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The Climate Monitoring SAF TOA Radiation “GERB” Datasets

Nicolas Clerbaux, Edward Baudrez, Ilse Decoster, Steven Dewitte, Alessandro Ipe,
Stijn Nevens and Almudena Velazquez-Blazquez

Royal Meteorological Institute of Belgium, Ringlaan 3 Av. Circulaire, 1180 Brussels, Belgium

Abstract. Since 2004, accurate top-of-the-atmosphere (TOA) broadband reflected solar and emitted thermal fluxes are available from the Geostationary Earth Radiation Budget (GERB) instruments on board the Meteosat Second Generation satellites. In the EUMETSAT Climate Monitoring SAF, those data are used to estimate monthly and daily mean TOA radiation products as well as a monthly mean diurnal cycle product. The daily and the diurnal cycle products take advantage of the geostationary orbit of GERB. Although the averaging process of geostationary observations could seem to be an easy task, different issues have to be taken into account to derive datasets with the highest possible accuracy. The main ones concern (i) the approach used to deal with missing data in the averaging process, (ii) the homogenization of radiometric level between different GERB instruments, and (iii) the correction of drift in instrument sensitivity. Furthermore, from the user point of view, realistic characterization of the monthly, daily and diurnal cycle accuracies is needed. To this end, the inter-comparisons with similar products from CERES (e.g. EBAFs and SYN1deg) is especially interesting as the products for these 2 missions are based on totally independent assumptions and modeling steps. In this paper we present the new Climate Monitoring SAF GERB dataset, the validation results and comparisons with CERES.

Keywords: TOA Earth Radiation Budget, Broadband radiometer, Climate Data Record, GERB, CERES.

PACS: 92.05.Df, 92.05.Fg, 92.60.Ry, 92.60.Vb, 92.70.Np

INTRODUCTION

In the Meteosat Field Of View (FOV), broadband observations of TOA Reflected Solar (TRS) and TOA Emitted Thermal (TET) are available from the Geostationary Earth Radiation Budget (GERB)[1] instruments on the Meteosat Second Generation satellites. GERB Edition-1 instantaneous fluxes are generated [2] by the GERB team and made available to the user community since Feb. 2004. Regard to polar orbiting instruments like CERES, the geostationary orbit of GERB allows broadband observation of the diurnal cycle. This kind of observations is especially asked by climate modelers for validation of the climate models but is also expected to be useful for monitoring of the diurnal cycles.

This paper describes the way the GERB, the SEVIRI and the CERES data are combined to derive the “GERB dataset” of monthly mean TOA fluxes within the Climate Monitoring SAF (CM SAF)[3]. The Spinning Enhanced Visible and InfraRed Imager (SEVIRI) and the Cloud and Earth Radiant Energy System (CERES)[4] data are used to, respectively, fill gaps in the GERB dataset and provide fluxes in the Arctic region. The SEVIRI and CERES observations are also used for validation of the “GERB dataset” [5].

At a first glance, it could seem to be easy to derive accurate monthly means quantities from instantaneous rectified geostationary observations like the TOA fluxes produced by the GERB team: a simple averaging of the images would provide the monthly means (see Figure 1). However, the following points have to be taken into account:

Missing data: different reasons have introduced a large number of gaps in the GERB dataset. Those gaps last from a single 15' Repeat Cycle (RC) up to several consecutive days. The GERB data availability between 1st Feb. 2004 and 31st Jan. 2011, i.e. the period covered by the first edition of the dataset, is provided the GERB “Dataset Generation Capability Description Document” (DGCDD)[6]. It is worth considering that those gaps are mostly not random but can be systematic for some time of the day, e.g. at the terminators and in case of sun glint over ocean, or some months of the year, e.g. during the sun avoidance seasons around the Equinoxes. We have analyzed the pro and contra and decided, within the CM SAF, to fill as much as possible the gaps using a GERB-like data produced from SEVIRI using NB-to-BB technique. The GERB-like data is corrected to the GERB radiometric level.

No coverage of the Arctic region: the geostationary satellite can not see this region or with such a high viewing angle that the estimation of the TOA fluxes is not accurate enough. In this region, it is decided to rely on CERES

data. The need of diurnal model, one important problem for ERB observation with polar satellite, is strongly reduced in the arctic region thanks to frequent overpasses.

Spatial regriding: the input GERB High Resolution (HR) data, provided on a geostationary projection at $(9\text{km})^2$ subsatellite resolution, must be converted to the CM SAF Sinusoidal Equal Area grid at $(45\text{km})^2$ resolution.

Radiometric level: significant differences of radiometric level are observed in the middle of the dataset, at the transition from Meteosat-8 to Meteosat-9. A re-calibration of the observations, described in [7], was then needed to obtain a homogeneous dataset.

Instrumental drift: broadband instruments like GERB or CERES are, in general, more subject to temporal degradation in the SW than narrowband instruments. The correction of the aging is a challenging problem that is best addressed when the length of the dataset is sufficient. Over the 7 years of the “GERB dataset” signs of aging is evident [5] but not enough data is already available for an accurate modeling of the aging.

ALGORITHM OVERVIEW

A complete description of the algorithm can be found in the Algorithm Theoretical Basis Document [7]. Here we just summarize the important points.

Correction factor for GERB-like: the 11-12 UTC and 12-13 UTC hourly intervals are used to estimate the correction factor to be applied to the GERB-like.

Hourly integration: In the nominal case, the hourly average of the flux is obtained from the four $15'$ measurements done within the hourly interval and the 2 measurements done just before and just after the interval. One hourly value is therefore computed from 6 instantaneous GERB fluxes using piecewise linear. In case of missing GERB data, GERB-like data is used. When data are missing, the averaging is done with the available data provided that: (i) there is at least 2 measurements out of the 6, and (ii) that at least one measurement lies in the hourly interval. If “extrapolation” is needed (i.e. the first or the last measurements are missing), the extrapolation is performed at constant value.

Averaging strategy: The basic principle of the averaging is shown on the Figure 1. From the hourly data, the daily means are computed as the average of (up to) 24 values. Similarly, the monthly mean diurnal cycle is estimated as the average of the hourly data over the different days of the month. Finally, the monthly mean images (TRS and TET) are estimated by averaging of the diurnal cycle.

Missing data: The main strategy to cope with the missing GERB data is to use the GERB-like data instead. The GERB-like is a side product of the RMIB GERB Processing [2]) which has mostly the same characteristics except the radiometric calibration and the existence of an additional error due to the NB-to-BB (especially for the TRS).

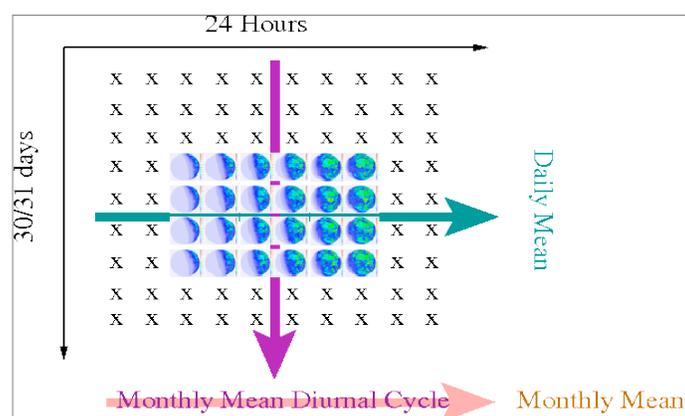


FIGURE 1. Averaging strategy.

Figure 2 provides an illustration of the 6 products provided in the CM SAF dataset.

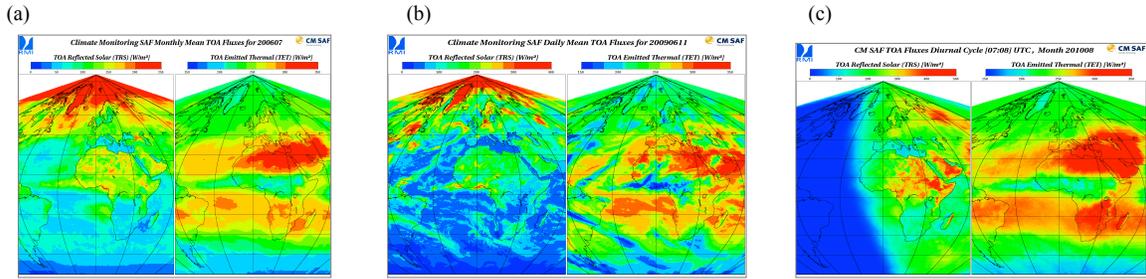


FIGURE 2. Illustration of the TRS (left sides) and TET (right sides) for the : (a) July 2006 month mean, (b) 11 June 2009 daily mean, and (c) August 2010 monthly mean hourly value for [07:08] UTC.

VALIDATION RESULTS SUMMARY

The accuracy of the monthly mean, daily mean and monthly mean diurnal cycle products can be decomposed as in TABLE 1 (extracted from [5]). The main sources of error identified are:

1. The uncertainty in absolute calibration of the GERB instruments.
2. The processing until level 3 (mostly data unfiltering, radiance-to-flux conversion, monthly averaging).
3. The additional errors introduced when GERB-like is used in replacement of GERB.
4. The additional error due to gaps in the data record.

TABLE (1): Summary of TOA Radiation GERB dataset accuracy.

Error sources	Monthly Mean (MM)		Daily Mean (DM)		MM Diurnal Cycle (DC)	
	TRS	TET	TRS	TET	TRS	TET
1. GERB instrument calibration uncertainty at 1 std. dev. [8][9]. The accuracy given in percent is transformed in W/m ² assuming TRS=100 W/m ² and TET 239 W/m ² .	2.25% 2.2 W/m ²	0.96% 2.4 W/m ²	2.25% 2.2 W/m ²	0.96% 2.4 W/m ²	2.25% 4.5 W/m ² (daytime TRS ~ 200 W/m ²)	0.96% 2.4 W/m ²
2. RMS error due to processing (unfiltering, ADM, averaging) estimated by comparison with: CERES EBAF (MM), SYN1deg-day (DM), and SSF (DC).	3 W/m ²	2 W/m ²	5.5 W/m ²	3.6 W/m ²	13.5 W/m ² (6-18UTC)	3.3 W/m ²
3. Additional error due to GERB-like (at 1 std. dev.). This error is given for 100% use of GERB-like but should in practice be multiplied with the actual fraction of GERB-like used in the product (this information is given in the file). This error includes the error due to the estimation of the monthly correction factor.	1.4 W/m ²	1.4 W/m ²	1.85 W/m ²	1.65 W/m ²	2.9 W/m ² (6-18UTC)	1.5 W/m ²
4. Additional error at 1 std. dev. due to missing MSG data (MSG failure, decontamination,...).	Estimated at 0.4 W/m ² (TRS) or 0.3 W/m ² (TET) per missing day. This error can be important for some months in the dataset but is equal to 0 for most of them (65 out of 84).		0.64 W/m ² +/- 0.2 W/m ² / missing repeat cycle (daytime)	0.56 W/m ² +/- 0.1 W/m ² / missing RC	1.9 W/m ² per missing day (at 12-13 UTC)	0.5 W/m ² per missing day
5. Total (RMS of above)	4.0 W/m²	3.4 W/m²	6.2 W/m²	4.6 W/m²	14.5 W/m² (12-13UTC)	4.3 W/m²

DISCUSSION

The assessment of the quality of the CM SAF TOA Radiation GERB Dataset of TRS and TET fluxes is obtained by inter-comparing them with the GERB-like and CERES (EBAF Ed2.6 [10], SYN1deg-day, and SSF) fluxes. The availability of different sources allows to explain the observed differences and to assign any discrepancy to GERB, to SEVIRI or to the CERES instrument and/or processing.

From comparison with CERES EBAF [10] we can estimate the RMS error of the monthly mean TRS and TET fluxes to 3 W/m² and 2 W/m², respectively. Similarly, from comparison with the CERES SYN1deg-day we estimated the RMS error on the daily mean TRS and TET to 5.5 W/m² and 3.6 W/m², respectively. For the monthly mean diurnal cycle we estimate the accuracy to 13.5 W/m² and 3.3 W/m², respectively for the daytime TRS and the TET. Those accuracy figures slightly increase when we account for the uncertainty of the GERB instrument calibration.

The computation of the monthly month GERB dataset is permitted by using GERB-like data to fill gaps in the GERB data record. The validation exercises provided evidence that the approach is valid and quantifies the additional error introduced at 1.4 W/m² at 1 standard deviation for both the monthly mean TRS and TET (slightly higher values are obtained for the daily mean and the MM diurnal cycle, see Table 1). Further improvements could be possible by using directly empirical SEVIRI-to-GERB regressions instead of theoretical regressions corrected in a second step. This is left for further editions of the dataset.

Concerning recommendations for future reprocessing, we suggest deriving GERB-like fluxes also when the backup satellite is replacing the operational one (e.g. following failure or during decontamination). The use of the backup satellite is expected to strongly improve the monthly means products for at least 9 months out of the 84 months considered in this Edition of the dataset.

The apparent aging of the GERB TRS should also be further investigated by the GERB team and, if confirmed, corrected either directly in the dataset or by the users using multiplicative factors provided in the PUM and/or distributed to the users via the CM SAF users list for this dataset.

ACKNOWLEDGMENTS

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