, …)



G2_SEV1_L20_HR_SOL_TH_20161231_090000_V006 solar & thermal fluxes

Example of GERB High Resolution product for 31 Dec. 2016 at 09:00 UTC

GERB Ongoing Activities

- GERB ED01 BARG and HR official release
  - The ARG products were released in 2006 but not the HR and BARG
  - Issue the "Quality Summary" for the BARG and HR
  - Release within a couple of weeks

- GERB ED02 new developments
  - Correction of GERB ageing (Parfitt et al., 2016) and SEVIRI ageing (Meirink et al., 2013)
  - Several improvements in the processing: aerosol ADM, wind speed from reanalysis, snow detection/ADM, better NB to BB (GERB-like), …

- Correction of the GERB De-Spin Mirror (DSM) ageing

- Adapt the GERB processing/GERB acquisition when GERB-2 (Indian Ocean) uses the Earth Sensor Unit

Covered in next slides

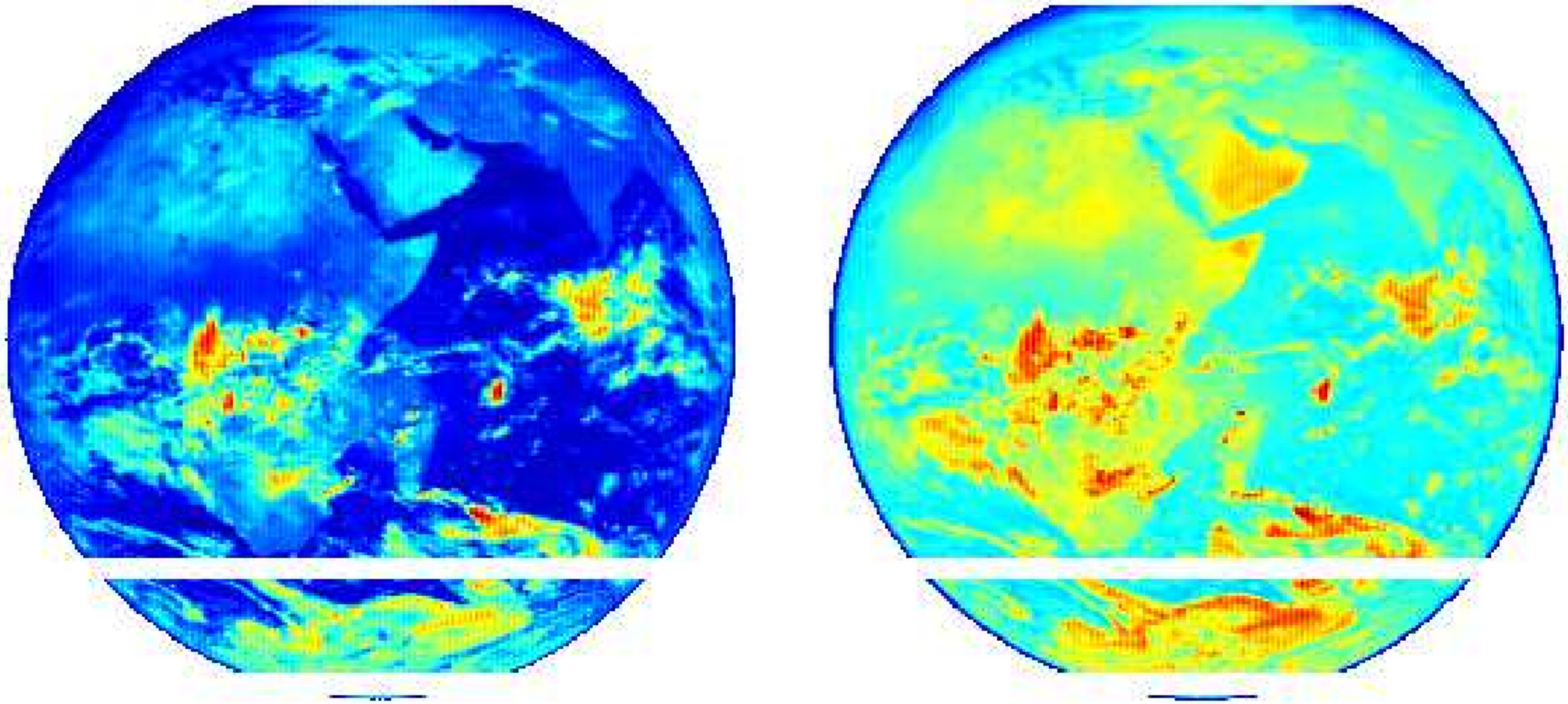
GERB De-Spin Mirror Ageing (slide 1/2)

Affect both GERB–2 and GERB–3

- GERB–2 launched in 2002 has been kept in save mode during a long time (2007-2016) before reactivated for the 41.5°E acquisition
- GERB–3recovered after being stuck during 2 years (2013-2015)

One side of the De-Spin Mirror (DSM) experienced more aging than the other

- overall signal response of back side of the mirror more than 4% lower
- Ageing mainly occurs in UV and blue

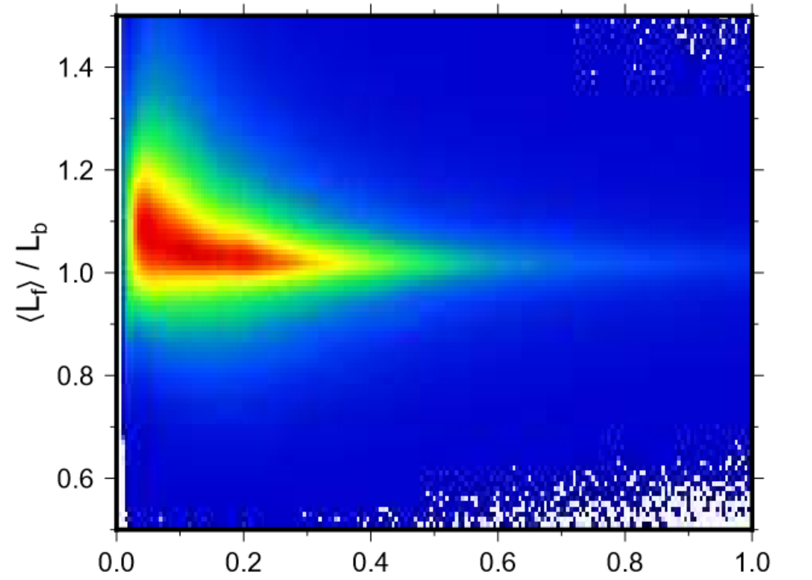


G2_L15N_20161231_090039_V002 SW & TW NANRG radiances

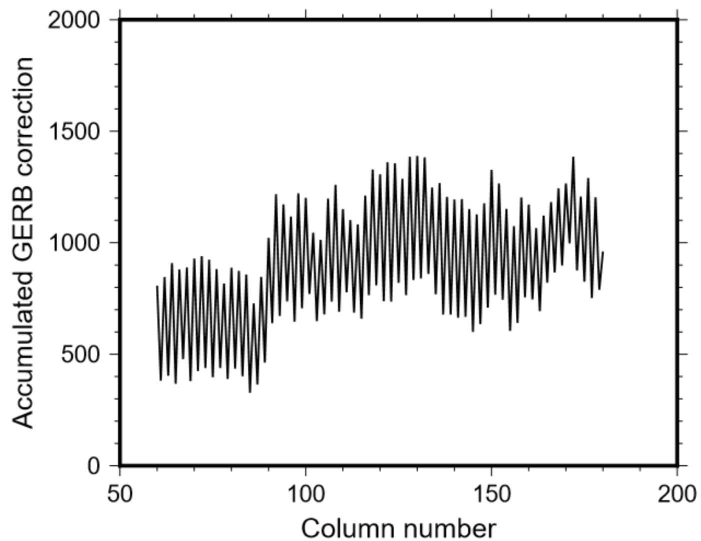
GERB De-Spin Mirror Ageing (slide 2/2)

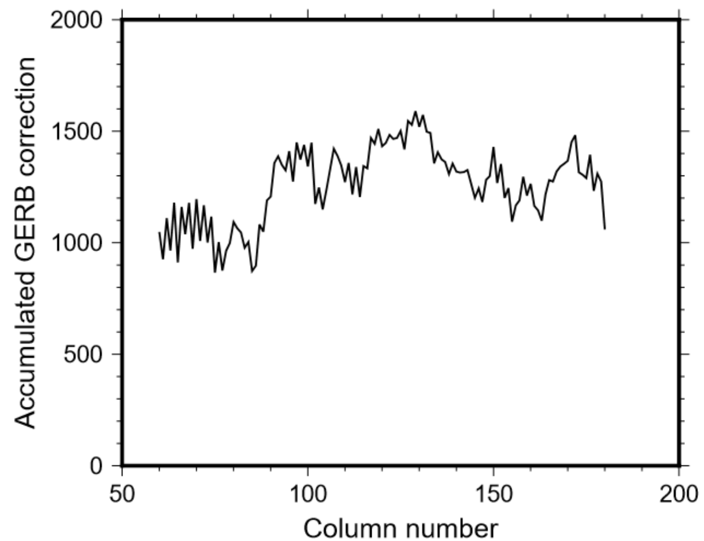
Suggested correction similar to GERB–3

- Ratio $\beta = \langle L_f \rangle / L_b$ versus ρ_b
- Polynomial fits $\beta = \mathcal{P}_3(\rho_b) + L_b \cdot \widetilde{\mathcal{P}}_3(\rho_b)$ for ocean & $\beta = \widehat{\mathcal{P}}_3(\rho_b)$ for land



Kind of ratio between GERB SW and GERB-like (based on SEVIRI): raw data (left) and after correction (right).

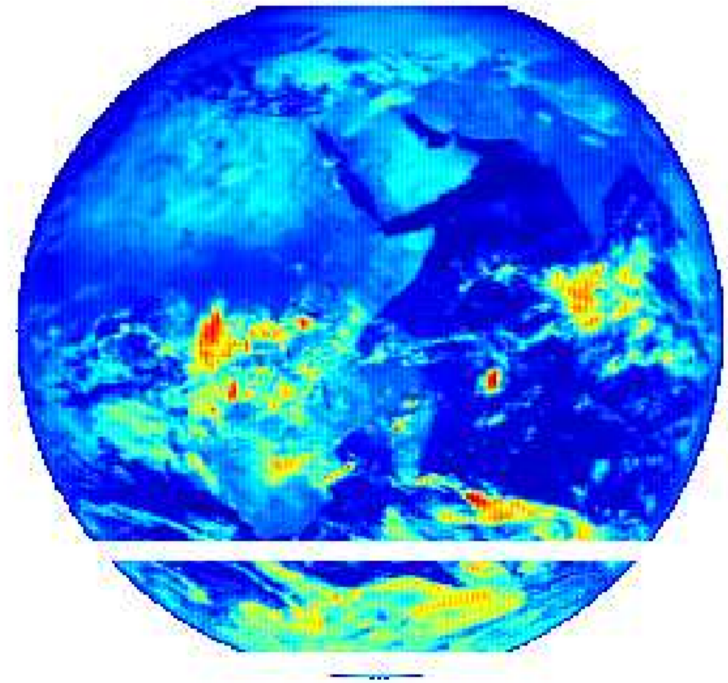




GERB-2 (Meteosat-8) using the Earth Sensor Unit (slide 1/2)

Time of start of line (TSOL) in acquisition given by

- Solar sensor unit (SSU)
- Earth sensor unit (ESU) during several months
  - columns need reordering
  - columns not spaced equidistantly
  - column sampling doubled
    - additional timing info → columns reordering
    - equidistant column spacing ← interpolation ← mirror asymmetry correction ← corrected geolocation ← equidistant column spacing…



G2_L15N_20161231_090039_V002 SW NANRG radiances

GERB-2 (Meteosat-8) using the Earth Sensor Unit (slide 2/2)

Time of start of line (TSOL) in acquisition given by

- Solar sensor unit (SSU)
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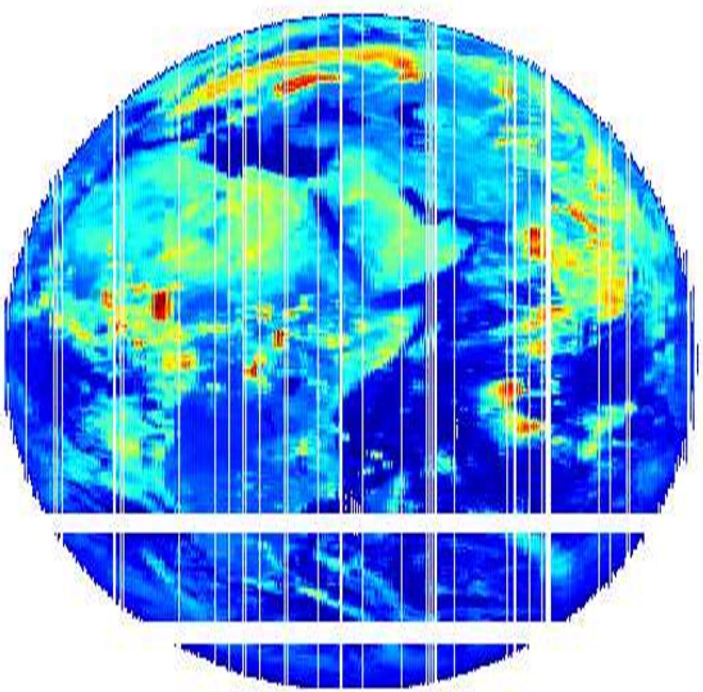


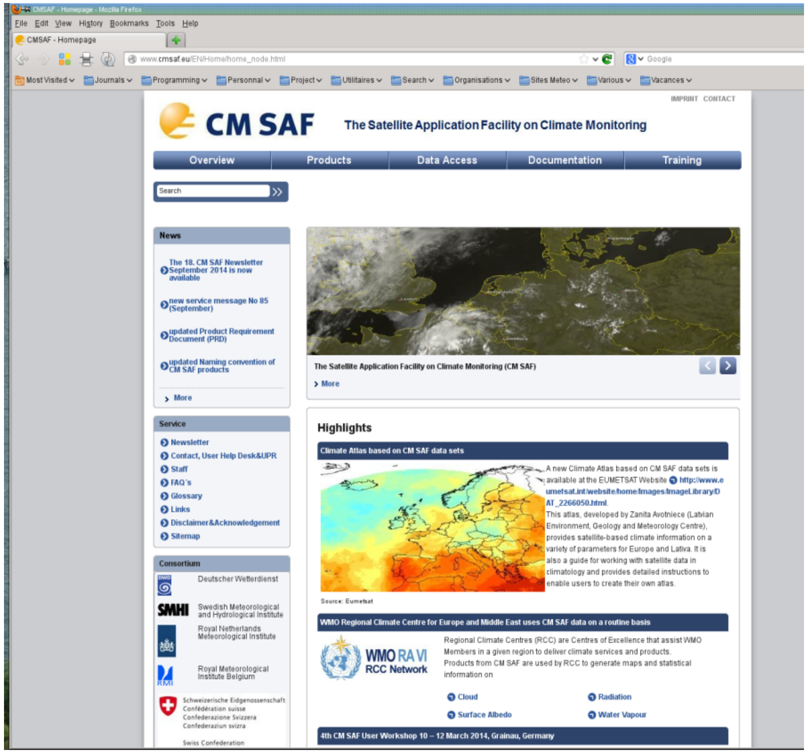
G2_L15N_20170701_093246_V002 SW NANRG radiances

Part II : Use of GERB data in the Climate Monitoring SAF (CM SAF) of EUMETSAT.

http://www.cmsaf.eu

What is CM SAF?

- Climate products from (weather) satellites
- Part of EUM ground segment
- **Products target the energy and water cycles**
- 3 types of products:
    - EDR = Environmental Data Record
    - ICDR = Interim Climate Data Record
    - TCDR = Thematic Climate Data Record
- Global/regional products
- Polar and geo satellites
- User's oriented programme: help desk, web user interface, data ordering system, users training events, …
- Operational: annual quality ass., Review, operation reviews, …
- Guidance from a steering group, visiting scientist programme, …



The energy and water cycles:

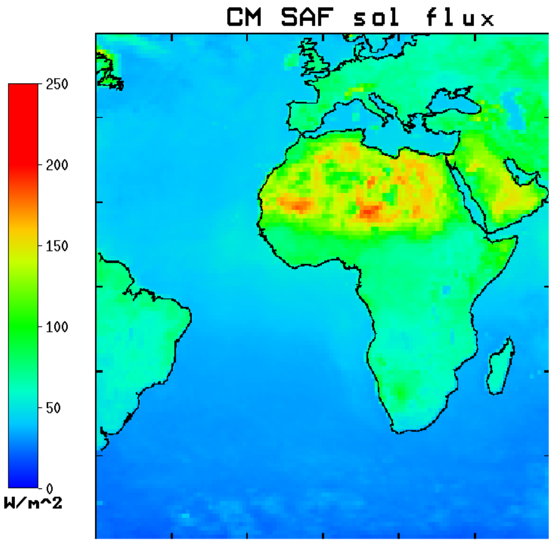
- TOA and surface radiation
- Cloud properties
- TCWV + profiles
- HOAPS retrieval (SSMI)
- Precipitation
- Aerosol
- Surface albedo, LST, latent/sensible heat fluxes
- …

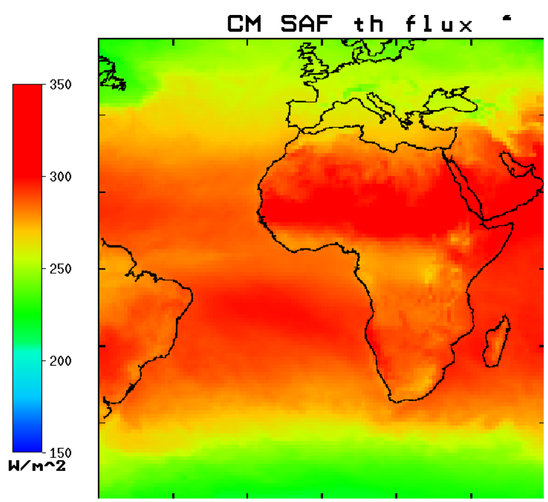
TOA Radiation Products in the CM SAF

Level 3 daily mean, monthly mean and monthly mean diurnal cycle (hourly values).

- GERB EDR
  - near real time
  - Since 2004
- GERB/SEVIRI ed01 data record
  - 2004-2012
  - Some shortcomings (incl. visible drift), users should use ed02
- MVIRI/SEVIRI ed01 data record
  - Long data record 1982-2015
  - GERB used “offline”
- GERB/SEVIRI ed02 data record
  - Feb. 2004 - April 2015
  - Drift corrected
  - All sky and clear sky fluxes
  - Just released (21 Sept. 2017)

Detailed in next slides





Example of products: monthly mean clear sky solar (top) and thermal (bottom) for April 2004

Toward CM SAF GERB/SEVIRI dataset ed02
Improvements wrt ed01

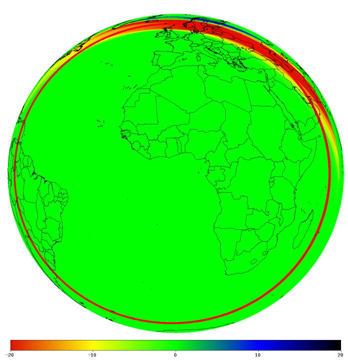
Edition-1
(released in 2013)

- GERB with masked sun-glint and terminator
- Feb. 2004 – Jan. 2011
- SEA $(45km)^2$ grid
- Allsky TRS and TET
- No aging correction
- Recalibration to GERB-1 level
- Only operational satellite

→

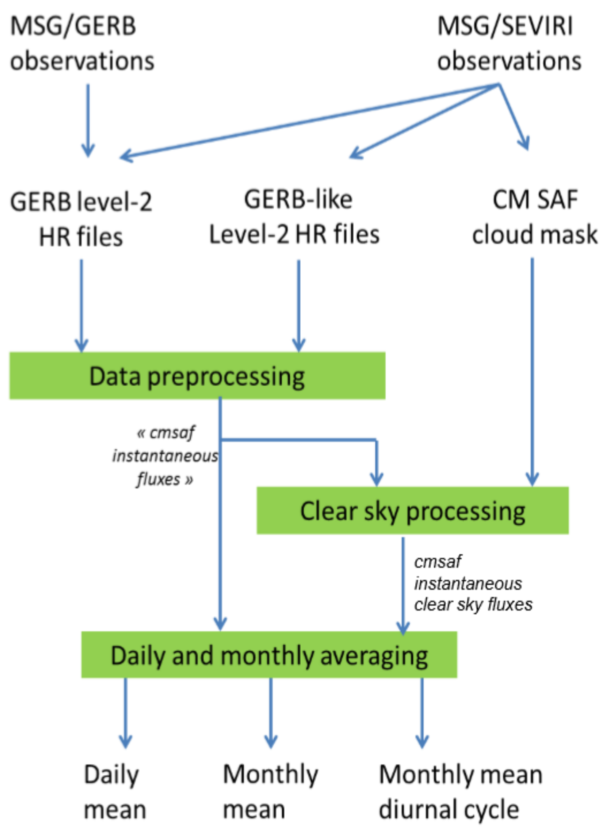
Edition-2
(to be released mid-2015)

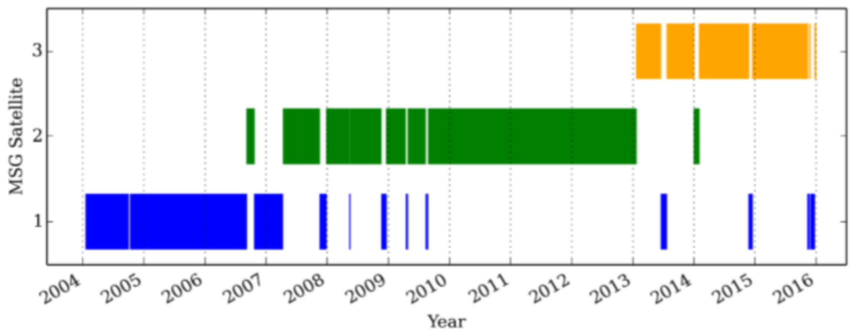
- Improved GERB data at input (filled HR files)
- Feb. 2004 – Jan. 2014
- GERB HR geo grid ($9km^2$ sub-sat)
- Allsky and clearsky TRS and TET
- GERB and SEVIRI SW aging corrections
- Recalibration to average of GERB-1 and GERB-2 level (TBC with GERB instrument principal scientist)
- Also use data from the backup MSG satellites in case of decontamination/ failure



CM SAF TOA radiation GERB/SEVIRI ed02 data record

- Time: 1st Feb. 2004 – 30th Apr. 2015
- Still based on GERB ED01 but:
- GERB and SEVIRI drifts corrected
- Some known limitations of the GERB fluxes are corrected (as in ED02)
- All sky and clear sky fluxes
- Incorporate data from backup satellite
- Processed on the GERB HR grid
- Final products are regridded on 0.1° x 0.1° lat-lon
- NetCDF files





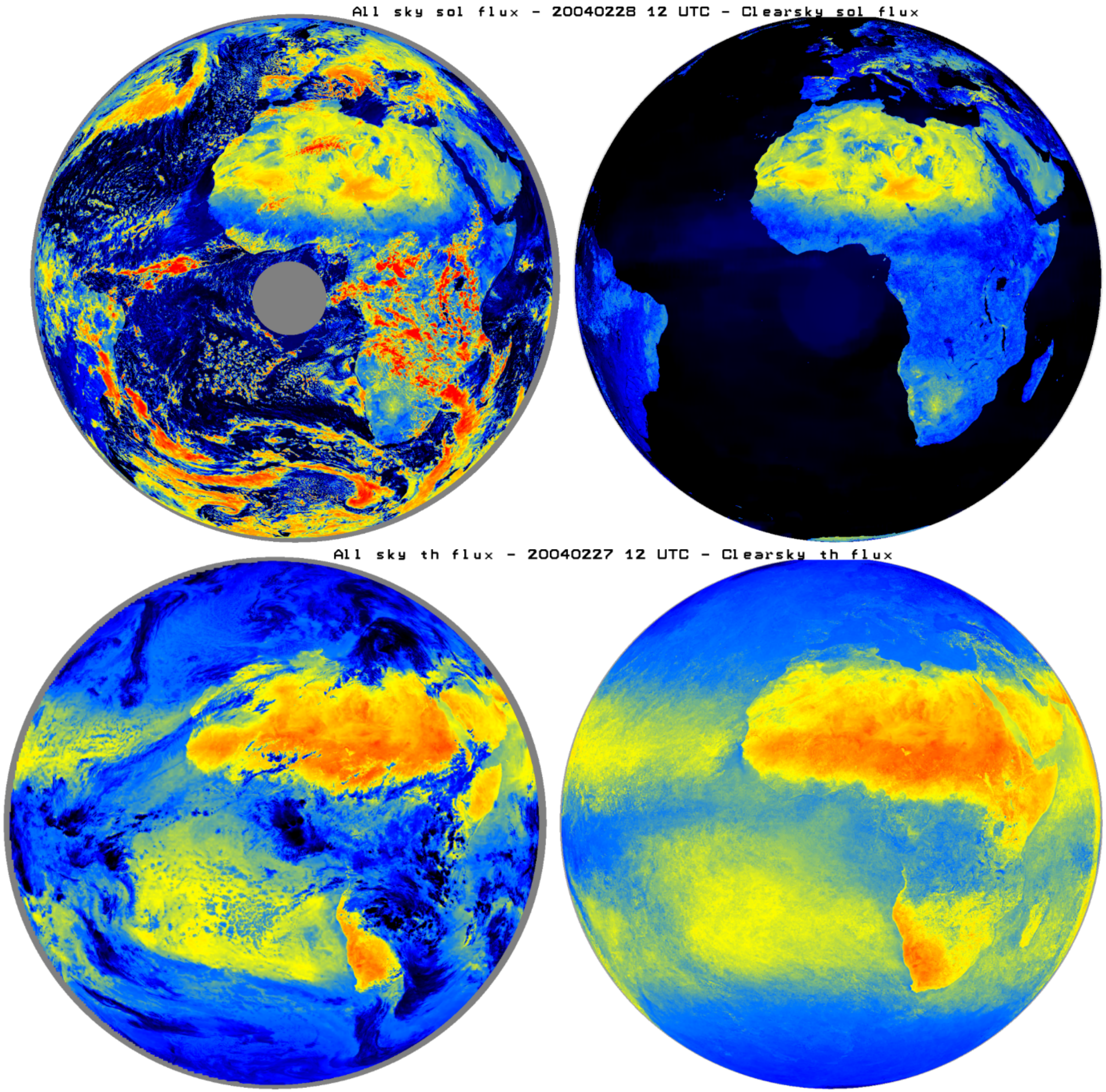
Illustrations all-sky / clear-sky "instantaneous" fluxes

TOA Reflected Solar (TRS) flux

aka SW flux

TOA Emitted Thermal (TET) flux

aka LW flux or OLR



Illustrations monthly mean fluxes

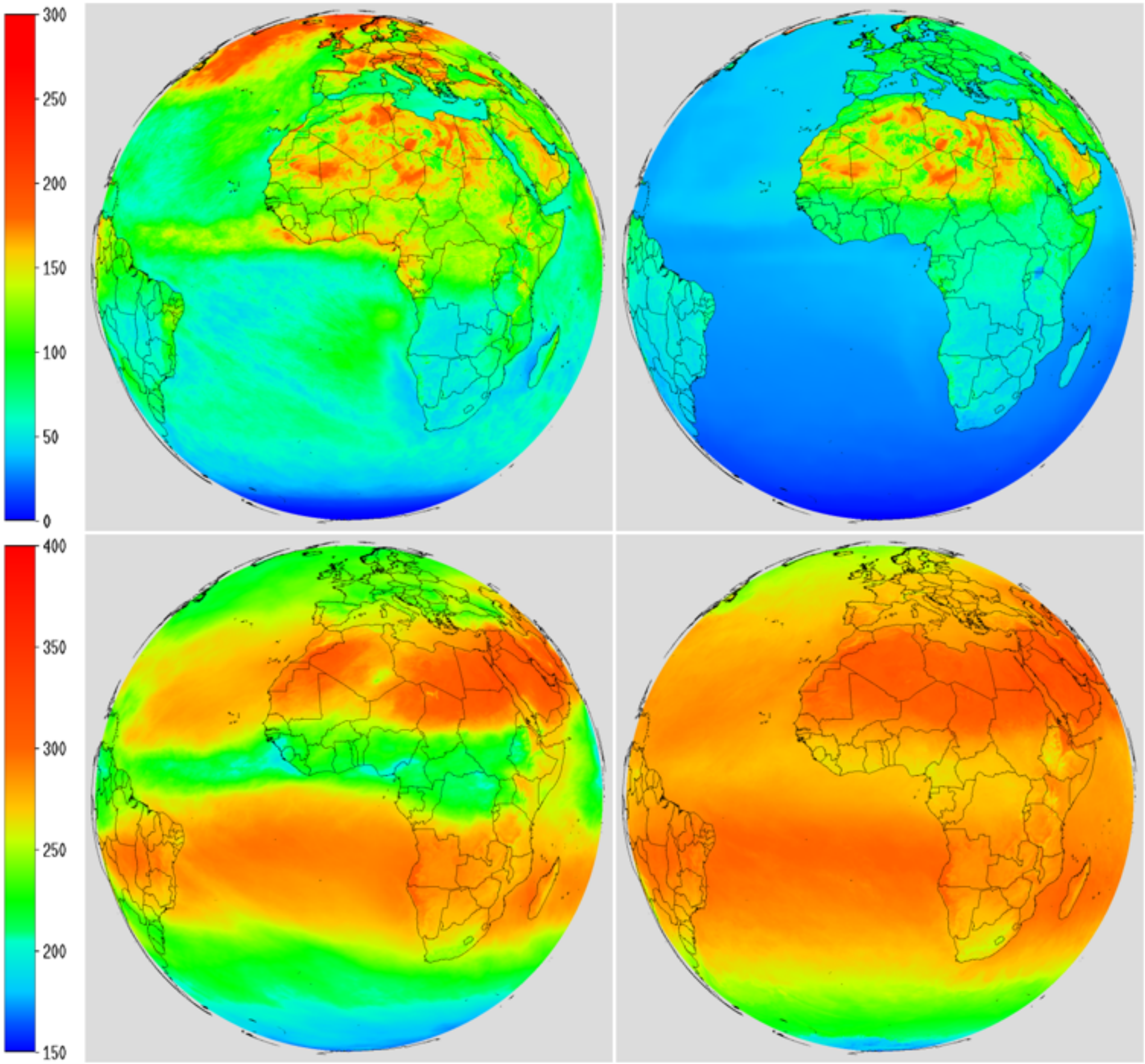


Figure 5 : Monthly mean products for June 2010. The upper panels are TRS, lower are TET. Left are all sky fluxes and right is clear sky fluxes. All fluxes are in W/m². The overlaid country borders are obviously not present in the data file.

Illustrations daily mean fluxes

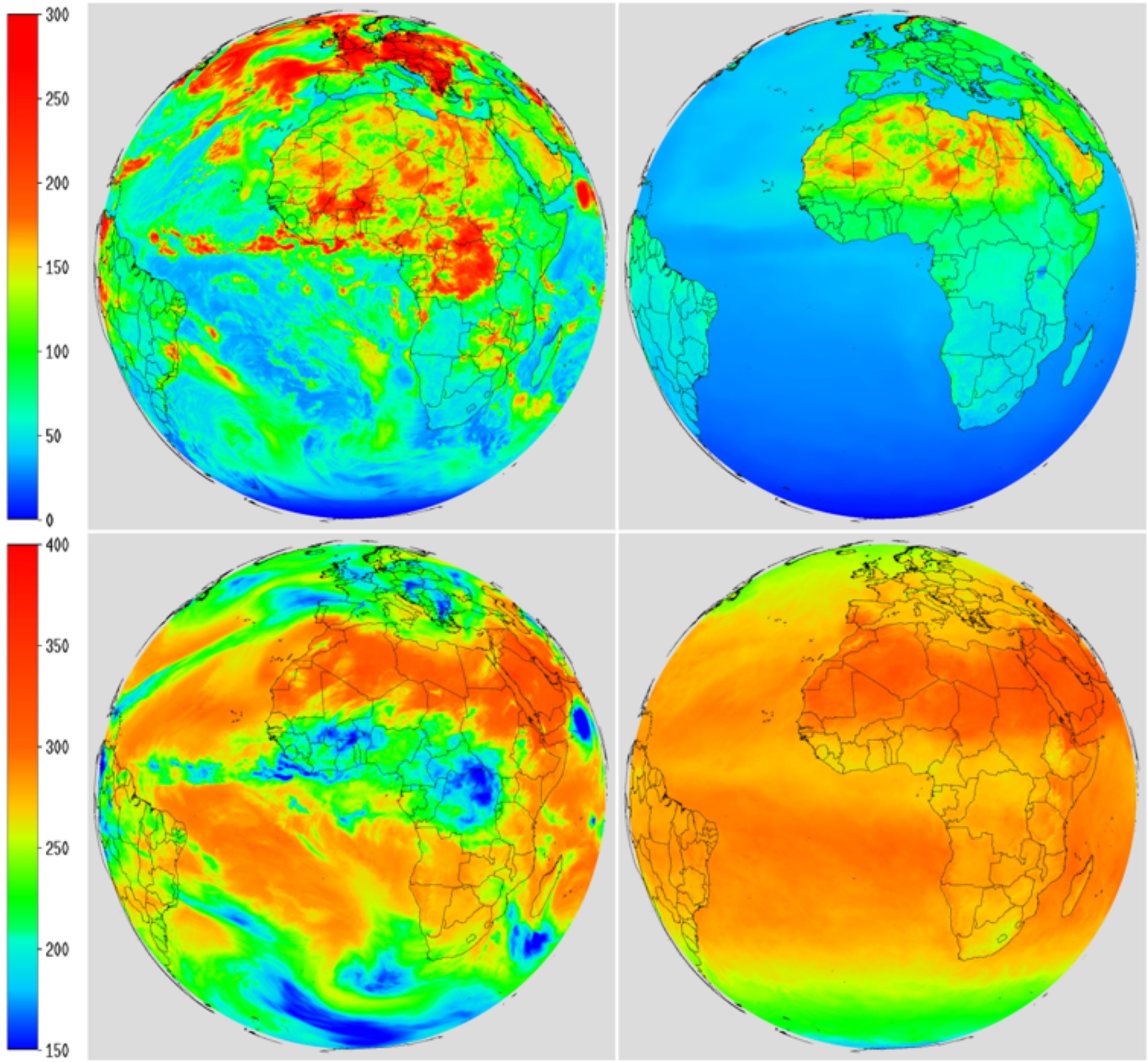


Figure 6 : Daily mean products for 1st June 2010. The upper panels are TRS, lower are TET. Left are allsky fluxes and right is clear sky fluxes. All fluxes are in W/m². The overlaid country borders are obviously not present in the data file.

Illustrations monthly mean diurnal cycle fluxes

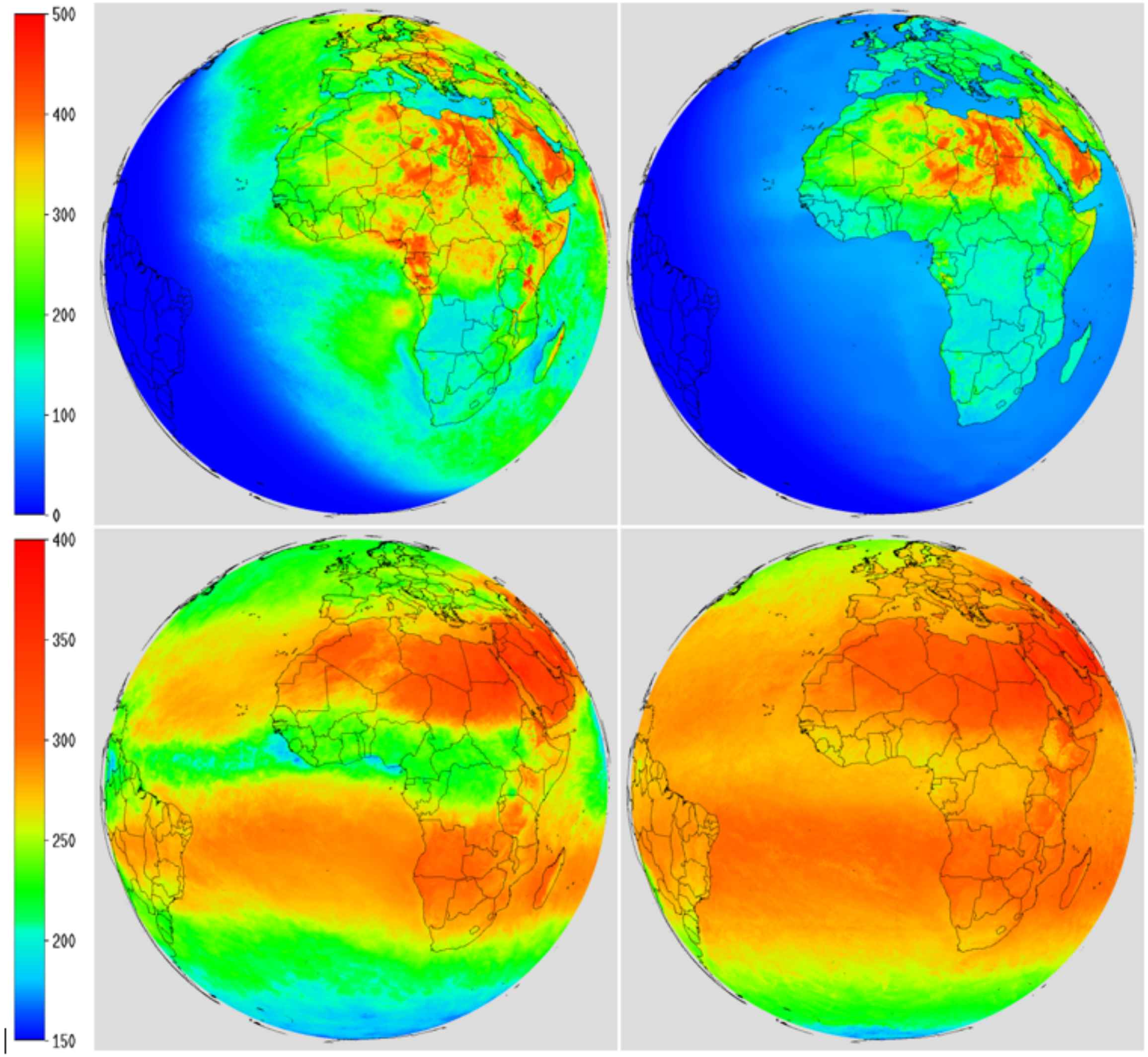
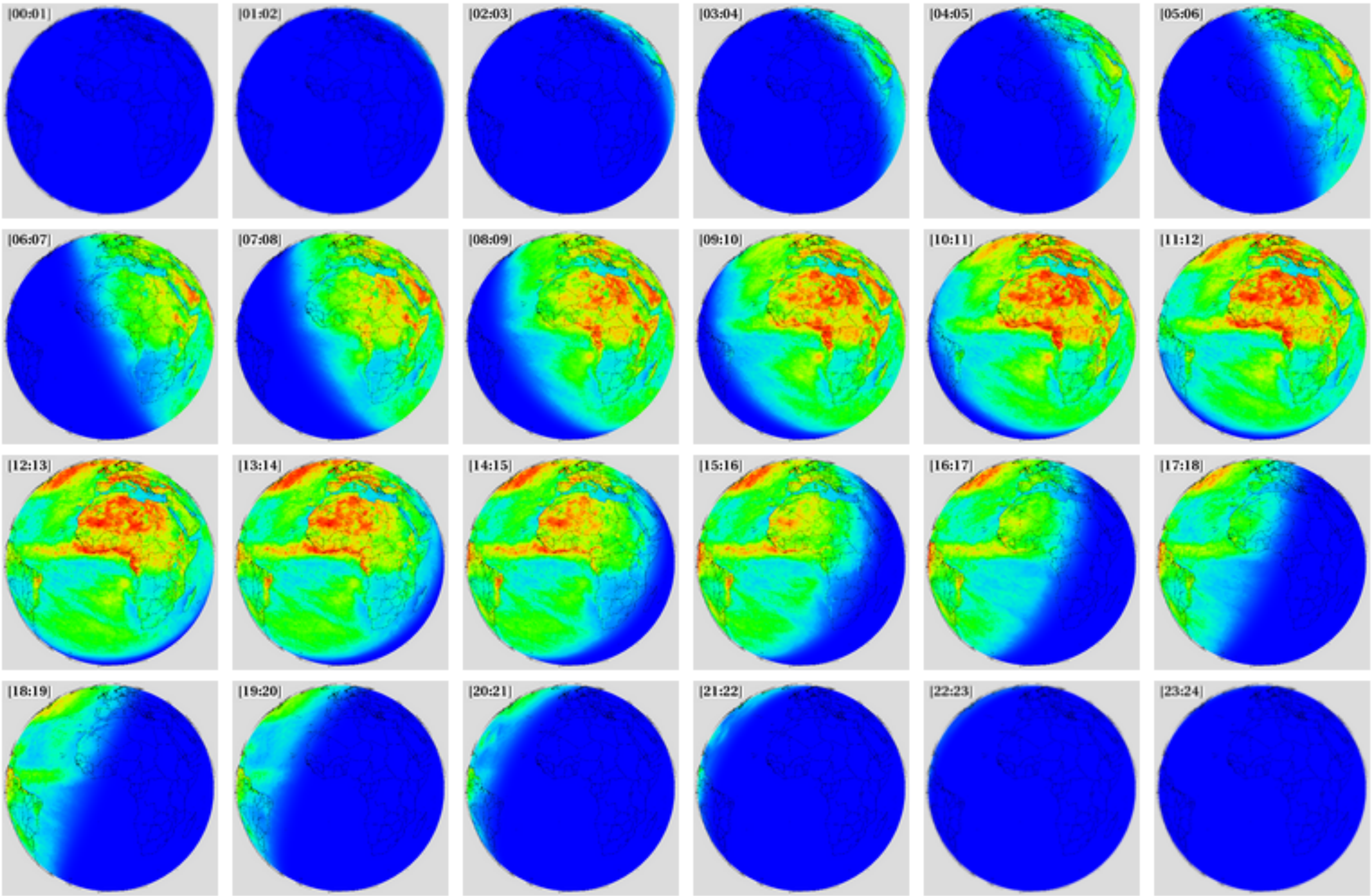


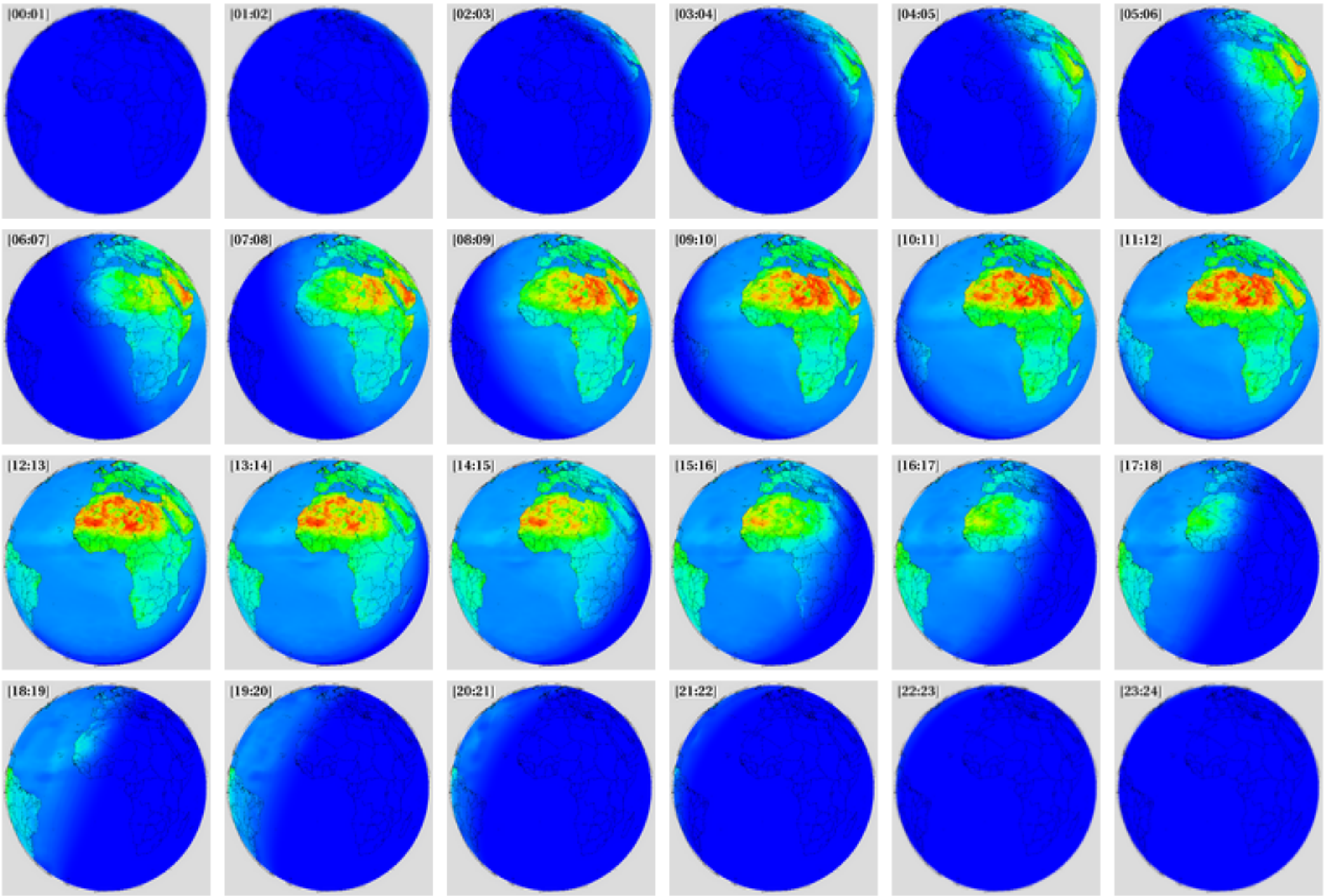
Figure 7 : Monthly mean diurnal cycle products for 1st June 2010 for [08:09] UTC time interval. The upper panels are TRS, lower are TET. Left are allsky fluxes and right is clear sky fluxes. All fluxes are in W/m². The overlaid country borders are obviously not present in the data file.

Illustrations monthly mean diurnal cycle fluxes : all sky solar



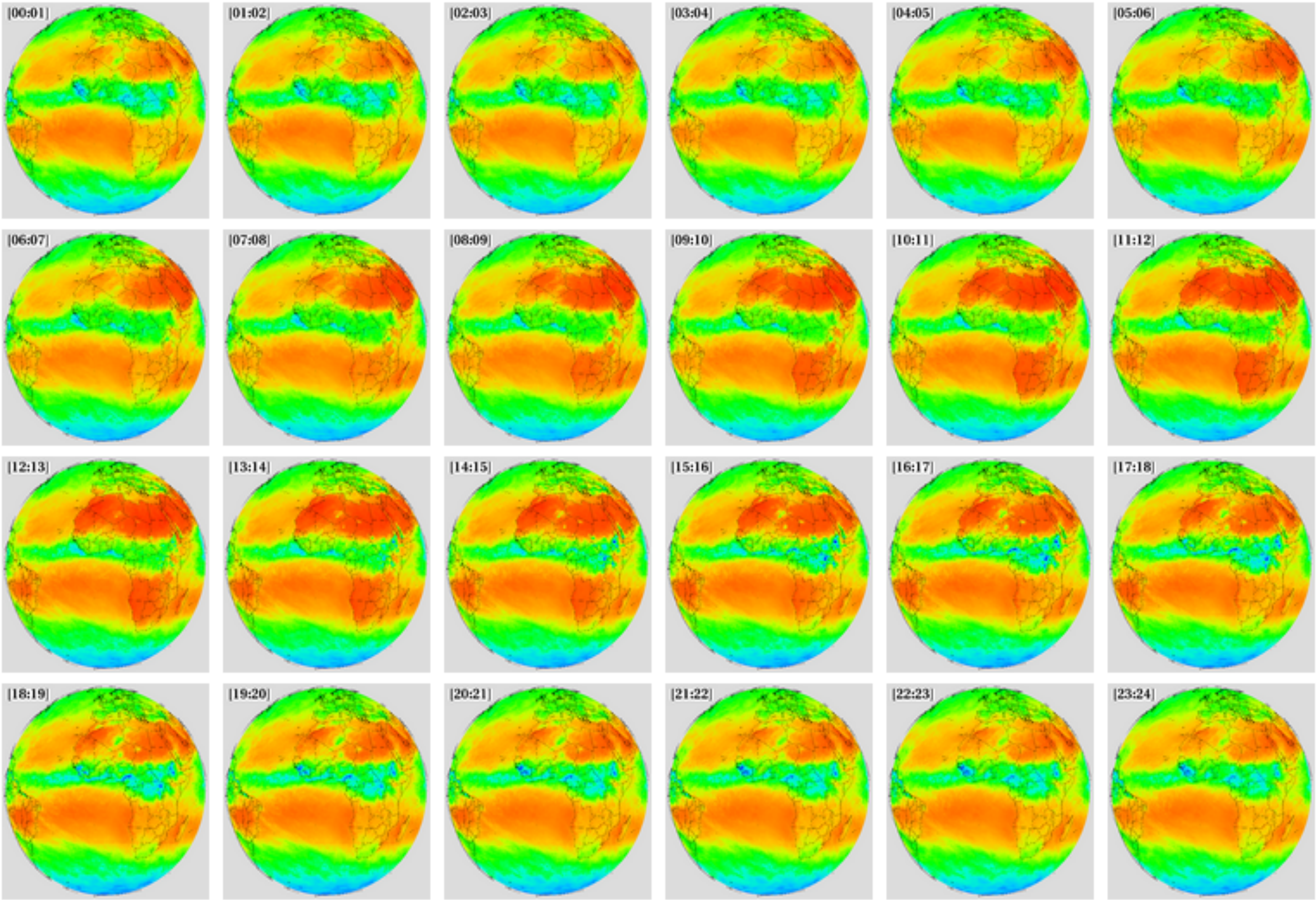
June 2010

Illustrations monthly mean diurnal cycle fluxes : clear sky solar



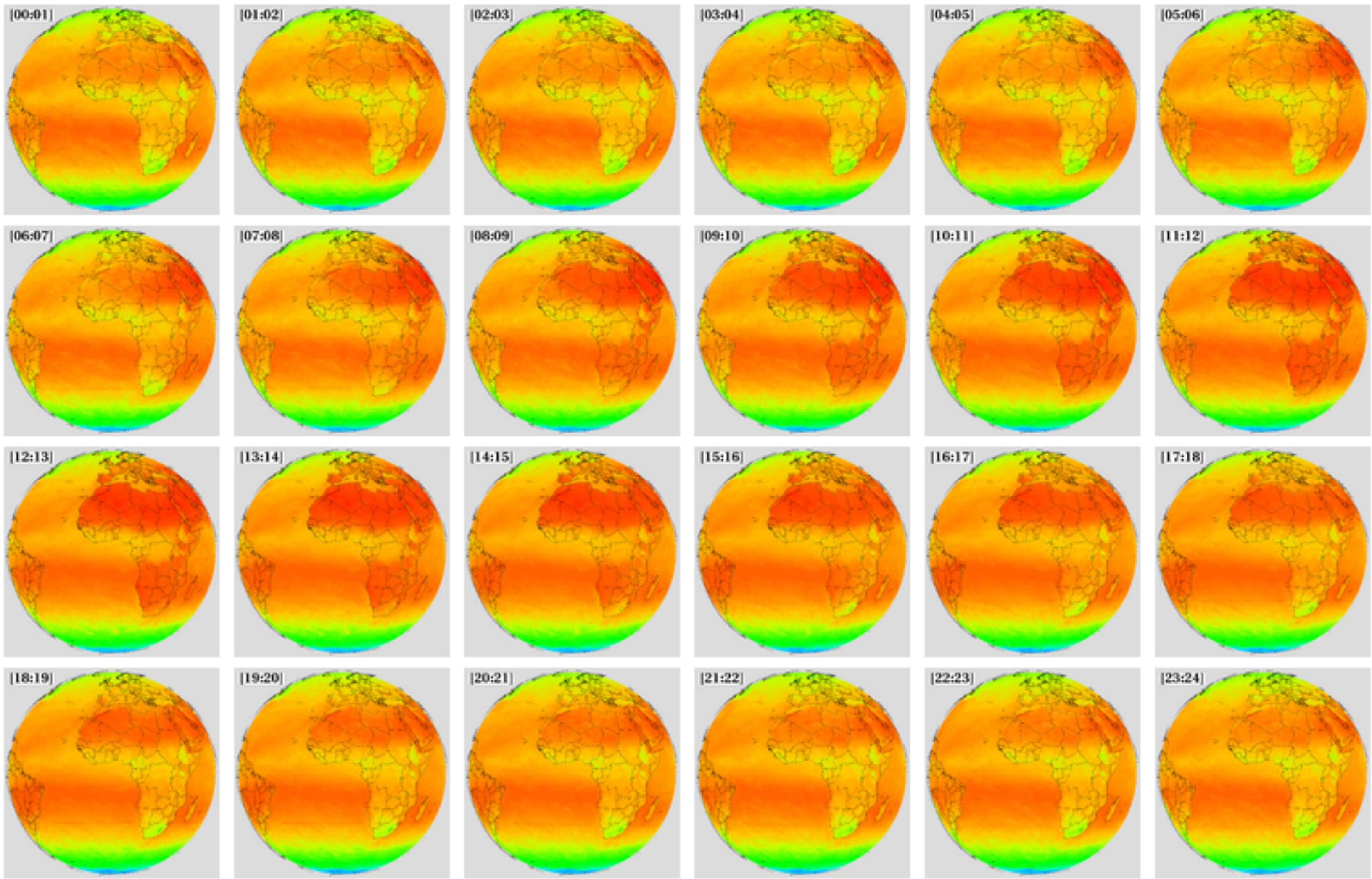
June 2010

Illustrations monthly mean diurnal cycle fluxes : all sky thermal



June 2010

Illustrations monthly mean diurnal cycle fluxes : clear sky thermal



June 2010

Ancillary fields in the NetCDF files

Ancillary image of:

- TOA incoming radiation (based on Dewitte and Nevens, 2016).
- Estimated accuracy
- Viewing zenith angle
- (average) Solar zenith angle
- percentage_sun_glint
- percentage_twilight
- percentage_persistent_cloudiness

Attributes:

- % GERB
- % GERB-like
- % backup satellite
- % missing input data
- Daily TSI value(s)
- Earth-Sun distance
- (…)

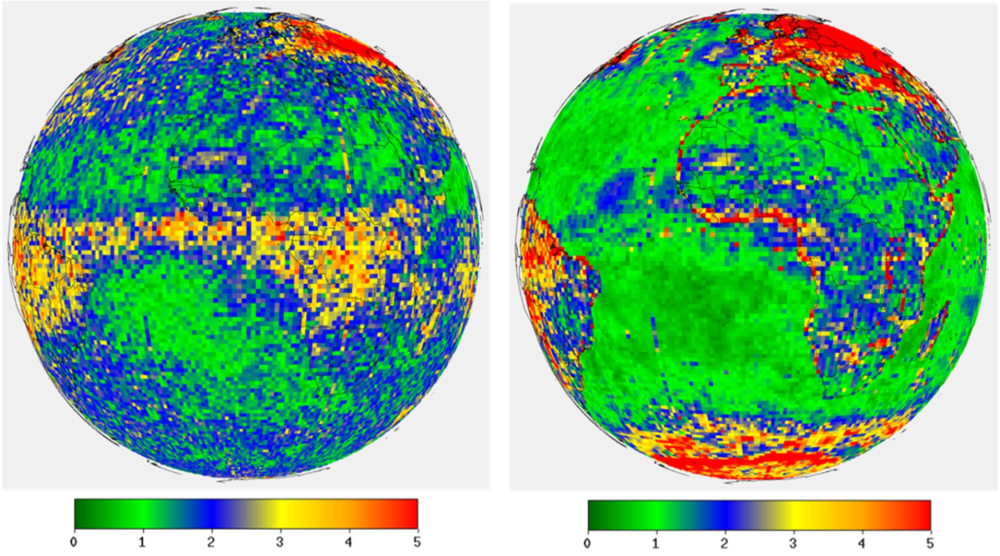


Figure 4 : illustrations of the field 'accuracy' in the NetCDF data files, for the monthly mean all sky (left) and clear sky (right) TRS flux in July. The accuracy is expressed in W/m².

General limitations and recommendations (see details in the PUM)

The following points should be considered when using the data:

•The data records are driven by the radiometric levels of the GERB-1 instrument (the instrument on MSG-2). The GERB-2 instrument (on MSG-1) fluxes have been scaled by 0.965 (TRS) and 1.004 (TET) to match the GERB-1 levels.

•The stability of the data records is only shallowly addressed during the validation and is not demonstrated. The data records are not aimed to be used for trend analysis.

•The data records have not been “energy balanced” (see for example Loeb et al., 2009). In all sky, the overall biases of the data records with respect to CERES EBAF ed 2.8 are -1.6 W/m² for the TRS and -3.0 W/m² for the TET [RD 4].

•The definition of the clear sky fluxes is not unique and is subject to bias, e.g. the dry bias (Sohn et al., 2006) when comparing with climate models. It is recommended to read the algorithm description in the ATBD [RD 3] before using the clear sky fluxes.

•Over the ocean, a post-processing of the TRS clear sky fluxes is implemented based on the assumption that clear ocean reflectivity and atmospheric effects should have smooth spatial variation [RD 3]. This post-processing performs an efficient cleaning of the persistent cloudiness but, a side effect, is also to suppress the effect of sea ice in the Southern Ocean, along the coast of Antarctica, and to a lesser extend along the Greenland.

•The clear sky fluxes (TRS and TET) contain the effect of aerosol, as long as they are not detected as “cloud” in the cloud mask. The product is therefore not suited for aerosol forcing studies.

•The fluxes are provided up to a VZA of 80° but their accuracies are known to decrease rapidly when the angle of observation exceeds 60°. The accuracy values reported in Table 7 are not valid beyond VZA > 60°. This fact should be kept in mind when using the data.

•The data is provided on a geostationary grid with spatial resolution of 9 x 9km at the subsatellite point (located at a longitude of 0°). However, definition of TOA fluxes at this scale does not make always sense especially at high VZA (atmospheric path, cloud parallax …). The fine spatial resolution of the products is aimed to allow an easy and accurate data regridding on larger areas, e.g. on the grid box of climate model.

•The reference level for the “TOA Radiation SEVIRI/GERB Data Records” is set to 20 km above the mean sea level, which is consistent with fluxes in (plan parallel) climate models and with the CERES products (EBAF, SYN, and SSF). To compare with other data records, users are advised to first check if the reference levels are identical. If not, the data records should be rescaled to the same reference level. To scale the fluxes from a reference level h1 (in km) to another reference level h2 (in km), the following multiplicative factor should be used (where R= 6 378.169 km is the Earth equatorial radius):

$$\text{factor} = (R+h_1)^2 / (R+h_2)^2$$

General limitations and recommendations (suite)

•The MSG-1 satellite is the prime satellite for the period from 1st Feb. 2004 to 30 April 2007. During this period, this satellite was not located at 0° longitude but at 3.4°W longitude. The covered region (defined by a VZA<80°) is then slightly different than for the rest of the data record with MSG-2 and MSG-3 located at 0°.

•The scene identification process is highly unreliable over snow covered regions as they exhibit VIS reflectance similar to the ones of clouds. The frequency of snow is however limited in the Meteosat FOV and the effect on the TRS products is expected to remain small.

•For permanent snow/ice surfaces, the bright desert ADM is used since they are the closest models in terms of albedo. The effect on the TRS is addressed in Bertrand et al. (2008).

•The SW ADM selection is based on constant surface type map (Bertrand et al., 2006). This could introduce flux error in region of seasonally varying vegetation like the Sahel and also in regions that have experienced significant changes during the last decades.

•For clear ocean in the sun glint region (SGA < 15°) the TRS instantaneous flux is not based on the radiance observation but instead on the CERES TRMM flux models (Loeb et al., 2003). Similarly, in twilight conditions (85° < SZA < 100°), a statistical model of the TRS is used (Kato and Loeb, 2003). Those "model" fluxes are used in the averaging processes. The effect on the MM and DM products is in general negligible, but can be significant for some hourly intervals of the MMDC TRS products. The ancillary fields *percentage_sunglint* and *percentage_twilight* in the TRS files provide, at pixel level, the frequencies of the use of those "model" fluxes.

•Clerbaux et al. (2003b) have shown that the geostationary TET fluxes may exhibit some bias (about 1%) in clear sky conditions in mountainous areas as the angular dependency models do not account for azimuthal anisotropy. Indeed, from a geostationary orbit, the Northern hemisphere is always observed from the South while it is the reverse in the Southern hemisphere.

•With geostationary observations, the viewing geometry is obviously fixed. This is likely to introduce systematic errors in the diurnal cycle products. This error is in part reduced in the TRS month and daily mean products thanks to the varying direction of solar illumination through the day.

Validation by intercomparison with CERES and HIRS OLR products

Source	Version	Variable	Temporal resolution	Spatial resolution	Period
CERES EBAF (Loeb et al., 2009)	2.8	TRS_AS TET_AS TRS_CS TET_CS	MM	1° x 1°	March 2000 onward
CERES SYN1deg-Day (Doelling et al.2013)	3A	TRS_AS TET_AS TRS_CS TET_CS	DM	1° x 1°	March 2000 onward
SYN MM	source cmsaf	TRS_AS TET_AS TRS_CS TET_CS	MM	1° x 1°	Feb. 2004 to April 2015
CERES SYN1deg-M3Hour (Doelling et al.2013)	3A	TRS_AS TET_AS TRS_CS TET_CS	MM in 3-hourly intervals	1° x 1°	March 2000 onward
CERES SSF1deg-Day Aqua	3A	TRS_AS TET_AS TRS_CS TET_CS	DM	1°x1°	July 2002 onward
CERES SSF1deg-Month Aqua	3A	TRS_AS TET_AS TRS_CS TET_CS	MM	1°x1°	July 2002 onward
HIRS OLR CDR – Daily (Lee et al., 2007, 2014)	1.2	TET_AS	DM	1° x 1°	Jan. 1979 to Dec. 2015
HIRS MM	source cmsaf	TET_AS	MM	1° x 1°	Feb. 2004 to April 2015

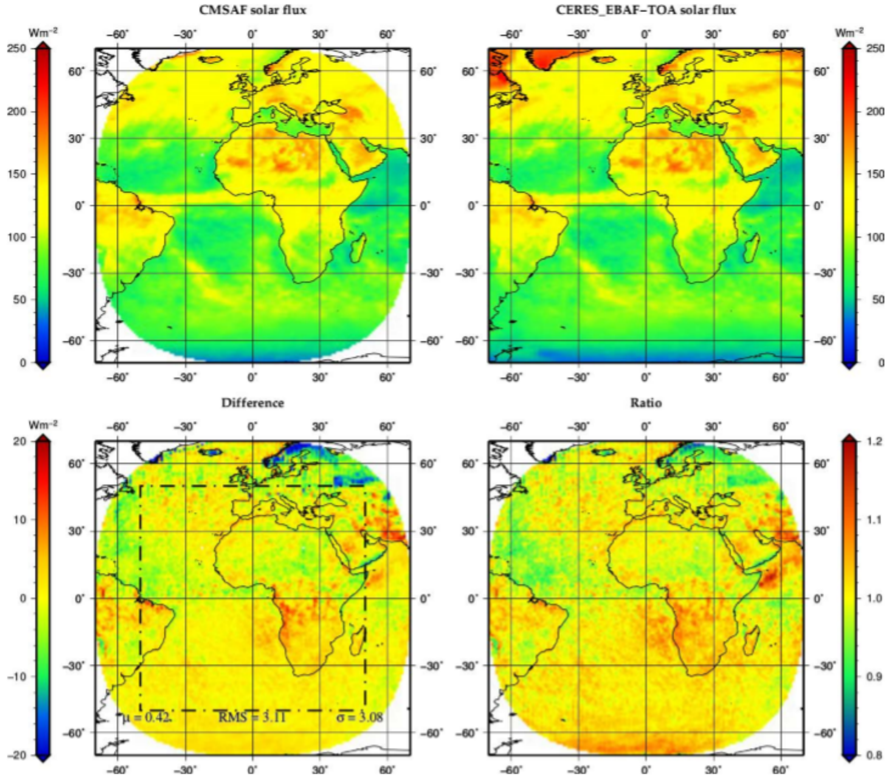


Figure 4: Example of regional comparison between a product *D* and a reference *R*. This particular example shows the comparison of the monthly mean solar flux with respect to CERES EBAF.

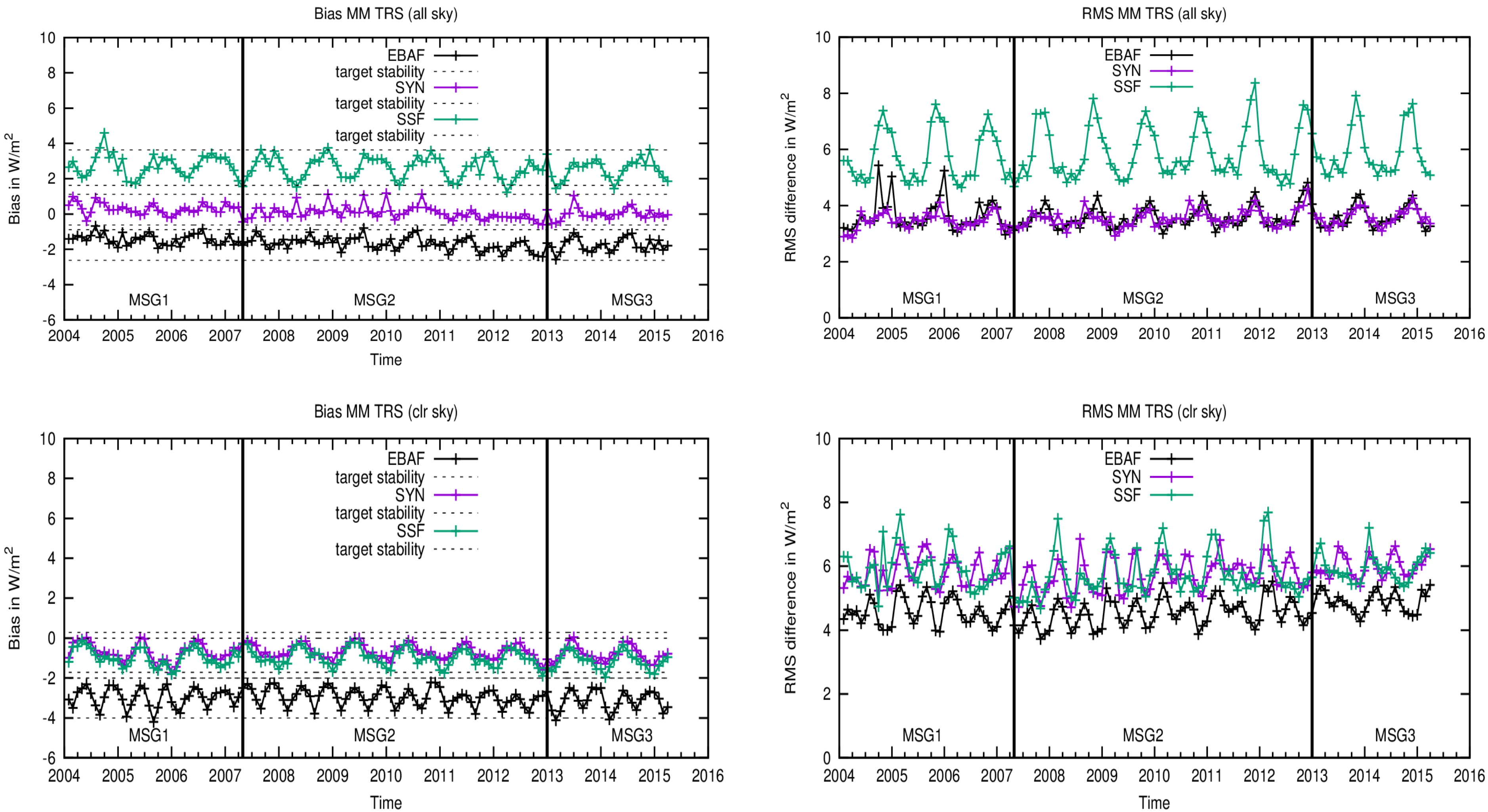
CM SAF TOA radiation GERB/SEVIRI ed02 dataset validation

Product		Requirement (threshold / target optimum)	RMS difference with CERES	
			all sky	clear sky
Monthly Mean	TRS	8/4/2 W/m²	3.5 W/m²	4.6 W/m²
	TET	4/2/1 W/m²	1.8 W/m²	3.0 W/m²
Daily Mean	TRS	16/8/4 W/m²	6.6 W/m²	6.1 W/m²
	TET	8/4/2 W/m²	4.5 W/m²	6.9 W/m²
Monthly Mean Diurnal Cycle	TRS	16/8/4 W/m²	10.9 W/m²	14.1 W/m²
	TET	8/4/2 W/m²	3.7 W/m²	5.6 W/m²

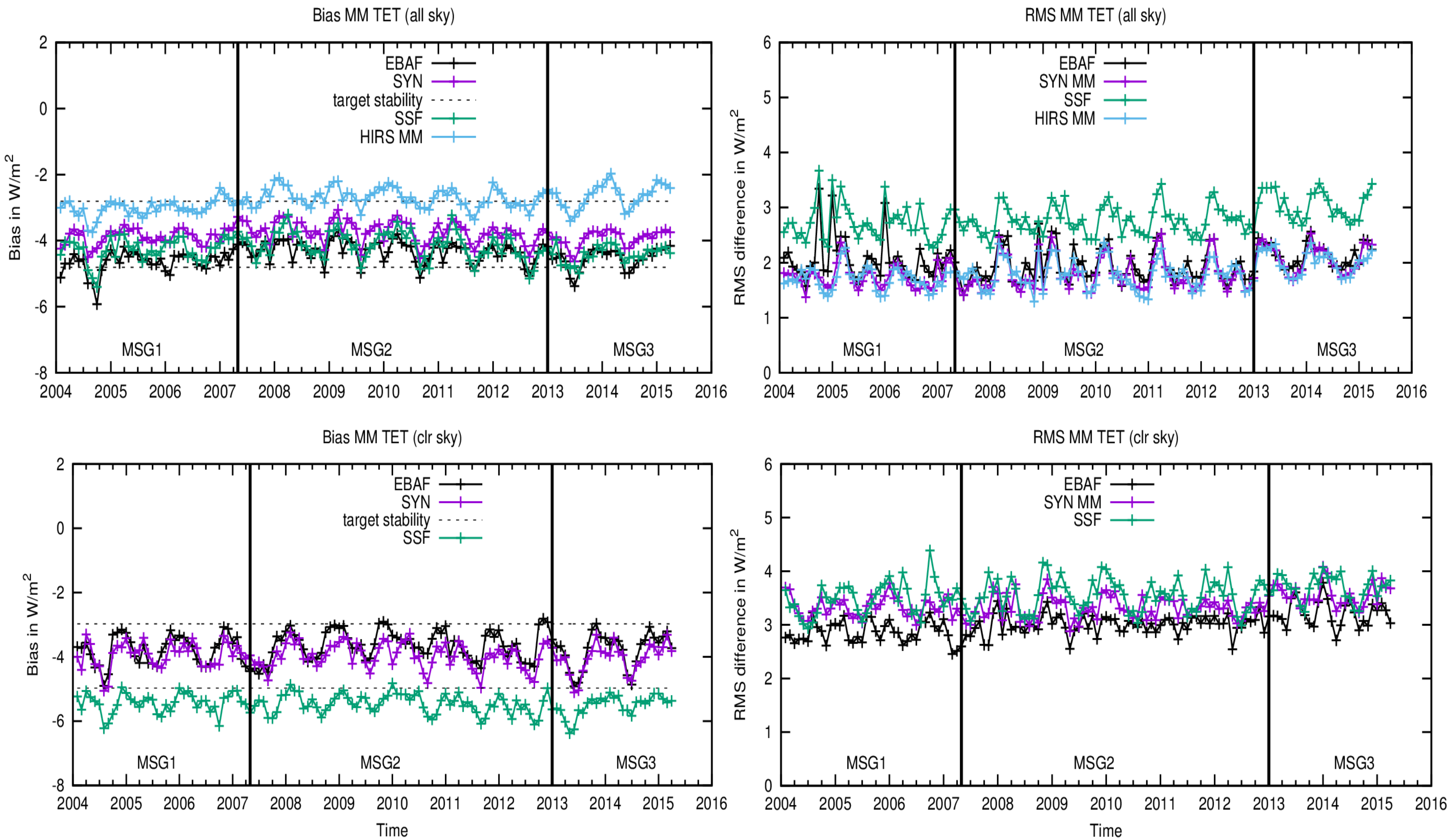
Estimated uncertainty at 1-sigma

(See Validation Report)

Solar flux bias (left) and RMS (right) wrt CERES

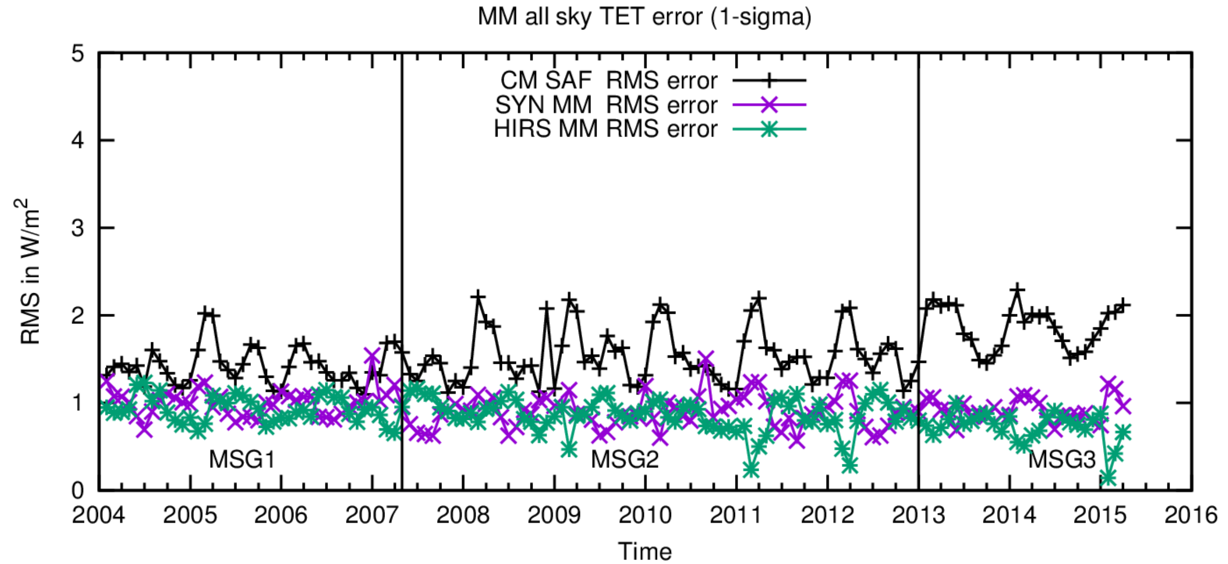


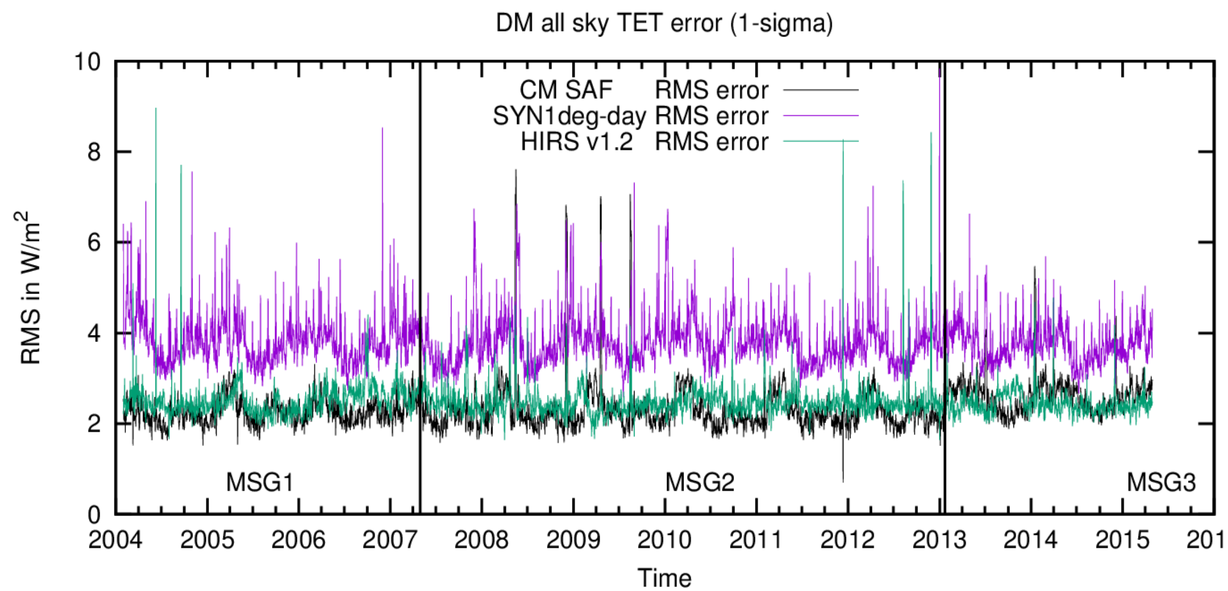
TET Bias (left) and RMS (right) wrt CERES and HIRS OLR



TET Accuracy by comparing 3 sources

$\sigma^2(A) = 0.5 * (RMS^2(A-B) + RMS^2(A-C) - RMS^2(B-C))$
$\sigma^2(B) = 0.5 * (RMS^2(A-B) + RMS^2(B-C) - RMS^2(A-C))$
$\sigma^2(C) = 0.5 * (RMS^2(A-C) + RMS^2(B-C) - RMS^2(A-B))$





Summary

GERB

- Ongoing activities in view of releasing as much data as possible to users but we are facing several unexpected problems

CM SAF

- Several datasets/products available in CM SAF (http://www.cmsaf.eu)
- Concerning TOA radiation:
    - MVIRI/SEVIRI data record (1982-2015)
    - GERB/SEVIRI data record (2004-2015)
- Both have:
    - Fine spatial resolution
    - Diurnal cycle

Thank you !