GERB-like data from Meteosat First Generation

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Abstract

The paper address the possibility to derive GERB–like reflected solar flux data from the visible channel of the MVIRI instrument on the Meteosat first generation. Regressions between the visible channel of Meteosat-7 and the GERB unfiltered radiance on Meteosat-8 are derived and validated at regional scale. In most of the field of view, the narrowband–to–broadband error remains less than 1%. However, the study of the stability between averaged GERB and GERB–like fluxes over a 2.5 years time period exhibits a drift of nearly 1% per year. This drift must be understood and corrected before the GERB–like processing can be applied to the entire Meteosat first generation database.

1 Introduction

Since February 2004 direct observation of the broadband radiant energy leaving the Top–Of–Atmosphere (TOA) is available from the Geostationary Earth Radiation Budget (GERB) [Harries et al., 2005] instrument on the Meteosat Second Generation satellites. The GERB database is slowly growing and is now extending over about 3.5 years. Before the GERB era, broadband filtered measurements have been done operationally with the Meteosat Visible and InfraRed Imager (MVIRI) instrument on board of the first generation of Meteosat satellite (Meteosat-1 to -7). In this work we address the possibility to derive GERB–like reflected solar flux data from the visible channel data of the MVIRI instrument. If this is feasible, the 25 years database of GERB and GERB–like data would be a valuable dataset to study climate forcings (surface albedo, aerosols,...) and feedbacks (reflected solar radiation, emitted thermal radiation) at regional scale and for the entire diurnal cycle.

2 The Meteosat visible channel and calibration

The relatively broad visible channel of the MVIRI instrument is sensitive to about 58 % of the reflected solar radiation $L_{sol}(\lambda)$. This number has been estimated is done on a database of simulated spectra at Solar Zenith Angle SZA = 40°, Viewing Zenith Angle VZA = 40°, and Relative Azimuth Angle RAA = 90°. For this geometry, Figure 1 shows the averaged spectral radiance curve $<L(\lambda)>$ over our database as well as the spectral radiance which is not–measured by the instrument $<L(\lambda)(1 - \phi(\lambda))>$. The not–measured radiation contains contributions of similar magnitude from wavelength below and above 0.8 $\mu$m. The first contribution lies in the "blue" part of the spectrum ($\sim 0.43 \mu$m) and this is challenging when ocean surface is observed. The second contribution lies in the near–infrared ($\sim 1.29 \mu$m) at wavelengths where

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Figure 1: (red) averaged spectral radiance curve $< L(\lambda) >$ simulated at $SZA = 40^\circ$, $mathrm{VZA} = 40^\circ$, $mathrm{RAA} = 90^\circ$ and (green) part which is not–measured by the Meteosat-7 visible channel $< L(\lambda)(1 - \phi(\lambda)) >$.

the reflected energy by a cloud is dependent on the thermodynamic phase at its top (ice particles absorb around $1.6 \mu m$). The inference of these 2 contributions can be done based on the visible measurements and ancillary information about the observed scene and the geometry ($SZA$, $VZA$, $RAA$).

State–of–the–art calibration coefficients for the Meteosat’s visible channels have been reprocessed using an adaptation of the SEVIRI Solar Channel Calibration (SSCC) method [Govaerts et al., 2004]. For Meteosat–7 the visible channel gain is estimated as

\begin{equation}
gain = 0.9163 + N \times 5.5195 \times 10^{-5}
\end{equation}

where $N$ is the number of day since the satellite launch (2nd Sep. 1997). This calibration has been used for this work.

3 Derivation of GERB-like data

Simultaneous Edition-1 GERB–2 (the instrument on Meteosat–8) data and Meteosat–7 data are available from 25th March 2004 up to 14 of June 2006. After that date the Meteosat-7 has been relocated over the Indian ocean. So, a bit more than 2 years of corresponding data are available. The observations are no perfectly coangular because during this period Meteosat–8 is located at $3.4^\circ$ longitude West of Meteosat–7. Therefore, the GERB Edition-1 broadband solar radiances have been corrected to simulate the radiance that would have been measured from the Meteosat-7 position. This correction is based on the CERES TRMM Angular Dependency Models (ADMs) [Loeb et al., 2003]

\begin{equation}
L_0^v = L_{3.4^\circ} \frac{R(SZA_0^v, VZA_0^v, RAA_0^v) A(SZA_0^v)}{R(SZA_{3.4^\circ}, VZA_{3.4^\circ}, RAA_{3.4^\circ}) A(SZA_{3.4^\circ})}
\end{equation}
where $L_{3.4^\circ}$ is the unfiltered solar reflected radiance measured by GERB at 3.4° longitude, $L_{0^\circ}$ is the estimation of the radiance that would have been measured from the 0° longitude, $R$ and $A$ are the anisotropic factor and the albedo of the best–suited ADM. For each GERB pixel, the best–suited model is selected among the 592 CERES TRMM models based on the GERB scene identification (surface type, cloudiness). The solar zenith angles $\text{SZA}_{0^\circ}$ and $\text{SZA}_{3.4^\circ}$ can differ slightly to compensate for time differences of up to 300 s which are allowed between GERB and Meteosat observation. The downscaling between the 2.5 km fine spatial resolution Meteosat and the coarse resolution of the Averaged Rectified geolocated (ARG) GERB pixel is realized using box averaging (i.e. square PSF) of $23 \times 45$ Meteosat pixels (i.e. $57.5 \times 112.5$ km at nadir). With the additional constraints on the SZA > 80° and VZA > 80° for both satellite observations, the daily number of corresponding observations is about $5 \times 10^5$. The Meteosat count is converted in NB radiance using the calibration given by Eq.(1).

The huge database of (Meteosat, GERB) couples of observations has been sorted according to the GERB surface type (ocean, dark vegetation, bright vegetation, dark desert, bright desert, snow), the SZA and VZA (in 20° bins), the RAA (in 45° bins) and the type of cloud cover. For this, 6 types of cloudiness are defined according to the cloud fraction CF, the cloud optical depth $\tau$ and the cloud phase $p$:

- clearsky: $\tau < 1$ or $\text{CF} < 25\%$,
- broken cloud: $\tau > = 1$ and $25 < \text{CF} < 75\%$,
- thin cloud water: $< 1 < \tau < 10$ and $\text{CF} > 75\%$ and $p < 50\%$,
- thin cloud ice: $< 1 < \tau < 10$ and $\text{CF} > 75\%$ and $p >= 50\%$,
- thick cloud water: $\tau > 10$ and $\text{CF} > 75\%$ and $p < 50\%$,
- thick cloud ice: $\tau > 10$ and $\text{CF} > 75\%$ and $p >= 50\%$.

This stratification defines 2304 bins. For each of these bins, the best linear fit between the Meteosat VIS reflectance $\rho_{VIS}$ and the GERB broadband reflectance $\rho_{BB}$ (corrected with Eq.(2)) is computed using least mean square criteria

$$\rho_{BB} = a + b \rho_{VIS}$$  \hspace{1cm} (3)

Typical values for the best fit parameters are $a \sim 0.03$ and $b \sim 0.86$, although these values slightly vary from bin to bin.

## 4 Stability

A key attribute of all climate dataset is its long term stability. According to [Ohring et al., 2005] the required stability for reflected solar radiance is 0.1 Wm$^{-2}$sr$^{-1}$ per decade. Figure 2 shows the stability of the ratio between GERB–like and (corrected) GERB reflected solar radiances on a daily basis. Although there exist important gaps on Figure 2, a general trend of about 1%/year is clearly observed in the ratio GERB–like/GERB. This trend turns into a value of $\sim 7$ Wm$^{-2}$sr$^{-1}$ per decade... The cause of this drift is currently under investigation. It is planned to performed the same exercise using the MSG High Resolution Visible (HRV) data to establish whether the drift is coming from the Meteosat–7 or from the GERB shortwave channel calibration.
5 Regional accuracy

Figures 3 shows the seasonal ratio of the averaged $<\text{GERB-like}>/ <\text{GERB}>$. High relative errors (i.e. in percent) are observed over some clear ocean regions but the absolute error (i.e. in W m$^{-2}$ sr$^{-1}$) remains however small. The effect of aerosol over the tropical ocean is well visible during the spring and the summer seasons. The GERB–like processing works correctly (absolute error below 1%) over most of the land surfaces, except over Southern Africa during summer and fall seasons. In this case underestimation of up to 4% regard to GERB is observed. The reason for this is that most of the area is classified as bright vegetation geotype but the vegetation content during this period is very low.

6 Use in Climate Monitoring SAF

Figure 4 illustrates the possible future use of Meteosat GERB–like data within the Climate Monitoring SAF project. The left and right panels show the monthly means TOA reflected solar flux for January 2005 for GERB (left) and Meteosat-7 GERB–like (right).

7 Conclusions and future works

Empirical narrowband–to–broadband regression for the visible channel of the Meteosat first generation works relatively well, provided that the regression is dependent on scene type and viewing and solar geometry. Concerning the land surface, improved performances should be obtained by making the regressions dependent on the vegetation content. This could be done by using seasonal climatology of the vegetation coverage or instantaneous vegetation index. On the other hand, the study of the stability exhibits a
Figure 3: Regional and seasonal average ratio of GERB-like/GERB.
significant drift of nearly 1\% / year. The cause of this drift must be fully understood and corrected before the GERB–like processing can be apply over the full Meteosat first generation database.

In addition to the visible channel unfiltering analyzed in this paper, empirical regressions to derive the Outgoing Longwave Radiation (OLR) from the infrared window and water vapor channels will be developed following a similar methodology but an adapted scene type stratification.

References


