Composite TOA clear–sky solar fluxes for the GERB processing

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Abstract

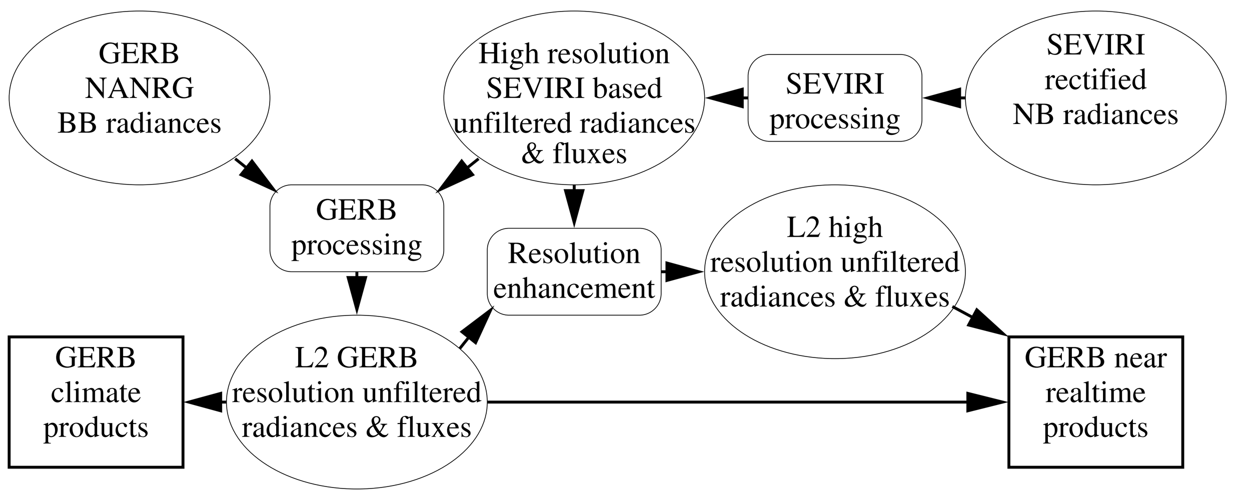
The estimation of the top–of–the–atmosphere (TOA) composite clear–sky fluxes is crucial in climate research. Indeed, such quantities serve as diagnostic variables to assess the accuracy of General Circulation Models (GCMs). They can also, once inverted, provide the surface albedos which in turns can be ingested in GCMs or monitored for changes. Moreover, they allow to estimate the cloud radiative forcing as well as its variations when considering decadal time–series. This has drawn the need to generate a dedicated TOA clear–sky flux product within the Geostationary Earth Radiation Budget (GERB) experiment.

The majority of techniques found in the literature to infer the solar clear–sky fluxes at a given repeat cycle considers the average of the fluxes associated to clear–sky conditions over some time period. A refinement of this approach consists to substitute the averaging process by a spline fit. Similarly, other methods operates on a shorter time period but increases the sampling to the complete diurnal cycle. Binning of these clear–sky samples according to the time allows to fit a spline, half-sine or even a more complex modeled curve. However, these techniques suffers from major drawbacks. First, the averaging does not take into account of the variability of the clear–sky fluxes with the solar zenith angle over the time period. Then, abovementioned curve fitting exclusively relies on theoretical models and not on measurements.

In this paper, we propose a new method to estimate solar clear–sky fluxes for the GERB processing without such drawbacks. It considers solar fluxes at a given repeat cycle and location over some time period. To maximize the number of clear–sky events within the GERB product footprints, it uses the High Resolution GERB L20 solar flux products as input. Moreover, the time period is dynamically chosen to enclose a fixed number of clear–sky conditions according to the scene identification provided in the products. It results that each footprint can be associated to a time–series of fluxes. Since the clear–sky fluxes are varying with the solar zenith angles over this time period, the clear–sky Clouds and the Earth's Radiant Energy System (CERES) shortwave broadband angular dependency models (ADMs) are used to model this variability. Composite clear–sky fluxes can then be derived for cloudy conditions over the time period based on such knowledge of their angular variations. Preliminary results are given together with a sensitivity study of the considered parameters.

1 Algorithm

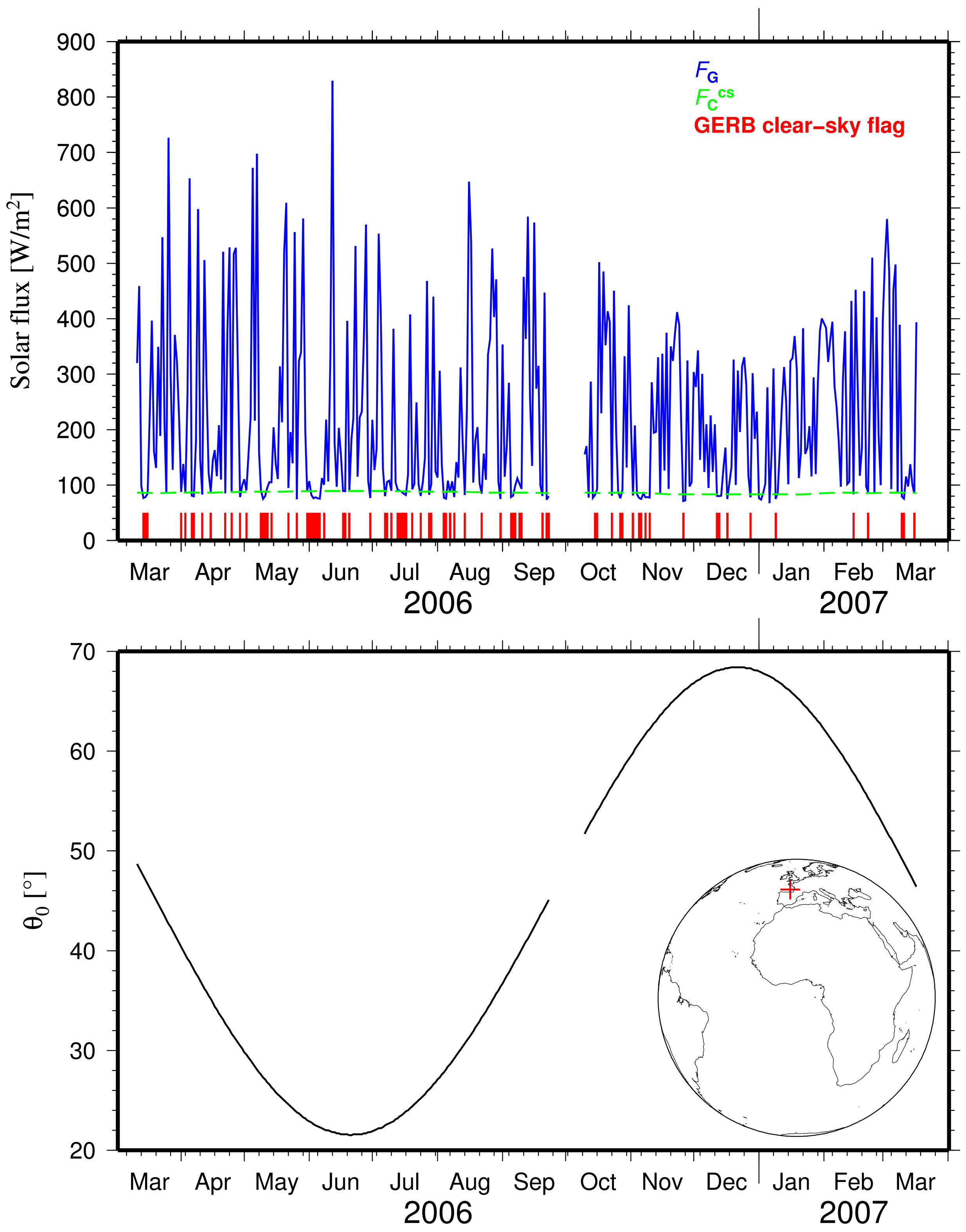
We propose here a method to estimate the instantaneous composite TOA solar clear–sky fluxes from the GERB L20 products. The GERB L20 processing is natively performed over 3×3 SEVIRI pixels footprints (about 10 km at nadir). The resulting high–resolution (HR) L20 products are then averaged or convoluted with the GERB point spread function (PSF) to the GERB instrument resolution (50 km at nadir) to generate the ARG and BARG products [2]. It is therefore obvious that any clear–sky estimation method will have to be based on HR products to reduce any errors resulting from the averaging/convolution process. Moreover, considering HR footprints allows to mitigate the number of partially cloud–filled footprints at the benefit of clear–sky (and overcast) footprints population.



This method is directly inspired from a previous technique which was developed to estimate composite TOA reflectances from visible SEVIRI channels [3]. It considers flux time–series at a given location (x, y) in the field–of–view (FOV) and repeat cycle (time of day t) up to Δ previous days from the current day $d^\star$. Basically, it assumes that the signal (flux time–series) can be separated into a clear–sky base curve on top of which a transient contribution is added depending on the atmospheric conditions (cloudiness, dust, aerosols, shadows). To take into account the slow varying dependency of the clear–sky fluxes over time with respect to the Sun position (solar zenith angle θ_0), the ratio α between GERB and the climatological CERES Tropical Rainfall Monitoring Mission (TRMM) clear–sky fluxes built from the associated shortwave broadband ADMs is considered:

$$\alpha(x,y,d,t) = \frac{F_G(x,y,d,t)}{\underbrace{A(\theta_0)\cdot E_0\cdot\cos\theta_0}_{F_C^{cs}(x,y,d,t)}} \qquad \text{for} \quad d = d^\star - \Delta,\ldots,d^\star,$$

where F_G is the GERB solar flux, F_C^{cs} the CERES TRMM climatological clear–sky flux, A the CERES TRMM climatological clear–sky albedo from the associated ADM and E_0 the solar constant taken equal to $1366\ \mathrm{W\cdot m^{-2}}$. We are implicitly assuming the dependency of θ_0 with (x, y, d, t).



Time–series for an ocean scene (44.97 N, 3.40 E) at 12:00 UTC.

The difference lies in the fact that the solar GERB fluxes are available together with ancillary data from the SEVIRI scene identification (sceneID) such as the associated cloud fraction [4] and ocean dust detection [1] over the HR footprints. We can therefore use such knowledge in our algorithm to filter the α values and to provide a set of ratio $\{\alpha^{cs}(x,y,d_n^{cs},t)$ where $n = 1,\ldots,N(x,y,d^\star,\Delta)\}$ associated to clear–sky conditions over the Δ previous days. The method then reduces to the selection of the most representative $\alpha^{cs}(x,y,d_k^{cs},t)$ from the previous set. The composite clear–sky flux F_G^{cs} is finally estimated from:

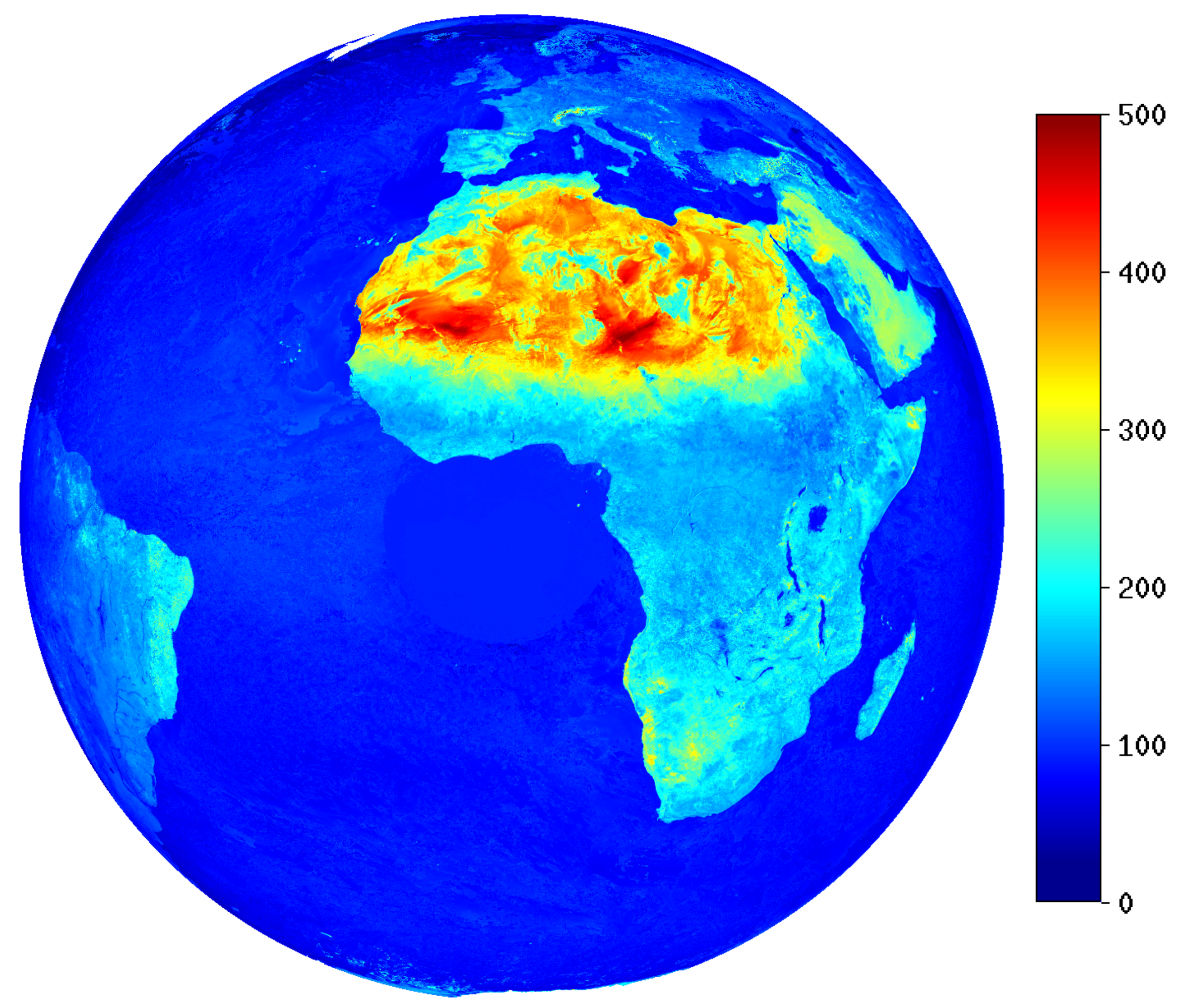
$$F_G^{cs}(d^\star) = \alpha^{cs}(d_k^{cs}) \cdot F_C^{cs}(d^\star)$$

where the dependency in (x, y, t) has been dropped for clarity. However, it is obvious that any selection strategy has to ensure that the composite clear–sky flux should be equal to the GERB flux for scenes identified as clear–sky by the sceneID. Moreover, due to persistent cloudiness over equatorial regions, Δ should be large enough to avoid the emptiness of the set $\{\alpha^{cs}\}$.

2 Preliminary results

Since the Edition 1 of the GERB HR products are only available after undergoing a strict quality assurance (QA) check, the fluxes of the sun–glint affected area within the FOV which do not satisfy this QA are masked out. Thus, the development and the improvement of our algorithm is carried out on GERB–like HR products. These products are only differing from the GERB HR products in the sense that the fluxes are estimated through a narrowband–to–broadband estimation from SEVIRI data and not corrected by the GERB instrument measurements. Moreover, fluxes in these products are provided over sun–glint regions.

The preliminary results F_G^{cs} showed here are computed by using $\Delta = 120$ days and selecting $\alpha^{cs}(x,y,d_k^{cs},t)$ as the most recent value relatively to the current day $d^\star$ within the set $\{\alpha^{cs}\}$.



Solar clear–sky GERB–like fluxes F_G^{cs} $[\mathrm{W\cdot m^{-2}}]$ for March 11 2007 at 12:00 UTC.

3 Future validation

The foreseen validation of the TOA GERB solar clear–sky fluxes once the algorithm will be finalized is twofold:

- Instantaneous solar clear–sky fluxes should exhibit a symmetric diurnal cycle with respect to the local noon. Such property will be used to assess the accuracy of those composite fluxes compared to an "ideal" (fitted) diurnal cycle.
- Monthly averaged fluxes will be compared to the CERES Energy Balanced and Filled (EBAF) TOA monthly fluxes [5]. However, discrepancies are expected to occur to some extent due to different broadband radiometers, sceneIDs and satellite orbits. Moreover, to perform meaningful comparisons, both datasets will first have to be corrected for any systematic offset.

4 Perspectives

Once validated both on an instantaneous as well as on a monthly basis, these clear–sky fluxes will allow to study the radiative forcing of clouds and aerosols according to their type, thermodynamic phase (for clouds) and/or optical depth. Such instantaneous radiative forcing studies will surely improve various parametrization schemes within GCMs and NWP models. On a longer time–scale, decadal study of these radiative forcing could provide an insight on the response of the global circulation with respect to the climate change.

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