Direct Unfiltering of GERB Data

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Abstract

This technical note describes the transformation of the GERB SW and LW filtered measurements into unfiltered solar and thermal radiances. The method is called ”direct unfiltering” as none spectral information from SEVIRI is needed, in contrario with the operational GERB unfiltering which uses some spectral information from the SEVIRI imager. This technical note provides the laws and parameters for the direct unfiltering of the GERB-2 and GERB-1 with the more recent version of the spectral response curves.

Contents

1 Introduction and Spectral Response Curves

A broadband radiometer typically measures filtered shortwave L_{sw} and longwave L_{lw} radiances. These radiances have to be converted into unfiltered reflected solar radiance L_{sol} and emitted thermal L_{th} radiance. This process is called unfiltering and consists in the estimation of the unfiltering factor α and the estimation of the contaminations:

$$L_{sol} = \alpha_{sw}(L_{sw} - L_{sw,th}) \tag{1}$$

$$L_{th} = \alpha_{lw}(L_{lw} - L_{lw,sol}) \tag{2}$$

where $L_{sw,th}$ is the thermal contamination in the SW channel and $L_{lw,sol}$ the solar contamination in the LW channel. For GERB the longwave radiance is not measured but is estimated from the TOT and SW measurements as

$$L_{lw} = L_{tot} - AL_{sw} \tag{3}$$

with the A factor set in such a way that the longwave radiance for a solar spectrum is zero

$$A = \frac{\int L_{5800K}(\lambda)\phi_{tot}(\lambda)d\lambda}{\int L_{5800K}(\lambda)\phi_{sw}(\lambda)d\lambda} \tag{4}$$

The operational GERB unfiltering is based on spectral information provided by the NB measurements of the SEVIRI imager as described in (Clerbaux et al., 2008b) and (Clerbaux et al., 2008a), respectively for the solar and thermal radiation.

In this technical note we present an unfiltering method that does not use any information from the SEVIRI instrument. This alternative unfiltering method can be of interest to derive unfiltered radiance directly from the Level 1.5 NANRG file (for example to study the detector-to-detector variability) or in case of inaccurate geolocation of the GERB measurements. The unfiltering is based on the observed BB measurements and on a crude surface type classification (ocean, vegetation, desert). The direct unfiltering method presented in this technical note is close to the operational CERES unfiltering method which is described in (Loeb et al., 2001).

The parameterization of the unfiltering and the estimation of the unfiltering error is based on 2 databases of spectral radiance curves. The first one contains simulated spectral radiance $L(\lambda)$ curves for reflected solar radiation and the second database for emitted thermal radiation. The generation of these databases is described in (Clerbaux et al., 2008b) and (Clerbaux et al., 2008a), and in the technical note (Clerbaux, 2007) (to be updated).

This document does not deal with the slight differences that exist between the spectral response curves of the different detectors of the GERB instrument (i.e. between the lines in the NANRG image). The correction for this dispersion in spectral response is described in (Clerbaux, 1999) but is not used in practice as the magnitude of this variability seems smaller than the incertainties in the SR characterization (to be confirmed).

In this technical note, we use the spectral response curves of the GERB-2 instrument (launched on MSG-1) as provided by Imperial College with labelling version "08072005". The Edition-1 of the GERB-2 dataset is based on these spectral response curves. The parameters for GERB-1 (on MSG2) are also provided but refer to a pre-release version of the curves. Indeed, a problem has been detected that needs the reprocessing of the GERB-1 detector spectral response. In the meanwhile, the spectral response of the GERB-1 detectors is set to the average curves of the GERB-2 detectors. Figure 1 shows the GERB-2 and GERB-1 averaged spectral response curves used in this technical note.

2 Unfiltering the shortwave channel

The mean filtered radiances and unfiltering factors are estimated for the "clear ocean" (L_o and α_o) and for the "cloud" (L_c and α_c). These values are used to defined "normalized filtered radiance" x and "normalized unfiltering factor" y as

$$x = \frac{L - L_o}{L_c - L_o} \tag{5}$$

$$y = \frac{\alpha - \alpha_c}{\alpha_o - \alpha_c} \tag{6}$$

The value of x normally lies in the range [0:1] while the value of y can be slightly negative over land surface. The following fit is used to estimate the unfiltering factor y from the filtered radiance x:

$$y = a + \frac{b}{(x+c)} + \frac{d}{(x+c)^2} \tag{7}$$

with the additional constraints that the fit must pass by the "clear ocean point" ($x = 0$,$y = 1$) and by the "cloud point" ($x = 1$,$y = 0$). So, there are only 2 free parameters in the set a, b, c, d.

For each $SZA = 0°, 10°, ..., 70°$, the various parameters are derived from the database of SBDART solar simulations. For this, the curves for $VZA = 0°, 15°, 30°, 45°, 60°$ and $RAA = 40°, 90°, 130°, 180°$ are mixed together to have unfiltering only dependent on the SZA (it is also possible to have unfiltering fit dependent on the 3 angles).

In practice:

- The clear ocean features (L_o and α_o) are estimated as the averaged L and α values for the clear ocean scenes in the database.
- The cloud features (L_c and α_c) are estimated as the averaged L and α values on the 10% brightest cloudy scenes in the database.
- For each scene types (ocean, vege, desert), an optimization under constraints is done to find the best parameters a, b, c, d that minimize the residual RMS error on the estimated y value.

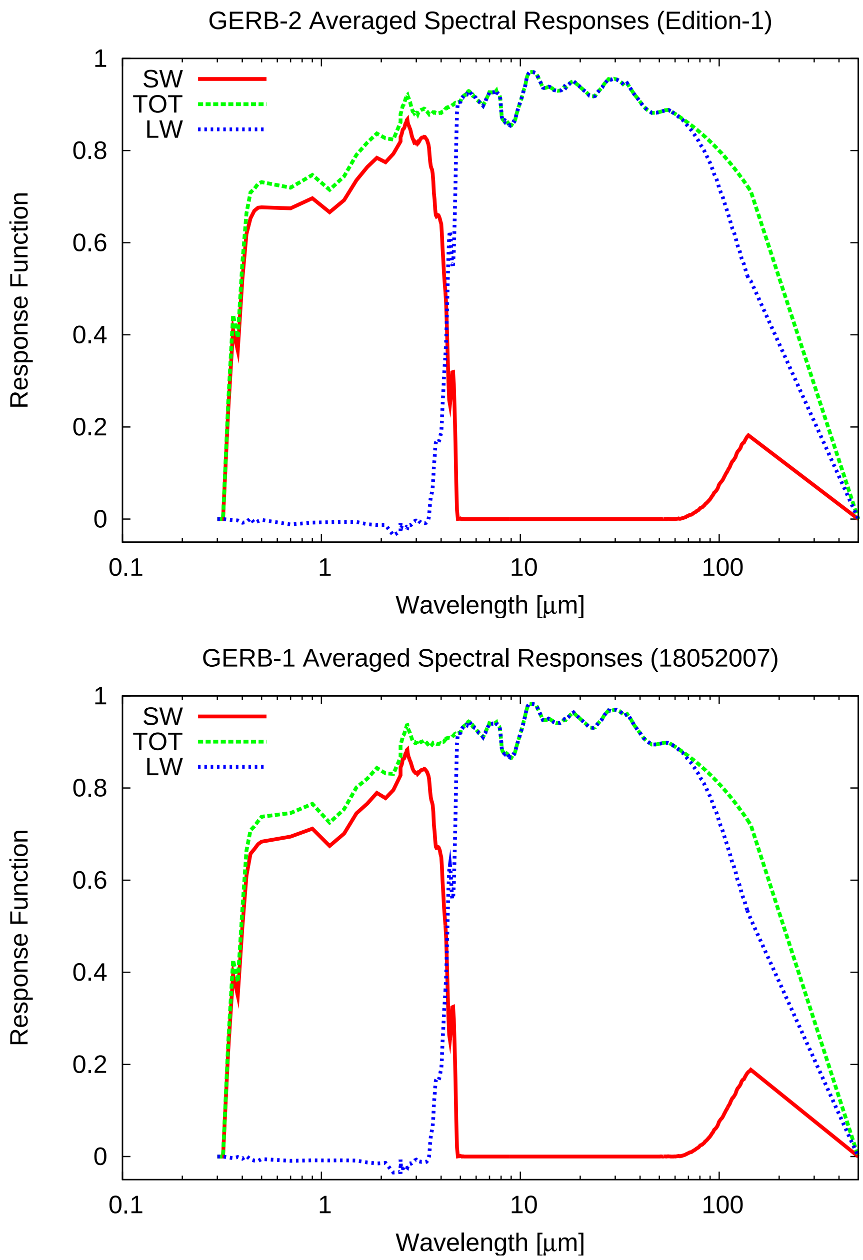

Figure 1: Top: averaged GERB-2 spectral response curves used for the Edition-1 processing. Bottom: Interim curve for GERB-1 (based on the G2 detector measurements).

Figure (2) illustrates the scatter plot of (x, y) values for the 3 surface types and the corresponding best fits for the $SZA = 0°, 30°, 60°$. We can see that the 3 fits are forced to cross on the $(x = 0, y = 1)$ and $(x = 1, y = 0)$ points. The interest of this is to limit the error introduced by an incorect surface type characterization (for example if, due an incorrect geolocation, the vegetation fit is used over a clear ocean pixel).

Table (1) gives the various parameters for the 3 surface type and for $SZA = 0°, 10°, ..., 70°$.

Table (2) gives the root mean square error of the direct unfiltering for the GERB-2 shortwave channel (similar numbers are for GERB-1). Cloudy scenes have about 1% RMS error, clear ocean 2% to 3% and clear land between 1% and 2%.

3 Shortwave thermal contamination

Figure (3) displays the scatterplots of $L_{sw,th}$ versus $L_{lw,th}$ for the 4620 scenes in the database of thermal simulations for different VZA. The contamination can be estimated as:

$$L_{sw,th} = a(VZA) + b(VZA)L_{lw,th}^4 \tag{8}$$

Table (3) gives the best fit parameters $a(VZA)$ and $b(VZA)$ and the RMS error of the fit for GERB-2 and GERB-1. All scene together the RMS error is about $0.07Wm^{-2}sr^{-1}$ but much higher error are abserved for warm scenes ($L_{lw,th} > 80Wm^{-2}sr^{-1}$) in the database. Up to $0.5Wm^{-2}sr^{-1}$ RMS errors are observed on Figure 3.

4 Unfiltering the longwave channel

Figures (4) show the scatterplots of unfiltering factor $\alpha_{lw,th}$ versus $L_{lw,th}$ for the scenes in the database at viewing zenith angle of $VZA = 0°$, $40°$, and $80°$. On those figures, a third order regression appears well-suited to estimate the unfiltering factor

$$\alpha_{lw,th} = \frac{L_{th}}{L_{lw,th}} = a(VZA) + b(VZA)L_{lw,th} + c(VZA)L_{lw,th}^2 + d(VZA)L_{lw,th}^3 \tag{9}$$

The parameterization of the unfiltering parameters is done by fitting the Eq.(9) on the database. Table 4 gives the best fit parameters a, b, c, d according to the viewing zenith angle VZA as well as the RMS error of the fit in %. The residual RMS error on the longwave unfiltering factor α is about 0.1% .

5 Longwave solar contamination

Figure (5) presents the scatterplots of $L_{lw,sol}$ versus $L_{sw,sol}$ for the scenes in the database and for Solar Zenith Angle of $SZA = 0°$, $40°$, and $80°$.

The contamination can be estimated as:

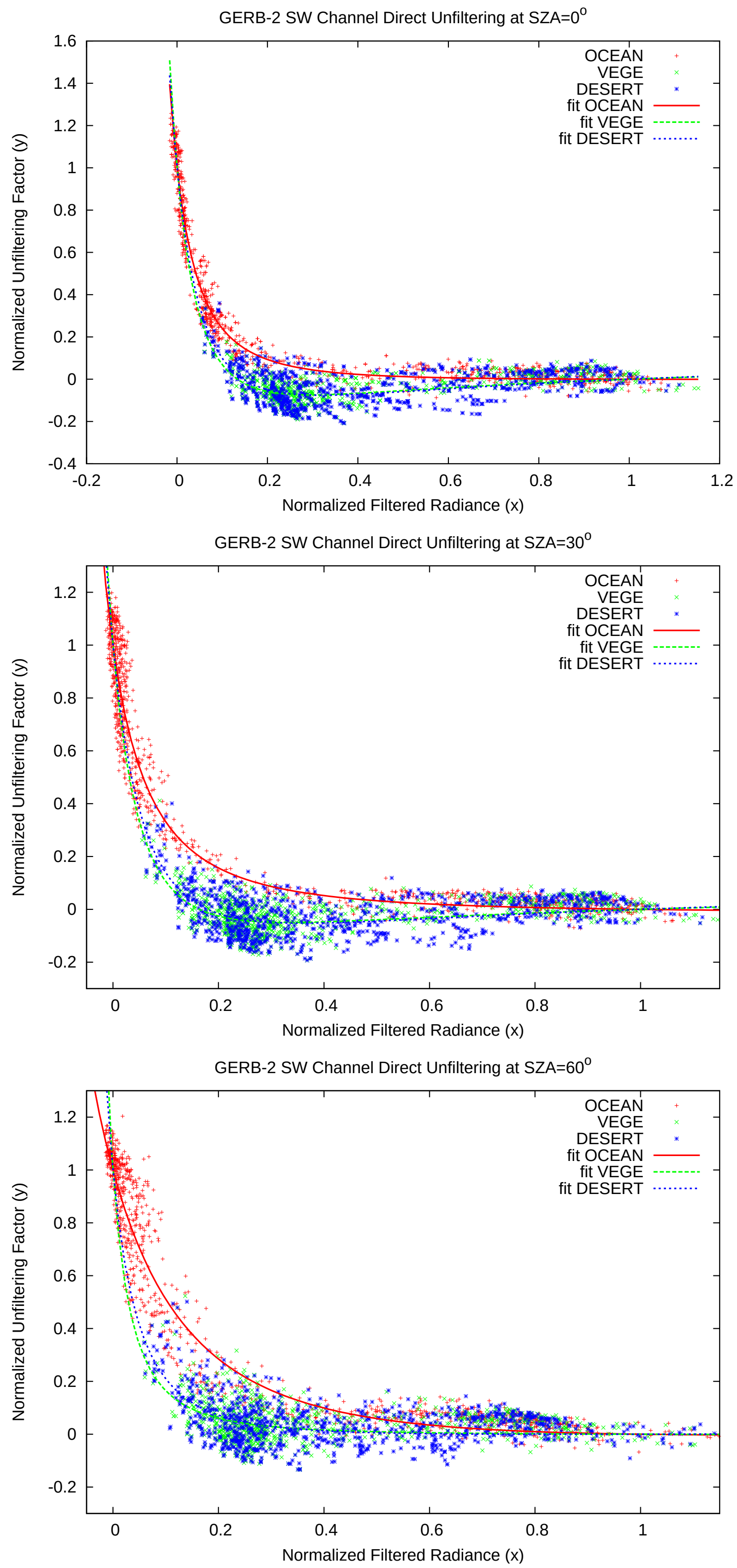

Figure 2: Scatter plot and best fit for the $SZA = 0°$, $30°$ and $60°$.

SZA [°]	L_o $[Wm^{-2}sr^{-1}]$	L_c $[Wm^{-2}sr^{-1}]$	α_o	α_c	OCEAN a	b	c	d
0	11.71466	227.59435	1.82876	1.54242	-0.02149	0.11330	0.01518	0.11437
10	11.47762	223.53845	1.83612	1.54221	-0.00800	0.10521	0.01194	0.10876
20	10.89129	212.20883	1.84074	1.54143	0.01463	0.09779	0.00833	0.10079
30	9.78713	194.00156	1.84382	1.54025	-0.00388	0.14300	0.02127	0.09090
40	8.46129	170.42718	1.85181	1.53820	-0.10990	0.22947	0.07581	0.07007
50	7.34500	143.49185	1.85208	1.53546	-0.22062	0.30059	0.14932	0.03947
60	6.36887	113.97197	1.83704	1.53109	-0.24569	0.34910	0.19876	-0.00165
70	5.41533	80.31106	1.80490	1.52718	-0.17437	0.36914	0.19765	-0.03080

SZA [°]	VEGETATION a	b	c	d	DESERT a	b	c	d
0	0.00706	-0.15791	0.12357	0.03304	0.13719	-0.19632	0.14200	0.04528
10	-0.00253	-0.15026	0.12217	0.03166	0.13145	-0.18831	0.14084	0.04375
20	-0.02024	-0.14004	0.12147	0.03028	0.12351	-0.17819	0.14093	0.04252
30	-0.01289	-0.12794	0.12196	0.02913	0.11475	-0.16829	0.14353	0.04239
40	0.03924	-0.10005	0.11672	0.02435	0.09433	-0.14095	0.14130	0.03800
50	0.08136	-0.05813	0.10274	0.01611	0.06241	-0.09607	0.13139	0.02881
60	0.07291	-0.00341	0.07285	0.00556	0.01438	-0.02887	0.10682	0.01433
70	0.02192	0.03174	0.03120	0.00001	-0.03188	0.03207	0.06062	0.00185

SZA [°]	L_o $[Wm^{-2}sr^{-1}]$	L_c $[Wm^{-2}sr^{-1}]$	α_o	α_c	OCEAN a	b	c	d
0	11.70448	230.48807	1.83084	1.52275	-0.01780	0.11086	0.01421	0.11488
10	11.46364	226.42105	1.83888	1.52251	-0.00511	0.10292	0.01117	0.10908
20	10.87648	214.96983	1.84378	1.52176	0.01582	0.09600	0.00789	0.10151
30	9.77361	196.45836	1.84672	1.52060	-0.00211	0.14092	0.02043	0.09239
40	8.44582	172.63783	1.85564	1.51850	-0.10567	0.22642	0.07327	0.07162
50	7.32986	145.35730	1.85633	1.51578	-0.21889	0.29807	0.14685	0.04156
60	6.35716	115.45905	1.84284	1.51139	-0.22761	0.33751	0.18300	0.00052
70	5.40970	81.36102	1.80728	1.50751	-0.19247	0.37029	0.20403	-0.03011

SZA [°]	VEGETATION a	b	c	d	DESERT a	b	c	d
0	0.00451	-0.15891	0.12436	0.03345	0.13300	-0.19042	0.14106	0.04411
10	-0.00454	-0.15098	0.12288	0.03200	0.12709	-0.18214	0.13975	0.04250
20	-0.02100	-0.14131	0.12233	0.03073	0.11969	-0.17279	0.13996	0.04143
30	-0.01384	-0.13035	0.12323	0.02985	0.11191	-0.16434	0.14296	0.04164
40	0.03745	-0.10246	0.11804	0.02503	0.09179	-0.13739	0.14064	0.03728
50	0.08147	-0.06119	0.10457	0.01688	0.06114	-0.09440	0.13119	0.02854
60	0.06788	-0.00625	0.07519	0.00612	0.01433	-0.02879	0.10680	0.01432
70	0.03180	0.03102	0.03095	0.00003	-0.03128	0.03127	0.06259	0.00208

Table 1: Parameters for the direct unfiltering of the GERB-2 (top) and GERB-1 (bottom) SW channel.

SZA [°]	OCEAN clear	OCEAN cloudy	VEGETATION clear	VEGETATION cloudy	DESERT clear	DESERT cloudy
0	1.78%	0.72%	1.09%	0.94%	1.36%	1.01%
10	1.71%	0.67%	1.10%	0.90%	1.36%	0.98%
20	2.22%	0.66%	1.14%	0.90%	1.37%	0.98%
30	2.60%	0.69%	1.20%	0.93%	1.39%	1.00%
40	2.58%	0.76%	1.29%	0.94%	1.42%	1.02%
50	2.58%	0.85%	1.40%	0.97%	1.48%	1.05%
60	2.78%	0.94%	1.53%	1.06%	1.56%	1.12%
70	2.81%	0.95%	1.64%	1.13%	1.65%	1.14%

Table 2: RMS error associated with the direct unfiltering of the GERB-2 SW channel.

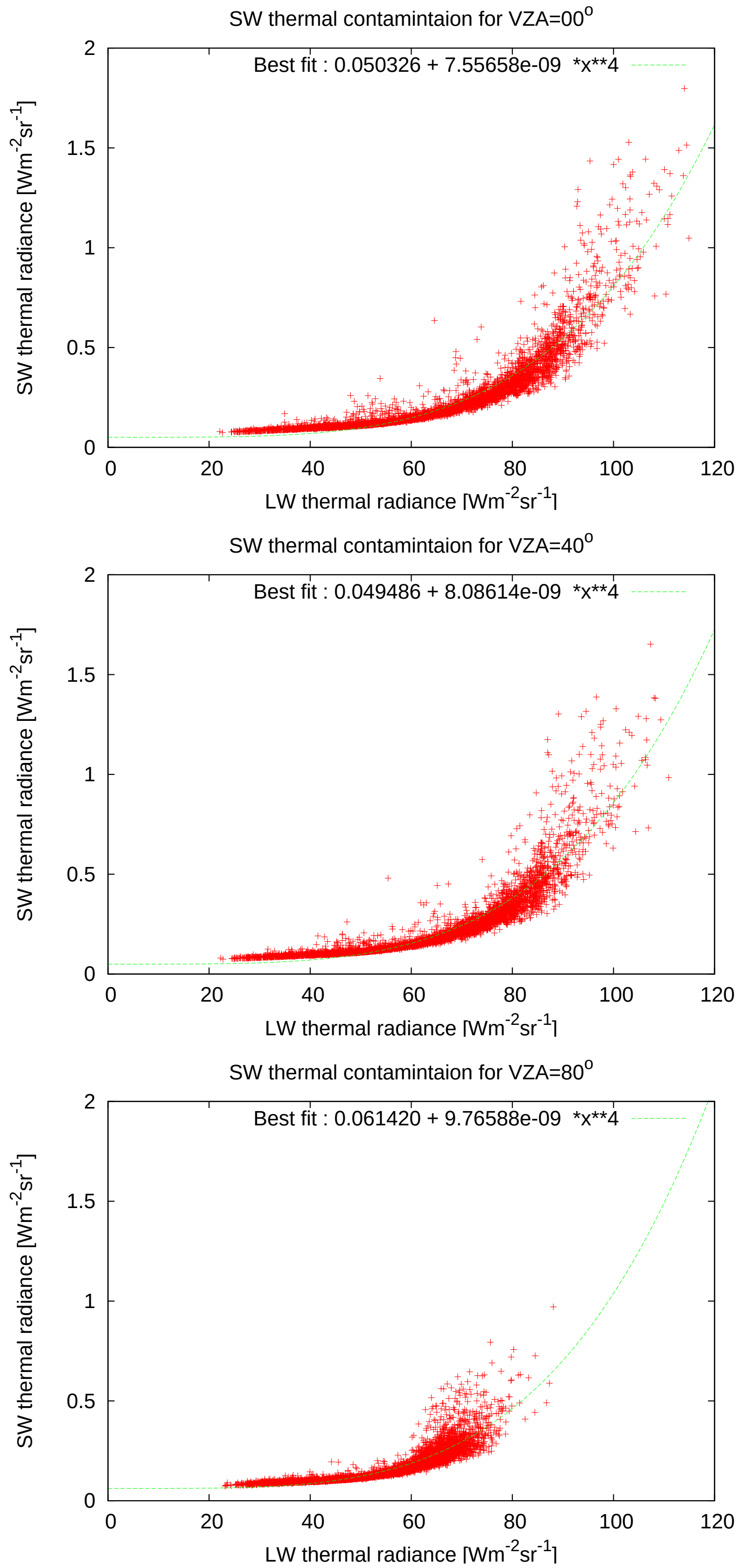

Figure 3: Shortwave thermal radiance $L_{sw,th}$ as a function of the longwave thermal radiance $L_{lw,th}$ for: $VZA = 0°, 40°, 80°$.

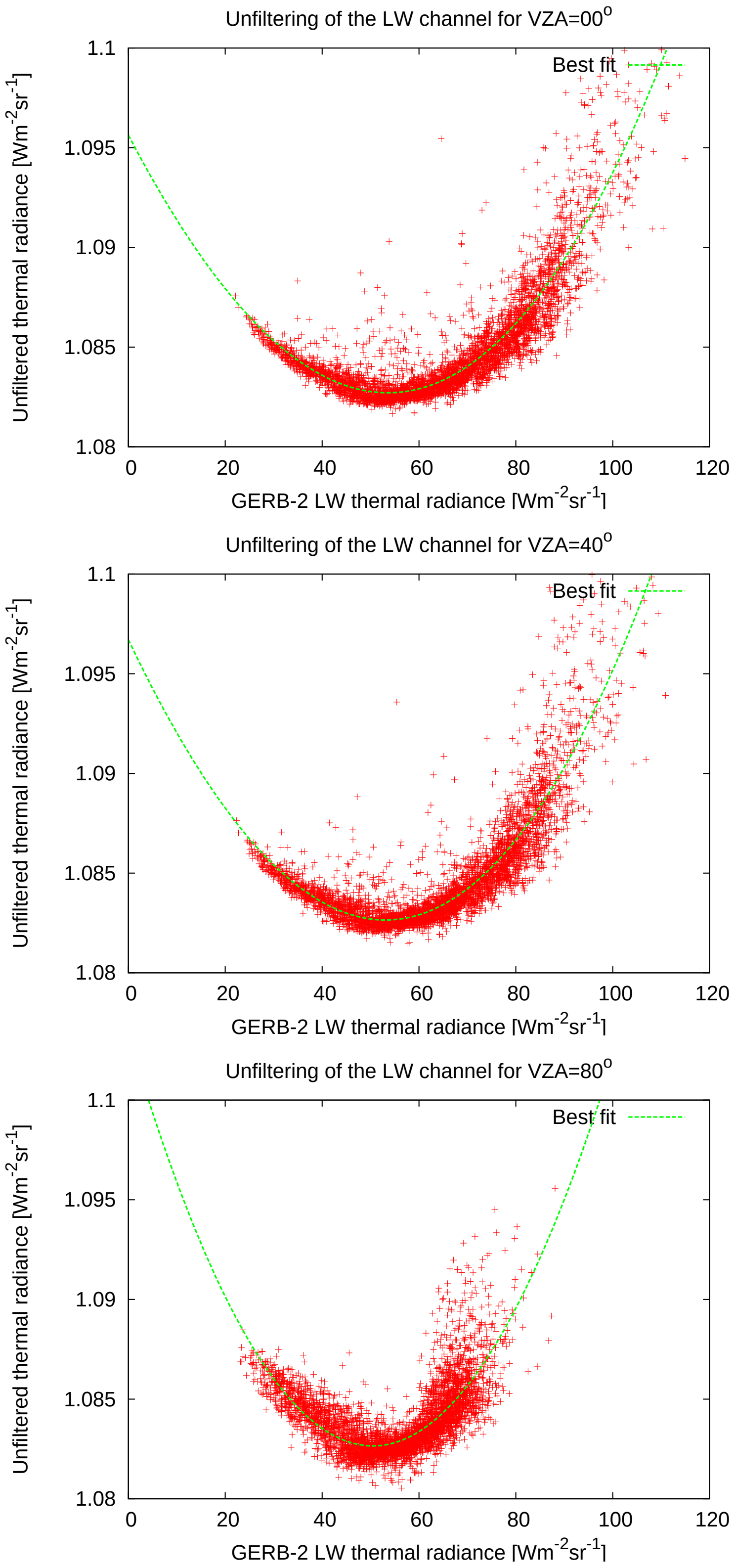

Figure 4: Scatterplot of GERB-2 longwave unfiltering factor $\alpha_{lw,th}$ as a function of the $L_{lw,th}$ radiance for $VZA = 0°, 40°, 80°$. The figure also shows the best fit of Eq.(9).

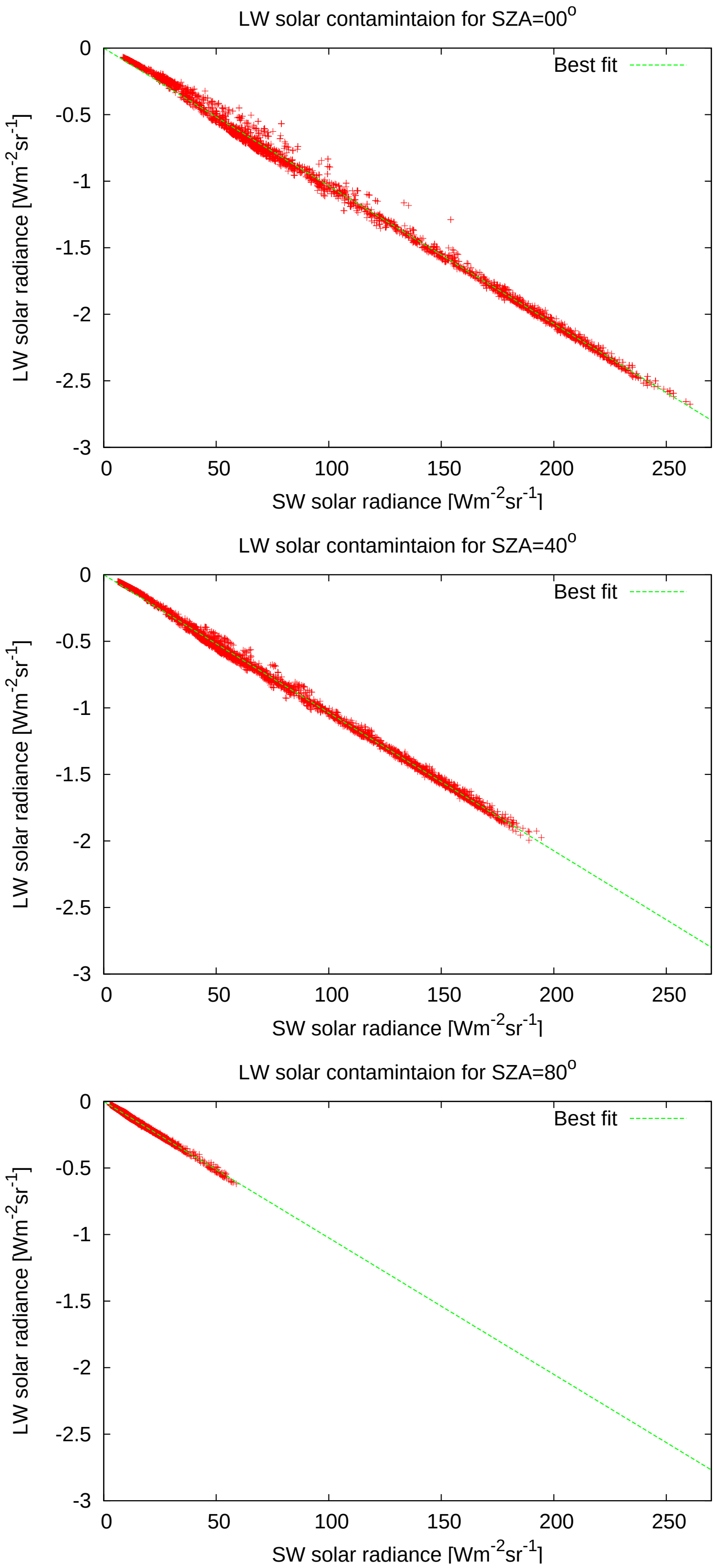

Figure 5: GERB-2 longwave solar radiance $L_{lw,sol}$ as a function of the shortwave solar radiance $L_{sw,sol}$ for $SZA = 0°$, $40°$, and $80°$.

VZA	GERB-2			GERB-1		
[°]	a	b	σ	a	b	σ
00	0.050326	7.55658e-09	0.066	0.051600	7.29081e-09	0.068
05	0.050305	7.56427e-09	0.066	0.051579	7.29823e-09	0.068
10	0.050246	7.58746e-09	0.066	0.051519	7.32061e-09	0.068
15	0.050154	7.62645e-09	0.066	0.051426	7.35823e-09	0.068
20	0.050035	7.68179e-09	0.066	0.051304	7.41163e-09	0.068
25	0.049894	7.75427e-09	0.066	0.051160	7.48157e-09	0.068
30	0.049741	7.84492e-09	0.066	0.051005	7.56904e-09	0.067
35	0.049597	7.95502e-09	0.066	0.050857	7.67528e-09	0.067
40	0.049486	8.08614e-09	0.066	0.050745	7.8018e-09	0.067
45	0.049442	8.24007e-09	0.066	0.050700	7.95034e-09	0.067
50	0.049513	8.41874e-09	0.065	0.050771	8.12276e-09	0.066
55	0.049774	8.62391e-09	0.064	0.051037	8.32077e-09	0.066
60	0.050344	8.85647e-09	0.063	0.051617	8.54521e-09	0.064
65	0.051395	9.1146e-09	0.061	0.052685	8.79437e-09	0.062
70	0.053187	9.38874e-09	0.058	0.054508	9.05903e-09	0.059
75	0.056194	9.64539e-09	0.052	0.057567	9.30693e-09	0.053
80	0.061420	9.76588e-09	0.042	0.062884	9.42374e-09	0.043
85	0.071513	9.24207e-09	0.027	0.073153	8.9196e-09	0.027

Table 3: Parameters a and b to estimate the thermal contamination in the GERB SW channel for GERB-2 and GERB-1. The RMS error σ on the estimated contamination is also given in $[Wm^{-2}sr^{-1}]$.

$$L_{lw,sol} = a(SZA)L_{sw,sol} \tag{10}$$

Table (5) gives the best fit parameters $a(SZA)$.

6 Discussion

Simple fits can be used for the direct unfiltering of the GERB longwave channel. The solar contamination in this channel can be estimated with an accuracy of about $0.04Wm^{-2}sr^{-1}$ (RMS error) and the unfiltering factor α with an accuracy of 0.1% (RMS error). This is acceptable. For this channel, the use of spectral information from SEVIRI (Clerbaux et al., 2008a) allows to reduce the RMS error on the unfiltering factor to about 0.05%

Unfortunately the situation is not the same for the SW channel. Higher errors are introduced in the estimation of the thermal contamination (RMS error of $0.07Wm^{-2}sr^{-1}$) and in the estimation of the unfiltering factor (between 1 and 3% RMS error). For this channel, the use of spectral information from SEVIRI (Clerbaux et al., 2008b) is clearly an asset as this allows to reduce the RMS error to less than 1%

References

Clerbaux, N., 1999: Correction of the dispersion in the gerb's detector spectral response curves. Technical Note MSG-RMIB-GE-TN-0031, RMIB.

— 2007: Generation of a data base of TOA spectral radiance fields. Technical Note MSG-RMIB-GE-TN-0030, RMIB.

VZA	a	b	c	d	σ
00	1.095631e+00	-4.637691e-04	3.813163e-06	6.362832e-09	0.112 %
05	1.095645e+00	-4.643447e-04	3.818022e-06	6.377603e-09	0.112 %
10	1.095686e+00	-4.660828e-04	3.832596e-06	6.423120e-09	0.112 %
15	1.095757e+00	-4.690168e-04	3.857167e-06	6.500530e-09	0.112 %
20	1.095859e+00	-4.733083e-04	3.893989e-06	6.602603e-09	0.113 %
25	1.095998e+00	-4.792181e-04	3.946855e-06	6.716111e-09	0.113 %
30	1.096180e+00	-4.870258e-04	4.019583e-06	6.830252e-09	0.113 %
35	1.096413e+00	-4.971613e-04	4.118362e-06	6.923948e-09	0.114 %
40	1.096706e+00	-5.101103e-04	4.250602e-06	6.970983e-09	0.114 %
45	1.097071e+00	-5.265610e-04	4.427279e-06	6.928006e-09	0.115 %
50	1.097523e+00	-5.473709e-04	4.662379e-06	6.737804e-09	0.116 %
55	1.098081e+00	-5.736062e-04	4.974067e-06	6.320759e-09	0.116 %
60	1.098763e+00	-6.062721e-04	5.380377e-06	5.595835e-09	0.116 %
65	1.099587e+00	-6.464527e-04	5.901754e-06	4.465291e-09	0.116 %
70	1.100583e+00	-6.954440e-04	6.560970e-06	2.818171e-09	0.114 %
75	1.101791e+00	-7.540661e-04	7.365302e-06	6.350151e-10	0.110 %
80	1.103274e+00	-8.214181e-04	8.273487e-06	-1.851875e-09	0.101 %
85	1.105575e+00	-9.140125e-04	9.530927e-06	-6.553592e-09	0.089 %

VZA	a	b	c	d	σ
00	1.081298e+00	-4.594298e-04	3.779824e-06	5.504211e-09	0.113 %
05	1.081312e+00	-4.600008e-04	3.784691e-06	5.516984e-09	0.113 %
10	1.081354e+00	-4.617490e-04	3.799610e-06	5.555096e-09	0.113 %
15	1.081425e+00	-4.646954e-04	3.824784e-06	5.619375e-09	0.113 %
20	1.081529e+00	-4.689905e-04	3.862140e-06	5.704890e-09	0.113 %
25	1.081670e+00	-4.749024e-04	3.915564e-06	5.797548e-09	0.114 %
30	1.081854e+00	-4.827262e-04	3.989235e-06	5.883989e-09	0.114 %
35	1.082090e+00	-4.928512e-04	4.088552e-06	5.947266e-09	0.115 %
40	1.082386e+00	-5.058158e-04	4.221673e-06	5.956990e-09	0.115 %
45	1.082756e+00	-5.222889e-04	4.399294e-06	5.870474e-09	0.116 %
50	1.083215e+00	-5.431644e-04	4.635870e-06	5.627694e-09	0.116 %
55	1.083783e+00	-5.694825e-04	4.948867e-06	5.152575e-09	0.117 %
60	1.084477e+00	-6.023223e-04	5.357515e-06	4.356584e-09	0.117 %
65	1.085321e+00	-6.429570e-04	5.885535e-06	3.121602e-09	0.117 %
70	1.086348e+00	-6.928649e-04	6.559102e-06	1.313888e-09	0.115 %
75	1.087606e+00	-7.533891e-04	7.396211e-06	-1.159326e-09	0.111 %
80	1.089181e+00	-8.249218e-04	8.382925e-06	-4.253106e-09	0.102 %
85	1.091655e+00	-9.259447e-04	9.802657e-06	-1.010458e-08	0.091 %

Table 4: Parameters for direct unfiltering of the GERB-2 (upper table) and GERB-1 (lower table) LW channel with Eq(9).

SZA	GERB-2		GERB-1	
$\circ$	a	σ	a	σ
00	-0.010356	0.038	-0.011066	0.036
10	-0.010369	0.033	-0.011079	0.031
20	-0.010373	0.029	-0.011085	0.027
30	-0.010372	0.026	-0.011086	0.024
40	-0.010369	0.023	-0.011087	0.021
50	-0.010361	0.020	-0.011085	0.018
60	-0.010345	0.016	-0.011075	0.015
70	-0.010316	0.012	-0.011056	0.011
80	-0.010254	0.006	-0.011003	0.006

Table 5: Parameters a to estimate the solar contamination in the GERB LW channel for GERB-2 and GERB-1.

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