GERB PROCESSING

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This document is outdated and does not represent the current state of the GERB processing.

Contents

CHANGE RECORD

Issue	Date	Approved by	Reason for change
Version 1	29/06/1999		new document
Version 1.1	20/08/1999		Figures added, Notation modified, § "Log and Error tracking" and § "Resource Availability" are now in "RGP: Data Flow"

1 Introduction

1.1 Purpose of this document

The purpose of the document is to give an overview of how the SEVIRI data is corrected by GERB data.

1.2 Scope of this document

This document is the description of what has been implemented. This document is not concerned neither by the scientific issue of the correction nor the estimation of the improvement made with GERB data on SEVIRI data.

2 Acronyms, abbreviations and definitions

2.1 Acronyms and abbreviations

Not all these acronyms may appear in this document.

AD	Applicable Document
ADM	Angular Dependency Model
ASI	Agency Spatiale Italiano
BATS	Belgian Advanced Technology Systems
BB	Broad Band
BDRF	Bidirectional Reflection Function
CERES	Clouds and the Earth's Radiant Energy System
CNRS	Centre Nationale de la Recherche Scientifique
DCT	Discrete Cosine Transform
ERB	Earth Radiation Budget
ERBE	Earth Radiation Budget Experiment
EUMETSAT	EUropean organsiation for the exploitation of METeteorological SATellites
FTP	File Transfer Protocol
Gb	Gigabit
GB	GigaByte
GERB	Geostationary Earth Radiation Budget
GGSPS	GERB Ground Segment Processing System
GIST	GERB International Science Team
GKSS	GKSS research centre
HD	High Density
HDF	Hierarchical Data Format
HRIT	High Rate Information Transmission
ICD	Interface Control Document
ICSTM	Imperial College of Science Technology and Medicine
IFR	Instantaneous Filtered Radiance
kb	kilobit
kB	kiloByte
LARC	LAngley Research Centre (NASA)
LU	Leicester University
LOS	Line Of Sight
LW	Long Wave
Mb	Megabit
MB	MegaByte
NANRG	Non Averaged, Non Rectified, Geolocated
NB	Narrow Band
NERC	Natural Environment Research Council
OSTC	Office for Scientific, Technical and Cultural Affairs

PSF	Point Spread Function
qlt	quick look time
RAL	Rutherford Appleton Laboratory
RD	Reference Document
RMIB	Royal Meteorological Institute of Belgium
RGP	RMIB Gerb Processing
ROLSS	RMIB On Line Short term Services
ScaRaB	Scanning Radiometer for radiation Budget studies
SEVIRI	Spinning Enhanced Visible and InfraRed Imager
SOL	Start Of Line
SBDART	Santa Barbara Discrete ordinate Atmospheric Radiative Transfer see http://arm.mrcsb.com/sbdart
SW	Short Wave
TAR	Tape ARchive
TBC	To Be Confirmed
TBD	To Be Determined
TOA	Top Of Atmosphere
TRMM	Tropical Rainfall Measurement Mission
UKMO	United Kingdom Meteorological Office
VIRS	VIsible and InfraRed Scanner
wrt	with respect to
WWW	World Wide Web

2.2 Definition of terms

Autorised Users

Authorised users will include RMIB, members of the GIST, GERB operations staff based at RAL, EUMETSAT and others. In order to become an Autorised user, users will be required to register with RMIB according to the rules established by the GERB Project Steering Group (TBC). Once the registration is approved the user will be able to obtain products from the ROLSS, and will be given their unique ROLSS account details, from which they will be able to get access to the products.

near real time (or NRT or nrt)

Between EUMETSAT and the GGSPS near real time means that the GGSPS at RAL will receive GERB data within 60 minutes (TBC) of the actual time at which the data was generated on board the GERB instrument.

quick look time (or QLT or qlt)

Between the GGSPS and RMIB, quick look time means that the RMIB will receive GERB data products within 4 hours of the actual time at which the corresponding data was generated on board the GERB instrument.

short term

Short term data usage refers to usage of the data within one month after their measurement.

long term

Long term data usage refers to usage of the data more than one month after their measurement.

Reference Earth Ellipsoid

(TBD)

GERB data loss

A GERB data loss is one for which the L1.5 radiances have not been obtained within the QLT.

SEVIRI data loss

A SEVIRI data loss is one for which the L1.5 SEVIRI images have not been received through the HRIT system within the QLT.

climate data

GERB climate data means the GERB products that are generated at RMIB for long term archival and data distribution at RAL.

near real time data

Near real data means the GERB products that are generated at RMIB and distributed for short term usage through the ROLSS server.

ROLSS server

The ROLSS server will be the RMIB based ftp server for near real time data distribution.

near real time processing

Near real time processing will be the processing that has to be done at RMIB as soon as a GERB or SEVIRI data file arrives.

daily, weekly, monthly processing

Daily, weekly, monthly processings will be the processings that have to be done at RMIB less frequently than the near real time processing, but that still need to be done on a regular basis.

casual processing

Casual processings will be those that have to be done at RMIB infrequently and irregularly, e.g. calibration table updates.

solar

Solar means relating to reflected solar radiation only.

thermal

Thermal means relating to emitted thermal radiation only

short wave

Short wave means radiation from the wavelengths below a cutoff wavelength of approximatively 4 micron.

long wave

Long wave means radiation from the wavelengths above a cutoff wavelength of approximatively 4 micron.

total wave

Total wave radiation means combined short wave and long wave radiation.

unfiltered

Unfiltered refers to a spectral integral of either solar or thermal radiation without spectral attenuation.

'GERB filtered' or simply 'filtered'

GERB filtered refers to a spectral integral, either over the short wave or over the long wave or over the total wave spectral interval, of radiation multiplied (filtered) with the GERB spectral response.

imager resolution

Imager resolution refers to SEVIRI pixel resolution

high resolution

HIgh resolution refers to 3 x 3 SEVIRI pixel resolution, this the highest resolution at which fluxes are derived

GERB resolution

GERB resolution refers to GERB footprint resolution

SEVIRI based products

SEVIRI based products refers to broadband radiance or flux estimates estimated from SEVIRI narrowband pixel data only.

level 2 fluxes

Level 2 fluxes refers to fluxes derived from combined GERB and SEVIRI data.

spectral unfilter factor

Ratio between the unfiltered broadband radiance and the filtered broad band radiance.

angular conversion factor

Ratio between the broad band flux and the unfiltered broad band radiance.

correction factor of SEVIRI by GERB

Ratio of the filtered broad band radiance measured by GERB and the same quantity model based on SEVIRI narrow band radiances.

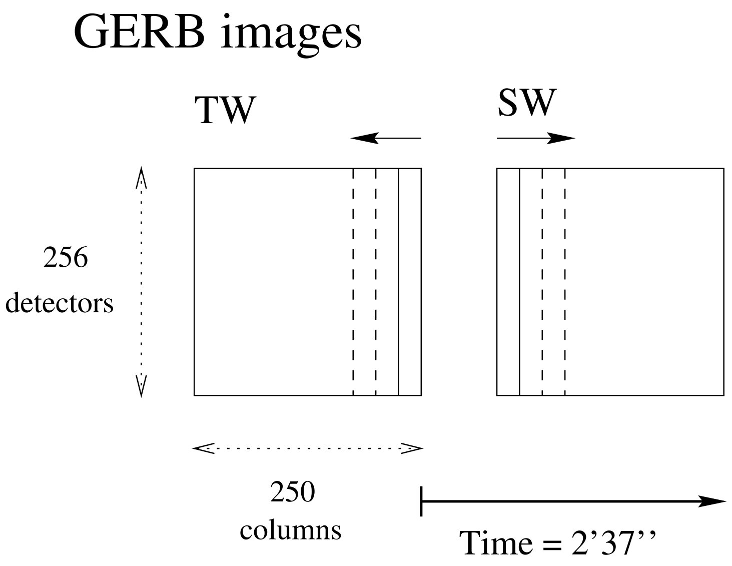

Figure 1: GERB image acquisition

3 GERB INSTRUMENT SUMMARY

The GERB instrument takes an image of the Earth each 2’37” minute. The scene is scanned row by row. The time between the scan of two rows is 600 ms. There is an additional time of 6x600 ms between each acquisition. A complete set is composed of two images (see figure 1). The first one is the total radiance and is scanned East to West (TBC). The second one is the short-wave radiance and is scanned West to East (TBC). The instrument is characterised by a point spread function (PSF) or angular response which states the weighting of what is seen by the instrument. Typically it is a gaussian-like function. The instrument is composed of 256 detectors. Each detector can have a different PSF. The number of lines is 256. So the GERB images have 256x256 pixels. At each image is associated a table of geolocation. The table values are given in angles with reference on the Earth. There are two values for each GERB pixel: the longitude and the latitude.

4 SEVIRI INSTRUMENT SUMMARY

The SEVIRI instrument takes an image of the Earth each 15 minutes. The data is scanned three lines by three lines (see figure 2). The start of scanning is synchronised with UTC each 15 minutes i.e. 0h00 0h15 0h30 ... The time between the scan of two sets of three lines is 600 ms. There is some time spent on housekeeping management between two images. The scanning is South to North (TBC). It is easy to derive the time when each line is scanned. The number of scans is 1200(TBC) so the height of the image is 3600(TBC) pixels. The number of values taken for each line is 3712. The image data is then processed by SEVIRI ground segment to produce a 3712x3712 pixels image (Level 1.5 SEVIRI data). There are eleven spectral bands taken with the SEVIRI instrument. The SEVIRI images are already rectified i.e. they are defined on a grid. The grid is a constant angle grid based on the nominal satellite position. The sampling distance is defined to be exactly 3 km by 3 km at the sub-satellite point.

5 SEVIRI DATA PROCESSING SUMMARY

The SEVIRI instrument has a very good space resolution but the calibration is expected to be worse than GERB for the visible bands. Futhermore SEVIRI is a narrow-band instrument and GERB

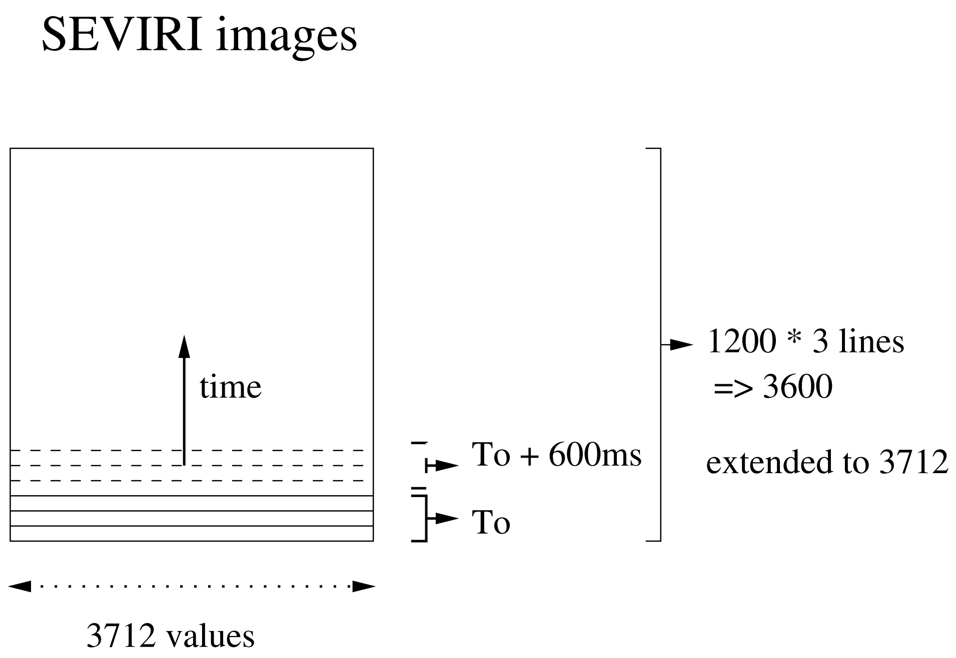

Figure 2: SEVIRI image acquisition

is a broad-band instrument that allows better estimation of radiation budget. Using different spectral bands i.e. different SEVIRI images and integral estimation, it is possible to estimate what would be the SW and the LW radiance seen by GERB without GERB PSF and at SEVIRI resolution. It is also possible with angular dependency models and scene identification to estimate the solar and thermal flux. The SEVIRI processing furnishes to GERB four images at SEVIRI resolution: SEVIRI SW estimation in the GERB SW window and SEVIRI LW estimation in the GERB LW window, SEVIRI solar flux and SEVIRI thermal flux.

6 DATA SIMULATION

Since the data will be available after the launch of the satellite, data is simulated to develop the GERB processing. The scene scanned by the two instruments is seen at different times. This time difference is an important feature to develop the processing. For the generation of artificial data, a set of rectangles is generated with a constant speed and a starting time in the Earth geolocation system (see figure 3).

6.1 Generation of the geolocation of SEVIRI data

The easiest way is to have a function giving the latitude and longitude of a specified pixel. The total scanning angle in both directions is 18° and the sampling rate is constant from the ideal satellite position at the distance of D^s (42 164 km). The Earth is modeled as an ellipse with two axes of 6378 km (equatorial radius, R^e) and 6357 km (polar radius, R^p). The geolocation is the intersection of the satellite line of sight and the Earth at angular constant sampling (see figure 4). See [CGMS-03] for a complete description of the geodesic SEVIRI geolocation.

The geocentric geolocation of the azimuth (φ) and elevation (θ) of the viewing direction of the satellite is given by the equations in the Earth coordinate system by:

$\left(\frac{X}{R^e}\right)^2 + \left(\frac{Y}{R^e}\right)^2 + \left(\frac{Z}{R^p}\right)^2 = 1$ the Earth ellipsoid equation

or

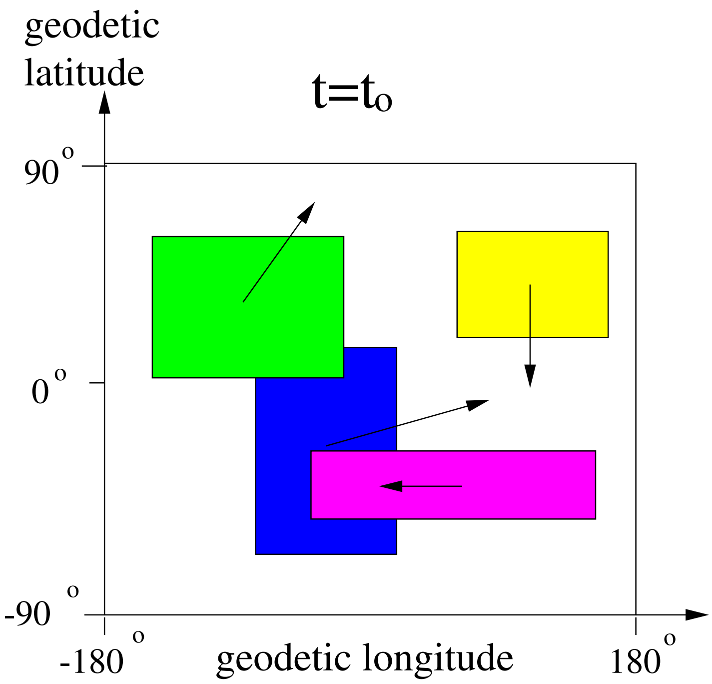

Figure 3: Artificial scene of moving rectangles

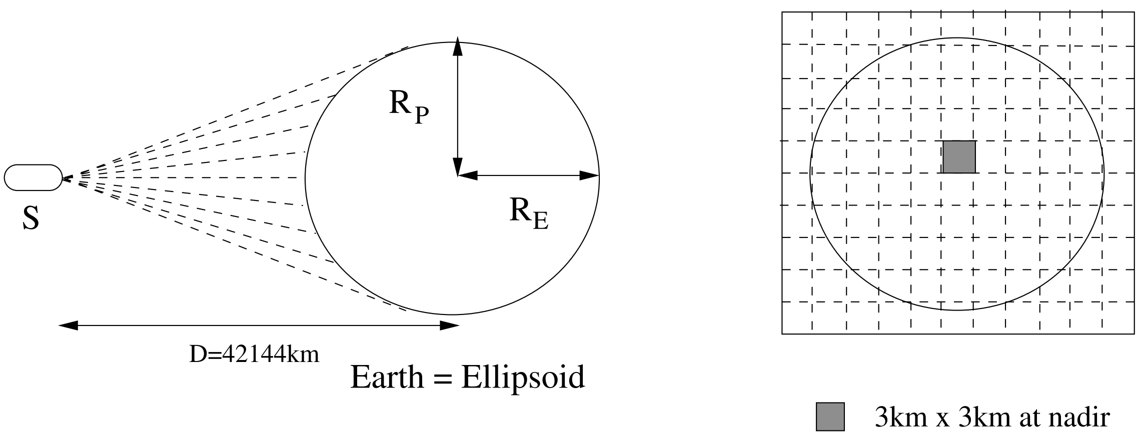

Figure 4: SEVIRI geolocation table

$x^2 + y^2 + \left(\frac{R^e}{R^p}\right)^2 z^2 = 1$ with $x = \frac{X}{R^e}$, $y = \frac{Y}{R^e}$ and $z = \frac{Z}{R^e}$

$$\begin{cases} x = \frac{D^s}{R^e} - l\cos\theta\cos\varphi \\ y = -l\cos\theta\sin\varphi \\ z = l\sin\theta \end{cases}$$ the viewing direction with l the line parameter

The intersection is given by the root of:

$$ax^2 + by^2 + c = 0$$

with
$a = \cos^2\theta + \sin^2\varphi\left(\frac{R^e}{R^p}\right)^2$
$b = -\cos\varphi\cos\theta$
$c = 1 - \left(\frac{R^e}{D^s}\right)^2$

The solution is then given by:
$d = b^2 - a\ c$ (if d is negative there is no intersection between the viewing direction and the Earth)
$l = -b - \frac{\sqrt{d}}{a}$(closer from satellite than $l = -b + \frac{\sqrt{d}}{a}$)
$x = 1 - l\cos\varphi\cos\theta$
$y = l\sin\varphi\cos\theta$
$z = l\sin\theta$
$geocentric\,longitude = \arctan(\frac{y}{x})$
$geocentric\,latitude = \arctan(\frac{z}{\sqrt{x^2+y^2}})$

These equations simply give the intersection between the Earth ellipsoid and the satellite viewing direction. To convert from geocentric to geodetic, only the latitude changes:

$$geodesic\,latitude = \arctan(\tan(geocentric\,latitude)\left(\frac{R^e}{R^p}\right)^2)$$

Since the number of lines of SEVIRI does not seem to be clearly fixed, the angular sampling value will be taken to have a 3 km by 3 km at the sub-satellite point. This gives a sampling angle of 0.00480322 radian in both direction.

6.2 Generation of the geolocation table of GERB data

The GERB data is not on a grid. So all the generated data can be realised on different grids.

Since the detectors are not perfectly aligned, a modification of the line of sight constant for each detector is generated. This information is implicitly included in the geolocation table. This is done by adding the same constant value to the azimuth and the elevation for each detector.

The position of the satelite is modified in four ways: position and three rotations. First the position of the satelite is modified with a random value on each axis between each scan[1] . The geolocation is therefore modified according to the equations, the shift in the three axes being $(\Delta x, \Delta y, \Delta z)$:

$$dx = \frac{\Delta x}{D^s},\ dy = \frac{\Delta y}{D^s},\ dz = \frac{\Delta z}{D^s}$$

with the viewing direction modified to:

[1] Since the maximum satellite speed is 80 m/s, it is better to avoid shifts higher than 48 m (distance done for one scan of 600 ms).

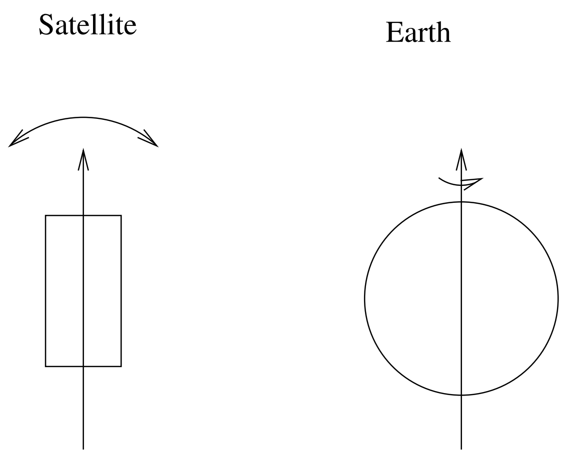

Figure 5: Second rotation

$$\begin{cases} x = \frac{D^s}{R^e} - l\cos\theta\cos\varphi + dx \\ y = -l\cos\theta\sin\varphi + dy \\ z = l\sin\theta + dz \end{cases}$$

The root is given by:
$a = \cos^2\theta + \sin^2\varphi\left(\frac{R^e}{R^p}\right)^2$
$b = -\cos\varphi\cos\theta(1+dx) - dy\sin\varphi\cos\theta + dz\sin\varphi\left(\frac{R^e}{R^p}\right)^2$
$c = (1+dx)^2 + dy^2 + dz^2\left(\frac{R^e}{R^p}\right)^2 - \left(\frac{R^e}{D^s}\right)^2$
$d = b^2 - a\ c$ (if d is negative there is no intersection between the viewing direction and the Earth)
$l = -b - \frac{\sqrt{d}}{a}$
$x = dx + 1 - l\cos\varphi\cos\theta$
$y = dy + l\sin\varphi\cos\vartheta$
$z = dz + l\sin\vartheta$
$geocentric\, latitude = \arctan(\frac{z}{\sqrt{x^2+y^2}})$
$geodesic\, longitude = \arctan(\frac{y}{x})$
$geodesic\, latitude = \arctan(\tan(geocentric\, latitude)\left(\frac{R^e}{R^p}\right)^2)$

The shifts in the three axis are stored for possible further processing since the position of the satellite is available in the SEVIRI header. For the moment, this information is not used in the processing.

It could be that the satellite axis is not parallel to the Earth rotation direction. This implies two kinds of possible modification of the viewing angles. First a rotation of an angle α in the plane perpendicular to the Earth satellite direction implies a rotation of the viewing angles according to:

$\theta^{'} = \varphi\cos\alpha + \theta\sin\alpha$
$\varphi^{'} = -\varphi\sin\alpha + \theta\cos\alpha$

This information is also stored for further processing. This information is necessary to know the rotation to apply to the PSF for the SEVIRI to GERB resolution processing.

Second, a rotation in a perpendicular plane to the previous one (see figure 5) is simply simulated by adding the same value to the elevation of each pixel of the scan.

Finally, if the acquisition is not done at the right time, a simple addition to the azimuth of each pixel of the scan simulates the effect.

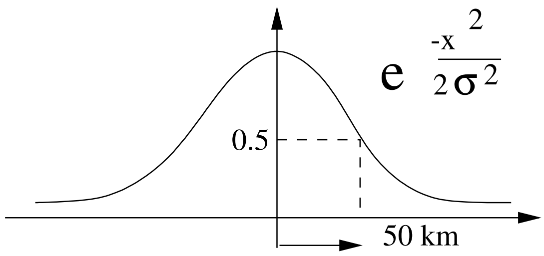

Figure 6: PSF as gaussian function

6.3 PSF Generation

The PSF can be roughly approximated by a gaussian function. The value at half of the amplitude is 50 km (see figure 6) so:

$$e^{-\frac{x^2}{2\sigma^2}} = 0.5 \qquad \rightarrow \sigma = 42,47 \text{ for } x = 50km$$

With 3σ in each direction (255 km), 99% of the surface function is covered. 255 km represents 85 pixels at SEVIRI resolution . So an image size of 85x85 pixels seems a good compromise.

For each line of the GERB image (each pixel of a line is scanned by the same detector), a different PSF table must be generated. Each PSF image can be different. The PSF is different for LW and SW. A total number of 512 PSF are generated.

For example, the value of pixel (i,j) for detector d in SW is given by:

$$P^d_{SW}(i,j) = \frac{1}{S^d_{SW}} e^{-9*(\frac{i^2}{2(\sigma^d_x)^2} + \frac{j^2}{2(\sigma^d_y)^2})}$$

with

$$S^d_{SW} = \sum_{i,j} P^d_{SW}(i,j)$$

where 9 is the square of the SEVIRI pixel distance (3 km) and where the variances (σ_x, σ_y) can be different for each detector.

The PSF is obviously normalised to 1.

6.4 Scene Generation

Scene rectangles are defined on the Earth ellipsoid in geodesic longitude and latitude coordinates. The speed in each direction is limited to the maximum speed of a cloud (0.001 degree/sec = 360 km/h). At each rectangle four values are associated: the SEVIRI GERB SW estimation, the SEVIRI GERB LW estimation, the SEVIRI solar flux and the SEVIRI thermal flux.

6.5 SEVIRI Images Generation

A SEVIRI image can be easily generated using the information of acquisition time (see 4) and geolocation (see 6.1).

6.6 GERB Images Generation

A GERB image can be generated using the information of acquisition time (see 3) and geolocation (see 6.2).For the generation of the SW image, the SW PSF is applied on the scene at GERB pixel acquisition time and position with the SEVIRI GERB SW estimation values. For the TW image

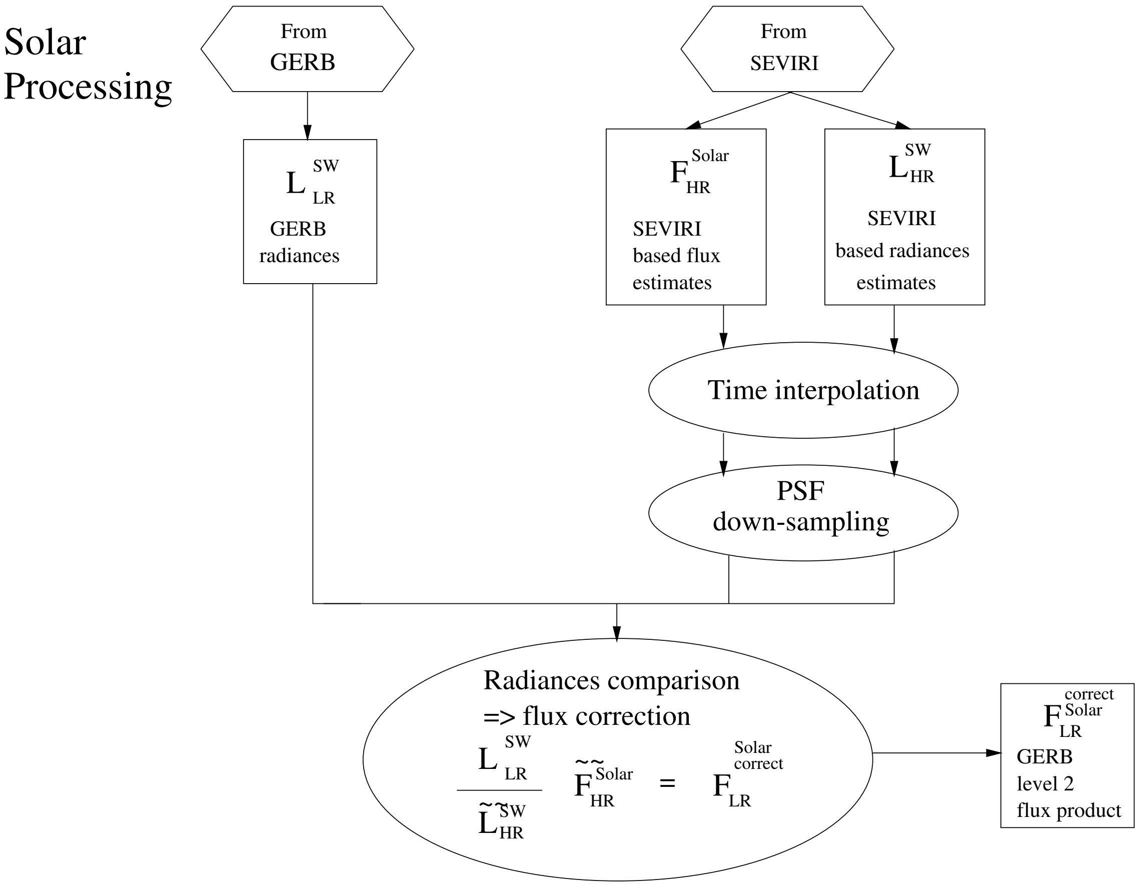

Figure 7: SW processing flow chart

generation, the same processing is applied using SW PSF with SEVIRI GERB SW and LW PSF with SEVIRI GERB LW. The TW is generated by:

TW=LW+A*SW

The value of A depends on the detector and is also generated randomly and close to one (in the range [0.9,1.1]). This value is saved for further processing. In the final implementation this value is available trough the ground calibration phase and can be updated in flight.

7 GERB PROCESSING

The SEVIRI GERB SW estimation image and the SEVIRI solar flux will be "down sampled" at the GERB resolution with the GERB SW PSF[2]. The ratio for each pixel between the GERB image and the SEVIRI GERB SW at GERB resolution will be applied to the SEVIRI solar flux at GERB resolution. Since the acquisition time is not the same for the two instruments, a linear interpolation will be done between the two time adjacent pixels. The geolocation is also different and spatial interpolation is used (see figure 7).

The same processing will be applied to the LW/thermal images with the additional interpolation on GERB data for the LW as a difference between the SW and the TW (see figure 8).

[2]There are a LW PSF and a SW PSF.

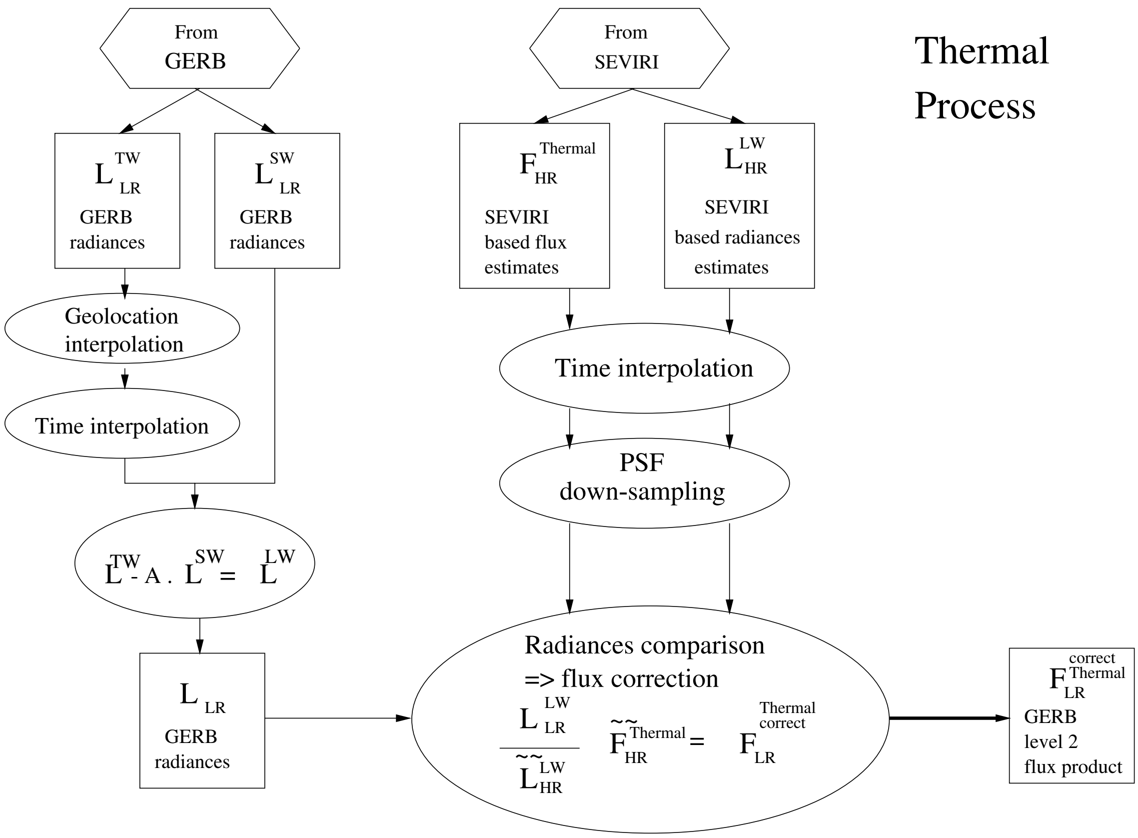

Figure 8: LW processing flow chart

7.1 SEVIRI time interpolation and PSF down sampling

To generate one pixel at GERB resolution and geolocation from SEVIRI data, the PSF convolution is centered on the four SEVIRI closest pixels to GERB pixel geolocation. The final result is a bilinear interpolation between the four values. Since all the operations are linear, this is the same than doing a bilinear interpolation on the SEVIRI image before applying the PSF. In order to correctly apply the PSF two additional processings are performed: a time interpolation and a PSF rotation (using the satellite angle rotation saved in the simulation phase or available in the SEVIRI header). Since the acquisition time is the same for a GERB row, the time interpolation is done for the pixels needed for a complete GERB row. The PSF rotation has a very huge computing time cost if it is done for each row. Since the time between two rows acquisition is very small, the PSF rotation is done once for a specified number of rows taking as rotation angle the mean of the values of the processed rows.

The SEVIRI GERB low resolution radiance is the SEVIRI radiance weighted by the PSF and interpolated:

Let

1. T^s be the time between two SEVIRI images
2. $t_{ijr}^{g|s}$ be the time of acquisition of GERB|SEVIRI pixel (i,j) for time slot r[3]
3. g_{ijr}^g(g_{ij}^s) be the geolocation of GERB (SEVIRI) pixel (i,j) for time slot r (SEVIRI geolocation does not depend on r)
4. $\lfloor t \rfloor_{kl}$ be the r index of the t_{klr}^s value inferior closer to t
5. $\widetilde{L}_{HR}^f(t,g)$ be the SEVIRI estimated radiance with GERB instrument spectral response for pixel (k,l) at time t and geolocation g at SEVIRI high resolution. In particular if $t = t_{klr}^s$ and $g = g_{kl}^s$, the radiance is the SEVIRI available pixel value from the SEVIRI processing.
6. $\widetilde{L}_{LR}^f(t,g)$ be the GERB low resolution radiance value estimated from SEVIRI at time t and geolocation g.
7. $I_G(i,j,k,l)$ be the interpolation coefficient between high and low resolution of GERB pixel (i,j) and SEVIRI pixel (k,l)
8. $\alpha^{sat}(t)$is the satellite rotation angle (see 6.2)
9. $P^d(k,l,\alpha)$ be the Point Spread Function at pixel (k,l) for detector d (there is a relation between d and the GERB pixel position (i,j), if i describes the lines d is equal to i). α is a rotation angle applied to the PSF to take into account the α^{sat}satellite rotation angle.

The time interpolation on SEVIRI images is simply a linear interpolation:

$$\widetilde{L}_{HR}^f(t,g_{kl}^s) = \frac{t_{kl\lfloor t \rfloor_{kl}+1}^s - t}{T^s}\widetilde{L}_{HR}^f(t_{kl\lfloor t \rfloor_{kl}+1}^s, g_{kl}^s) + \frac{t - t_{kl\lfloor t \rfloor_{kl}}^s}{T^s}\widetilde{L}_{HR}^f(t_{kl\lfloor t \rfloor_{kl}}^s, g_{kl}^s)$$

The down-sampling is:

$$\widetilde{L}_{LR}^f(t_{ijr}^g, g_{ijr}^g) = \sum_{k,l} I_G(i,j,k,l) \sum_{m,n=-N}^{N} P^d(m,n,\alpha^{sat}(t_{ijr}^g))\widetilde{L}_{HR}^f(t_{ijr}^g, g_{k+m,l+n}^s)$$

where $I_G(i,j,k,l)$ is simply the closest pixel or the bilinear interpolation on geolocation. For closest pixel:

$I_G(i,j,k,l) = 1$ if $\left|g_{ij}^g - g_{kl}^s\right| \leq \left|g_{ij}^g - g_{mn}^s\right|$for all (m,n)
$= 0$ elsewhere

[3]Let r be even for SW and odd for TW

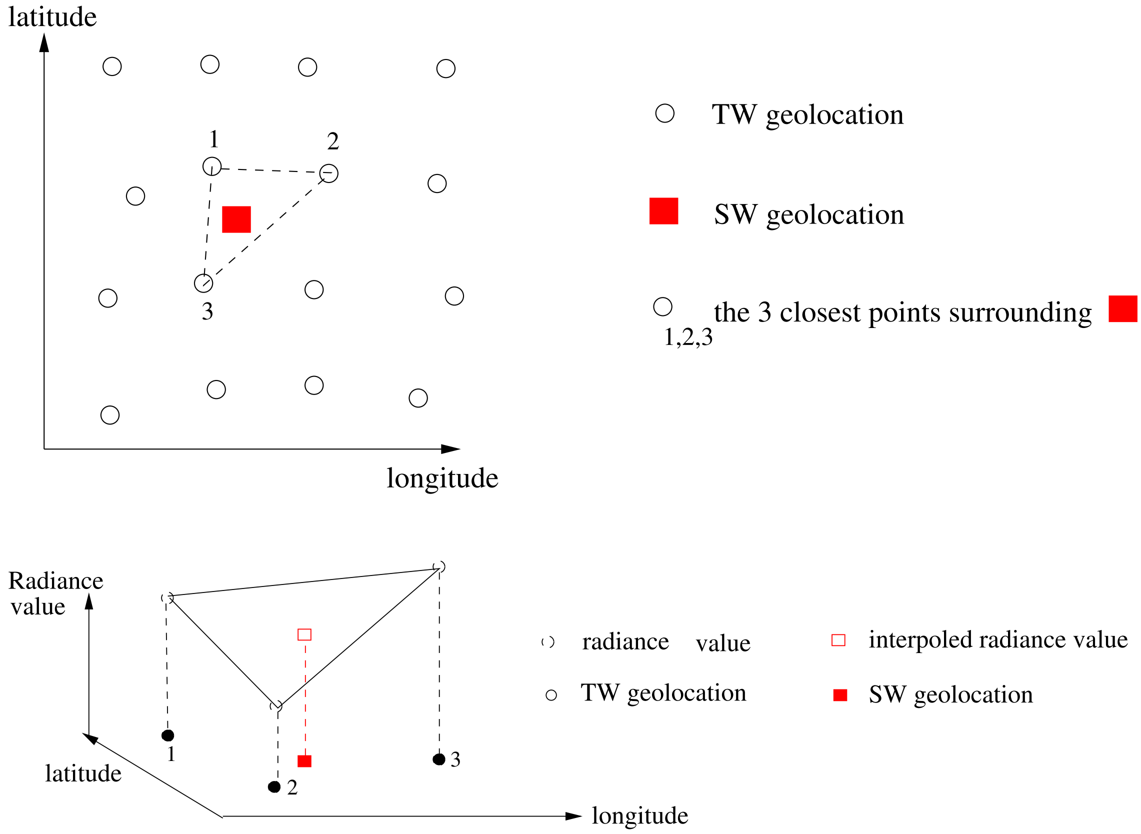

Figure 9: TW interpolation

For bilinear interpolation, the SEVIRI geolocation is inverted i.e. to a geolocation is related a couple of values (f_k, f_l) that are not necessary integers and that represents the coordinates of the SEVIRI pixel if there were no spatial sampling but continuous acquisition. Let (f_i, f_j) be the SEVIRI coordinates of GERB pixel (i, j). The bilinear interpolation is then done between the pixels $\{([f_i], [f_j]), ([f_i]+1, [f_j]), ([f_i], [f_j]+1), ([f_i]+1, [f_j]+1)\}$ where [x] is the rounding of x to the closest inferior integer.

7.2 LW Interpolation

The geolocation of the TW images are different from the SW geolocation since the acquistion time is different. A geolocation interpolation must be realized. The geolocation interpolation is done using the triangle surrounding the pixel position[4] (see figure 9). If no triangle can be found (in the Earth borders), a simple distance weighted sum is used. The same space interpolation is realised on the A parameters and on the rotation angle α (see 6.2) of the satellite. The A parameters are supposed to be updated each 6 months. To determine the LW image, the difference between the TW and the SW image must be done but the acquisition times are different. By linear interpolation, a TW image at SW acquisition time is created. The used A parameter will be the mean between the interpolated TW A and the SW A. Since the SW and TW acquisition are done successively but in reverse order, the interpolation is the same for all the pixels of one line. A TW file is needed for two different LW interpolation.

The equations are:

[4] After some investigations, three points interpolation is better than four because the fourth point can be very far away from the new position. This is a consequence of the constant grid projection on a sphere.

Let

1. $L^f_{LR,SW|TW|LW}(t,g)$be the GERB SW|TW|LW low resolution radiance value of pixel (i,j) at time t and geolocation g (this is the available data if the geolocation and time fit the furnished data).
2. $I_{geo}(i,j,k,l)$be the geolocation interpolation coefficient for TW geolocation to SW geolocation

Then a first interpolation in space is done on the TW from TW geolocation convertion to SW geolocation:

$$L^f_{LR,TW}(t^g_{ij(2n+1)}, g^g_{ij2n}) = \sum_{k,l} I_{geo}(i,j,k,l) L^f_{LR,TW}(t^g_{kl(2n+1)}, g^g_{kl(2n+1)}) (1)$$

The new TW is defined at SW pixel position whithout time interpolation. Since the three closest point are used, the interpolation in time can be omitted. The omitted time interpolation can be higher than one scan since the link between the geolocation and the image position can vary from image to image.

Let (k_1,l_1), $(k_2,l_2)$and (k_3,l_3) be the three closest TW pixel indexes to the SW geolocation g^g_{ij2n}. The following system is solved:

$$\begin{pmatrix} L^f_{LR,TW}(t^g_{k_1l_1(2n+1)}, g^g_{k_1l_1(2n+1)}) \\ L^f_{LR,TW}(t^g_{k_2l_2(2n+1)}, g^g_{k_2l_2(2n+1)}) \\ L^f_{LR,TW}(t^g_{k_2l_2(2n+1)}, g^g_{k_2l_2(2n+1)}) \end{pmatrix} = \begin{pmatrix} lat(g^g_{k_1l_1(2n+1)}) & lon(g^g_{k_1l_1(2n+1)}) & 1 \\ .. & .. & 1 \\ .. & .. & 1 \end{pmatrix} \begin{pmatrix} a \\ b \\ c \end{pmatrix}$$

That can be rewritten for easier manipulation:

$$\overline{B}_{ij(2n+1)} = \overline{\overline{A}}_{ij(2n+1)} \overline{C}_{ij(2n+1)}$$

So, the equation 1 becomes:

$$L^f_{LR,TW}(t^g_{ij(2n+1)}, g^g_{ij2n}) = \begin{pmatrix} lat(g^g_{ij2n}) & lon(g^g_{ij2n}) & 1 \end{pmatrix} (\overline{\overline{A}}_{ij(2n+1)})^{-1} \overline{B}_{ij(2n+1)}$$

The same applies to the TW image of slot 2n-1:

$$L^f_{LR,TW}(t^g_{ij(2n-1)}, g^g_{ij2n}) = \begin{pmatrix} lat(g^g_{ij2n}) & lon(g^g_{ij2n}) & 1 \end{pmatrix} (\overline{\overline{A}}_{ij(2n-1)})^{-1} \overline{B}_{ij(2n-1)}$$

If the above equation is developped, it can be written:

$$L^f_{LR,TW}(t^g_{ij(2n+1)}, g^g_{ij2n}) = \sum_{p=1}^{3} I_{geo}(i,j,k_p,l_p) L^f_{LR,TW}(t^g_{k_pl_p(2n+1)}, g^g_{k_pl_p(2n+1)})$$

The same interpolation is applied on the A parameters and on the αrotation angle:

$$A_{i,2n+1} = \sum_{p=1}^{3} I_{geo}(i,j,k_p,l_p) A_{k_p}$$

$$\alpha_{i,2n+1} = \sum_{p=1}^{3} I_{geo}(i,j,k_p,l_p) \alpha_{k_p}$$

Finally the TW image at SW time and geolocation is:

$$L^f_{LR,TW}(t^g_{ij2n}, g^g_{ij2n}) = \frac{(t^g_{ij2n} - t^g_{ij2n-1})}{(t^g_{ij2n+1} - t^g_{ij2n-1})} L^f_{LR,TW}(t^g_{ij2n-1}, g^g_{ij2n}) + \frac{(t^g_{ij2n+1} - t^g_{ij2n})}{(t^g_{ij2n+1} - t^g_{ij2n-1})} L^f_{LR,TW}(t^g_{ij2n+1}, g^g_{ij2n})$$

The A parameters becomes:

$$A_{i,2n} = \frac{(t^g_{ij2n} - t^g_{ij2n-1})}{(t^g_{ij2n+1} - t^g_{ij2n-1})} A_{i,2n-1} + \frac{(t^g_{ij2n+1} - t^g_{ij2n})}{(t^g_{ij2n+1} - t^g_{ij2n-1})} A_{i,2n+1}$$

The same interpolation is realised on the α rotation angle.

And finally the LW is computed as:

$$L^f_{LR,LW}(t^g_{ij2n}, g^g_{ij2n}) = L^f_{LR,TW}(t^g_{ij2n}, g^g_{ij2n}) - (\frac{1}{2}A_i + \frac{1}{2}A_{i,2n}) L^f_{LR,SW}(t^g_{ij2n}, g^g_{ij2n})$$

7.3 Thermal and Solar Flux at GERB resolution

The SEVIRI solar and thermal flux images are time and space interpolated as the SEVIRI SW and LW images. The ratio between the SEVIRI SW at GERB resolution and the GERB SW is applied on the SEVIRI solar flux at GERB resolution. The same is done with the LW/thermal images.

The equations are:

$$F^{corrected}_{LR,solar}(t^g_{ij2n}, g^g_{ij2n}) = \frac{L^f_{LR,SW}(t^g_{ij2n}, g^g_{ij2n})}{\widetilde{L}^f_{LR,SW}(t^g_{ij2n}, g^g_{ij2n})} \widetilde{F}_{LR,solar}(t^g_{ij2n}, g^g_{ij2n})$$

$$F^{corrected}_{LR,thermal}(t^g_{ij2n}, g^g_{ij2n}) = \frac{L^f_{LR,LW}(t^g_{ij2n}, g^g_{ij2n})}{\widetilde{L}^f_{LR,LW}(t^g_{ij2n}, g^g_{ij2n})} \widetilde{F}_{LR,thermal}(t^g_{ij2n}, g^g_{ij2n})$$

7.4 File Availability

In order to process the data, some files are needed. The existence of these files has to be verified. To determine which SEVIRI files are needed for a specific GERB file, the first acquisition time and last acquisition time for the files must be compared. The SEVIRI needed files are the ones that the first acquisition time surrounds the GERB last acquisition time and that the last acquisition time surrounds the GERB first acquisition time. Normally, there are three SEVIRI files but in some cases two files can be sufficient. Since the acquisition time of a LW is the same as SW, the file availability is not changed except for the availability of the previous and next TW file in time.

The A file used will be the more recent file found.

Errors in input files are defined as a specific big negative value. These specific values will be propagated along all the processing.

8 PROGRAMS STRUCTURE

8.1 Directory Structure

The following directories are used to store the data:

Directory name	Data	Type	File Name
SEVIRI/GEO	geolocation of SEVIRI	ims<f,f,uc>	SeviriGeo
SEVIRI/GSWE	SEVIRI SW estimation	im<f>	GSWE_<date>_<version>.rma
SEVIRI/GLWE	SEVIRI LW estimation	im<f>	GLWE_<date>_<version>.rma
SEVIRI/GSFE	SEVIRI solar estimation	im<f>	GSFE_<date>_<version>.rma
SEVIRI/GTFE	SEVIRI thermal estimation	im<f>	GTFE_<date>_<version>.rma
GERB/L15_GEO	GERB geolocation	ims<f,f,uc>	L15_GEO_<date>_<version>.rma
		mat<f>	L15_MaD_<date>_<version>
GERB/L15_SW	GERB SW	im<f>	L15_SW_<date>_<version>.rma
GERB/L15_TW	GERB TW	im<f>	L15_TW_<date>_<version>.rma
GERB/A	A	vec<f>	A_<date>
PSF/PSFXX	PSF of size XX by XX	im<f>	PSF_<detector>.rma
L20_GERB/L20_TF	GERB thermal flux data	im<f>	L20_TF_<date>_<version>.rma
L20_GERB/L20_SF	GERB solar flux data	im<f>	L20_SF_<date>_<version>.rma

The types are:

1. im for image (IP_image)
2. ims for images (IP_images)
3. mat for matrix (MP_matrix)
4. vec for vector (MP_vector)
5. f for 4 bytes floating point format
6. uc for 1 byte unsigned integer format

The name of the files follows the convention of the project (MSG-RAL-GE-TN-0008). <date> is the date description as YYYYMMDDHHMMSS and version is the software version used to generate the data.

These directories will be defines placed in the GERB library file gerb_path.h. (TBC)

The following directories are used for program management and inter-program intermediate data sharing:

Directory name		Type
lock	Lock for concurrent processing	Empty file
Remove	Link to files that are not anymore needed	link
bin	binaries and cron files	

8.2 Log and error tracking

(see [DF])

References

[RIT] [CGMS-03] LRIT/HRIT Global Specification. Issue 2.5

[DF] "RMIB GERB Processing: Data Flow", L. Gonzalez , MSG-RMIB-GE-TN-0009