# Direct Unfiltering of GERB Data

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**Abstract**

This technical note analyzes the transformation of the GERB SW and LW filtered measurements into unfiltered solar and thermal radiances. This note provides laws and parameters for direct unfiltering, that means without using information about spectral signature provided by SEVIRI.

## Contents

# 1 Introduction

- By **unfiltering** we mean the transformation of the GERB shortwave $L_{sw}$ and longwave $L_{lw}$ filtered radiances into solar $L_{sol}$ and thermal $L_{th}$ radiances due to reflection and thermal emission, respectively. The longwave radiance is not measured but is estimated from the total measurement: $L_{lw} = L_{tot} - A\,L_{sw}$.
- By **direct** we mean without using any other informations than the GERB radiances. Examples of useful informations are: idea of the spectral signature provided by SEVIRI, map of the surface type, ...
- In this technical note, we use the spectral response curves of the GERB-2 instrument (launched on MSG-1) as provided by Imperial College on September 26th 2002. Possibly, new releases of this data will be available in the future. In this case, the parameterizations hereafter will be updated.
- This document does not deal with the slight difference that exist between the spectral response curves of the different detectors of the instrument (that means the lines in the NANRG image). The correction for this dispersion in spectral response is described in [1] but will probably not be used in operation because this dispersion is quite limited. This will be checked in-orbit.
- The parameterization of the unfiltering and the estimation of the unfiltering error is based on a data base of spectral radiance curves. The generation of this data base is described in [2].
- The direct unfiltering presented in this technical note is close to the CERES unfiltering method which is fully described in [3].

## 2 Unfiltering the shortwave channel

Although a second order regression is used for CERES, we propose to use a first order regression:

$$L_{sol} \;=\; a(\theta_s) \;+\; b(\theta_s)\, L_{sw,sol} \tag{1}$$

where:

- $L_{sol}$ is the unfiltered solar reflected radiance to be estimated,
- $L_{sw,sol}$ is the part of the GERB SW measurement which is due to the solar reflected radiation. It is derived from the SW measurement $L_{sw}$ after subtraction of the small contribution of the thermally emitted radiation to the SW measurement $L_{sw,sol} = L_{sw} - L_{sw,th}$. The estimation of $L_{sw,th}$ is explained in the section §4.
- $a(\theta_s)$ and $b(\theta_s)$ are the regression parameters (or "unfiltering parameters") which are dependent on the solar zenith angle $\theta_s$.

The equation (1) corresponds to the unfiltering factor:

$$\alpha_{sw,sol} \;=\; \frac{L_{sol}}{L_{sw,sol}} \;=\; \frac{a(\theta_s)}{L_{sw,sol}} \;+\; b(\theta_s) \tag{2}$$

The figure (1) shows the scatterplots of $\alpha_{sw,sol}$ versus $L_{sw,sol}$ for the 4620 scenes in the database at $\theta_s = 0^o$ (top) and $\theta_s = 80^o$ (bottom). The best fits (hyperbolas) are also drawn.

The parameterization of the unfiltering parameters $a(\theta_s)$ and $b(\theta_s)$ is done by fitting the equation (2) on the database. An alternative option would consist in fitting the equation (1) on the database (this is done by CERES) but we preferred to fit the unfiltering factor to better take into account the dark scenes (ocean) in the unfiltering.

The table hereafter gives, according to the solar zenith angle $\theta_s$, the best fit parameters $a(\theta_s)$ and $b(\theta_s)$ and the residual relative mean square error [%] on the estimated $\alpha$ values:

```
00 2.222408 1.319553 0.3833%
10 2.211020 1.319461 0.3824%
20 2.175285 1.319174 0.3798%
30 2.110243 1.318660 0.3753%
40 2.006464 1.317859 0.3689%
50 1.847291 1.316689 0.3607%
60 1.602635 1.315080 0.3507%
70 1.216671 1.313248 0.3379%
80 0.603612 1.313691 0.2991%
90 0.000000 1.313691 xxxxxxxx
```

The parameter $b$ is close to 1.315 whatever the solar zenith angle is. The intercept $a$ is depending on this angle. The residual error on the unfiltering factor $\alpha$ is about $\epsilon = 0.4\%$. As the radiative transfer computations are not possible at $\theta_s = 90^o$, the parameters for this angle have been extrapolated from the ones at $\theta_s = 80^o$.

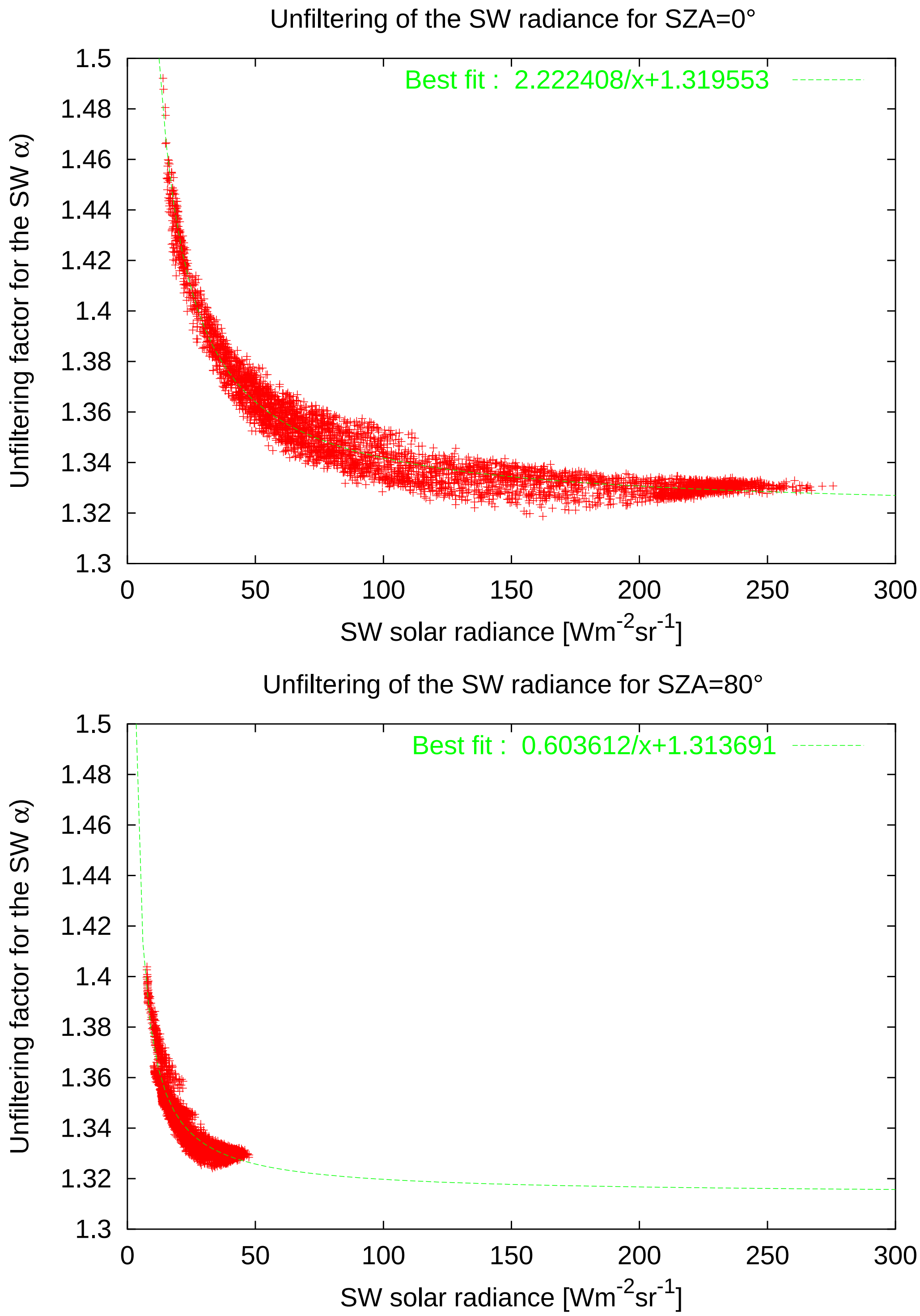



Figure 1: Shortwave unfiltering factor $\alpha_{sw,sol}$ as a function of the $L_{sw,sol}$ radiance for the nadir Sun ($\theta_s = 0^o$, top) and for grazing illumination ($\theta_s = 80^o$, bottom).

# 3 Unfiltering the longwave channel

Figure (2) shows the scatterplots of unfiltering factor $\alpha_{lw,th}$ versus $L_{lw,th}$ for the scenes in the database at viewing zenith angle of $\theta_v = 0^o$ and $\theta_v = 80^o$. On this figure, a third order regression seems well-indicated to estimate the unfiltering factor:

$$\begin{aligned} \alpha_{lw,th} &= \frac{L_{th}}{L_{lw,th}} = a(\theta_v) + b(\theta_v)\, L_{lw,th} + c(\theta_v)\, L^2_{lw,th} + d(\theta_v)\, L^3_{lw,th} \\ \Rightarrow L_{th} &= a(\theta_v)\, L_{lw,th} + b(\theta_v)\, L^2_{lw,th} + c(\theta_v)\, L^3_{lw,th} + d(\theta_v)\, L^4_{lw,th} \end{aligned} \tag{3}$$

where:

- $L_{th}$ is the unfiltered thermally emitted radiance to be estimated,
- $L_{lw,th}$ is the part of the GERB LW measurement which is due to the thermal emission. It is derived from the LW measurement $L_{lw}$ after subtraction of the small contribution of the solar reflected radiation to the LW measurement $L_{lw,th} = L_{lw} - L_{lw,sol}$. The estimation of $L_{lw,sol}$ is explained in the section §5.
- $a(\theta_v)$, $b(\theta_v)$, $c(\theta_v)$ and $d(\theta_v)$ are the regression parameters (or "unfiltering parameters") which are dependent on the viewing zenith angle $\theta_v$.

The parameterization of the unfiltering parameters is done by fitting the equation 3 on the database. As for the SW, we prefered to fit the unfiltering parameter $\alpha_{lw,th}$ rather than the uinfiltered radiance $L_{th}$.

The table hereafter gives, according to the viewing zenith angle $\theta_v$, the best fit parameters $a(\theta_v)$, $b(\theta_v)$, $c(\theta_v)$, $d(\theta_v)$ and the residual relative mean square error [%] on the estimated $\alpha$ values:

```
00 1.105176e+00 -4.030578e-04  1.035538e-07 2.344693e-08 0.0848%
05 1.105176e+00 -4.027900e-04  9.271087e-08 2.354313e-08 0.0848%
10 1.105173e+00 -4.018771e-04  5.836537e-08 2.384152e-08 0.0851%
15 1.105166e+00 -4.002376e-04 -1.057769e-09 2.435303e-08 0.0855%
20 1.105153e+00 -3.977849e-04 -8.788723e-08 2.509601e-08 0.0861%
25 1.105137e+00 -3.945253e-04 -2.035423e-07 2.608838e-08 0.0869%
30 1.105115e+00 -3.903170e-04 -3.524132e-07 2.736713e-08 0.0879%
35 1.105085e+00 -3.849457e-04 -5.403659e-07 2.898040e-08 0.0891%
40 1.105045e+00 -3.781144e-04 -7.757815e-07 3.099778e-08 0.0905%
45 1.104989e+00 -3.694410e-04 -1.069881e-06 3.351375e-08 0.0921%
50 1.104914e+00 -3.584275e-04 -1.438237e-06 3.666226e-08 0.0938%
55 1.104807e+00 -3.440030e-04 -1.908690e-06 4.066347e-08 0.0957%
60 1.104634e+00 -3.237925e-04 -2.536174e-06 4.592047e-08 0.0976%
65 1.104332e+00 -2.934058e-04 -3.421917e-06 5.316931e-08 0.0992%
70 1.103773e+00 -2.435443e-04 -4.779401e-06 6.394713e-08 0.1000%
75 1.102638e+00 -1.513421e-04 -7.129159e-06 8.198483e-08 0.0996%
80 1.100141e+00  4.193113e-05 -1.184773e-05 1.174488e-07 0.0980%
85 1.094446e+00  4.961671e-04 -2.311772e-05 2.043633e-07 0.1021%
90 1.094446e+00  4.961671e-04 -2.311772e-05 2.043633e-07(extrapolated)
```

The residual error on the unfiltering factor $\alpha$ is about $\epsilon = 0.1\%$. As the radiative transfer computations are not possible at $\theta_v = 90^o$, the parameters for this angle have been extrapolated from the ones at $\theta_v = 85^o$.

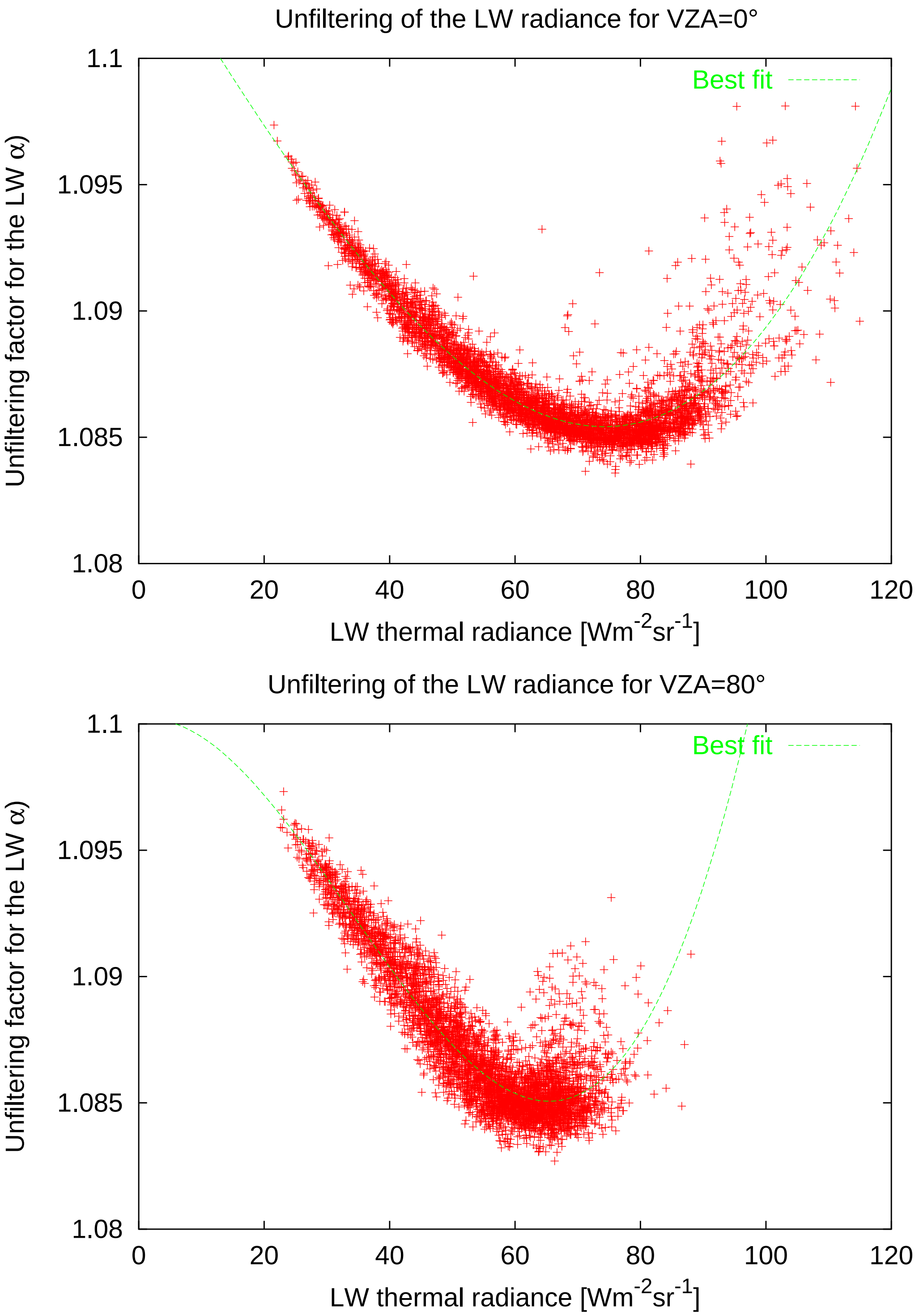



Figure 2: Longwave unfiltering factor $\alpha_{lw,th}$ as a function of the $L_{lw,th}$ radiance for: nadir viewing zenith angle ($\theta_v = 0^o$, top) and for grazing observation ($\theta_v = 80^o$, bottom).

# 4 Shortwave thermal contribution

Figure (3) displays the scatterplots of $L_{sw,th}$ versus $L_{lw,th}$ for the 4620 scenes in the database observed at $\theta_v = 0^o$ (top) and $\theta_v = 80^o$ (bottom). The contamination can be estimated as:

$$L_{sw,th} = a(\theta_v)\ L^4_{lw,th} \tag{4}$$

The table hereafter gives the best fit parameters $a(\theta_v)$ and the residual absolute mean square error in $[Wm^{-2}sr^{-1}]$ on the estimated $L_{sw,th}$ values. Even if the relative error introduced by the simple fit (4) is relatively important, the absolute error (at 1-sigma) is less than a tenth of $[Wm^{-2}sr^{-1}]$.

```
00 7.737691e-09 0.071351
05 7.744708e-09 0.071355
10 7.765946e-09 0.071365
15 7.801893e-09 0.071379
20 7.853212e-09 0.071391
25 7.920780e-09 0.071390
30 8.005898e-09 0.071364
35 8.110464e-09 0.071289
40 8.236974e-09 0.071132
45 8.388548e-09 0.070840
50 8.569284e-09 0.070335
55 8.784968e-09 0.069489
60 9.043729e-09 0.068096
65 9.356382e-09 0.065821
70 9.737011e-09 0.062106
75 1.020460e-08 0.056006
80 1.078309e-08 0.045994
85 1.149532e-08 0.030841
90 1.149532e-08 (extrapolated)
```

**Note:** *night time GERB measurement may be used to improve/validate the estimation of $L_{sw,th}$. Indeed, during the night the solar contribution vanishes and the instrument directly measures the $L_{sw,th}$ and the $L_{lw,th}$.*

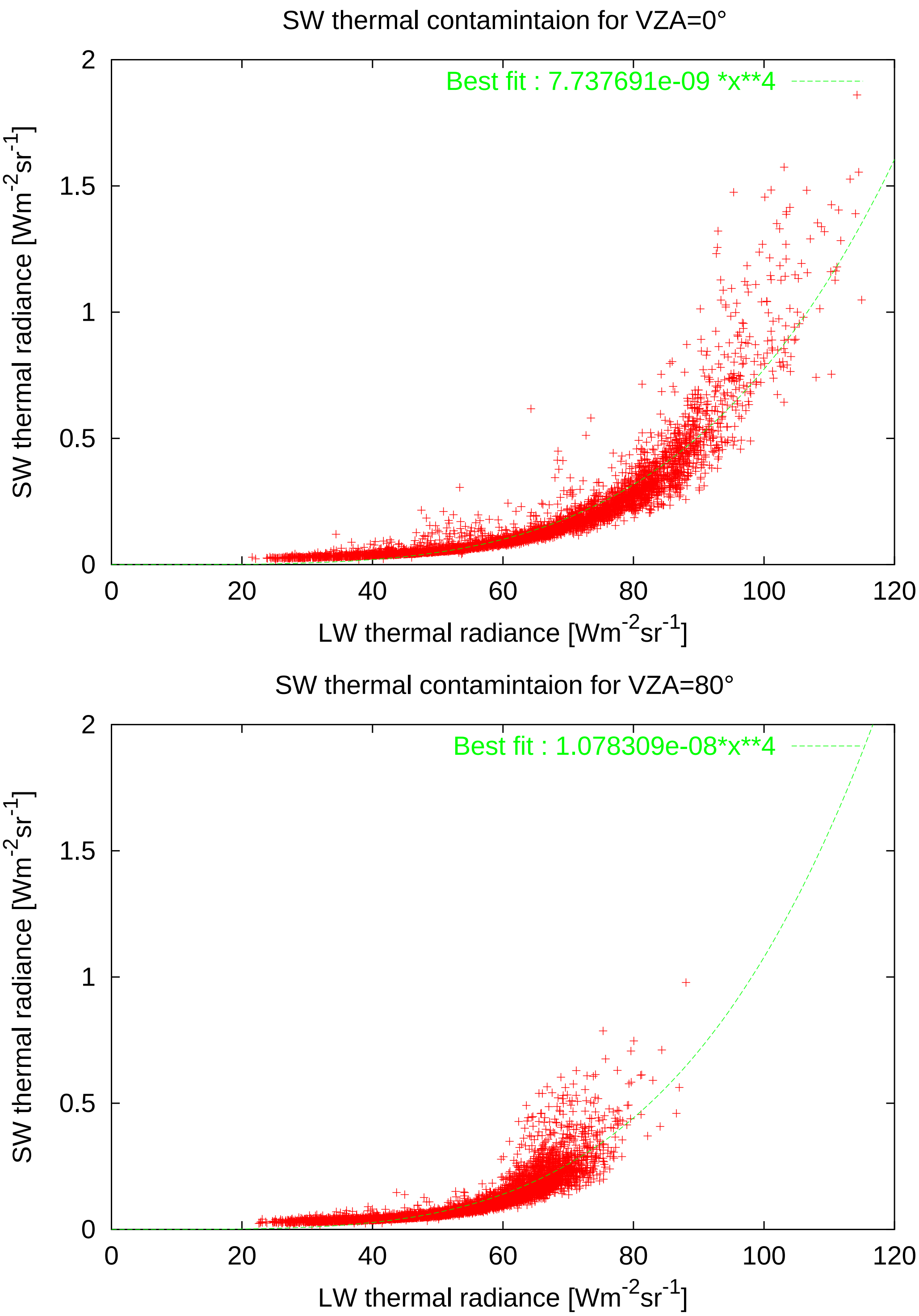



Figure 3: Shortwave thermal radiance $L_{sw,th}$ as a function of the longwave thermal radiance $L_{lw,th}$ for: nadir viewing zenith angle ($\theta_v = 0^o$, top) and for grazing observation ($\theta_v = 80^o$, bottom).

## 5 Longwave solar contribution

Figure (4) presents the scatterplots of $L_{lw,sol}$ versus $L_{sw,sol}$ for the scenes in the database for Sun at $\theta_s = 0^o$ (top) and at $\theta_s = 80^o$ (bottom). The contamination can be estimated as:

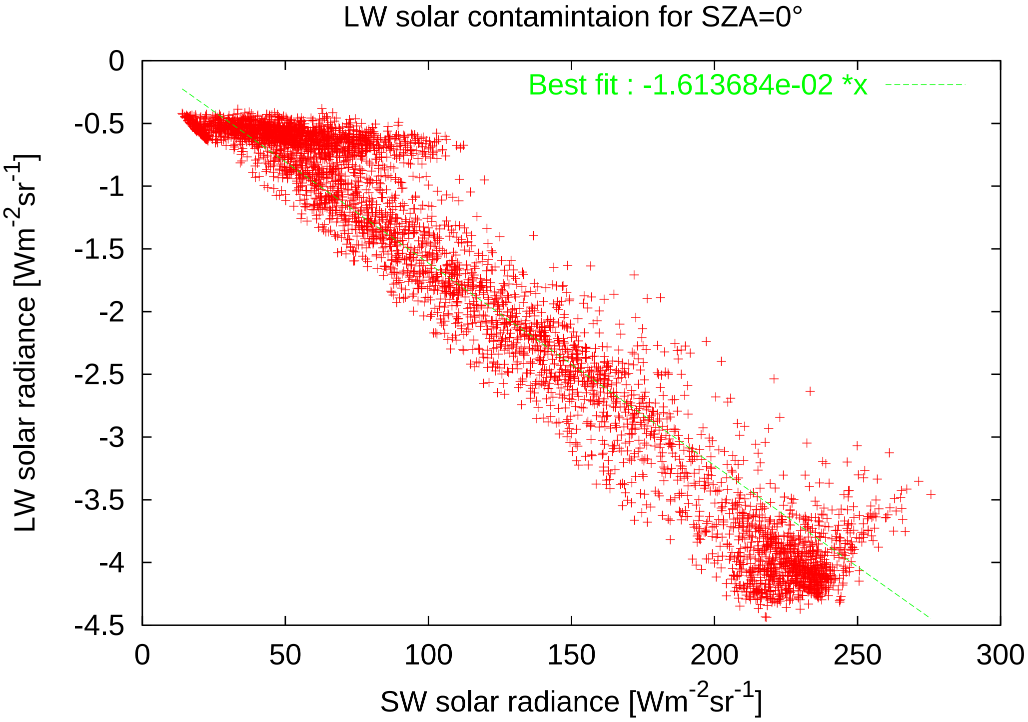
$$L_{lw,sol} = a(\theta_s)\ L_{sw,sol}$$

The table hereafter gives the best fit parameters $a(\theta_s)$ and the residual absolute mean square error $[Wm^{-2}sr^{-1}]$ on the estimated $L_{lw,sol}$ value. The longwave solar radiance is difficult to be estimated from the SW measurement and the error on the estimation of this quantity is relatively important.

```
00 -1.613684e-02 0.348608
10 -1.613539e-02 0.342023
20 -1.612892e-02 0.322635
30 -1.611157e-02 0.291604
40 -1.607547e-02 0.251078
50 -1.601341e-02 0.204492
60 -1.592185e-02 0.156722
70 -1.579842e-02 0.112599
80 -1.556468e-02 0.068427
90 -1.556468e-02 (extrapolated)
```

Due to the difficulty which appears when estimating the LW solar radiance from the SW measurement, the error associated to tis estimation is quite important. The error of $0.35\,Wm^{-2}sr^{-1}$ for the sun at the zenith corresponds to about 0.5% of the average LW radiance at nadir view ($64.74\,Wm^{-2}sr^{-1}$).

**Note:** *as shown in annex, the SEVIRI spectral information is very helpful to estimate the longwave solar contamination.*



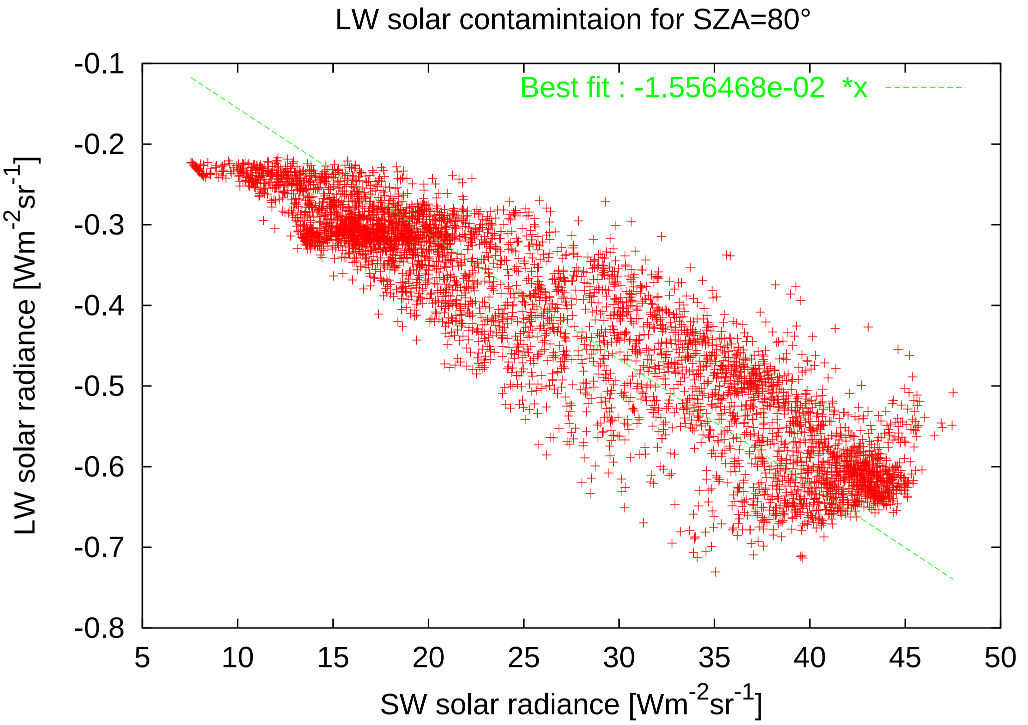




Figure 4: Longwave solar radiance $L_{lw,sol}$ as a function of the shortwave solar radiance $L_{sw,sol}$ for the for the nadir Sun ($\theta_s = 0^o$) and for grazing illumination ($\theta_s = 80^o$).

# 6 Conclusions

- The direct unfiltering is possible and relatively accurate (according to the instrument radiometric characteristics). The unfiltering can be improved using spectral information from the SEVIRI imager and/or information about the surface type (or surface albedo).

- The scatterplots (3) and (4) show that the (direct) estimation of the contaminations $L_{sw,th}$ and $L_{lw,sol}$ is not easy.

- The total unfiltering error can be seen as due to; (i) the subtraction of the contamination and (ii) the estimation of the unfiltering factor $\alpha$. The table hereafter summarizes these errors for the thermal and solar radiations:

| | | |
|---|---|---|
| **thermal :** | error due to $L_{lw,sol} \sim 0.35\ Wm^{-2}sr^{-1}$ | error on $\alpha_{lw,th} \sim 0.1\%$ |
| **solar:** | error due to $L_{sw,th} \sim 0.07\ Wm^{-2}sr^{-1}$ | error on $\alpha_{sw,sol} \sim 0.4\%$ |

- For the thermal radiation the main source of errors is due to the contamination by solar reflected radiation during the day. As shown in annex, the SEVIRI spectral information is here helpful.

- For the solar radiation, the main source of errors is due to the estimation of the unfiltering factor $\alpha_{sw,sol}$.

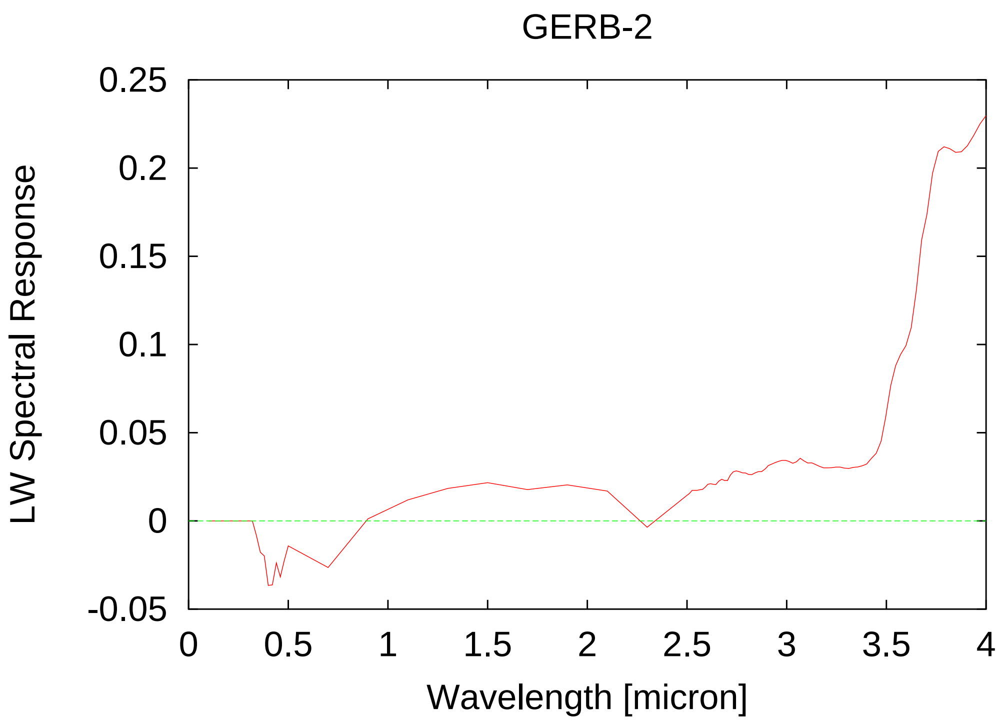



Figure 5: GERB-2 LW spectral response in the shortwave part of the spectrum.

# 7 Annex: use of SEVIRI for the $L_{lw,sol}$ estimation

The best first order regression to estimate the longwave contamination by solar radiation using the SEVIRI narrowband radiances is (for $\theta_s = 0^o$):

$$L_{lw,sol} = -0.21 - 0.104\, L_{0.6\mu m} - 0.027\, L_{0.8\mu m} + 0.0997\, L_{1.6\mu m} \quad (5)$$

and the absolute residual error on $L_{lw,sol}$ is $0.12\ Wm^{-2}sr^{-1}$ which is must better than the error on the same quantity for the direct unfiltering ($0.34\ Wm^{-2}sr^{-1}$). Figure (5) shows that the longwave spectral response in the shortwave part of the spectrum is negative for $\lambda < 0.85\mu m$ and positive for higher wavelengths. This agrees well with the sign of the coefficients in (5).

# References

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

[2] N. Clerbaux. Generation of a data base of toa spectral radiance fields. Technical Note MSG-RMIB-GE-TN-0030, RMIB, December 1999.

[3] N.G. Loeb, K.J. Priestley, D.P. Kratz, E.B. Geier, R.N. Green, B.A. Wielicki, P.O. Hinton, and S.K. Nolan. Determination of unfiltered radiances from the clouds and the earth's radiant energy system instrument. *Journal of Applied Meteorology*, 40:822–835, 2001.