QUALITY SUMMARY:
GERB L1.5 NARG: filtered radiance Edition 1 product and L1.5 GEO geolocation product

GERB project team, last update 14 November 2006

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This document is designed to inform users of the accuracy of the data products as determined by the GERB team and summarises the important validation results. The document also provides cautions on the appropriate use of the data and provides references to further, more detailed information.

This document covers the level 1.5 NANRG and level 1.5 GEO edition products, please note that for the L15_GEO products only the longitude and latitude values are part of the edition release, the other values within these products should not be used for scientific purposes. For the level 1.5 NANRG none of the values within the Geolocation part of the HDF structure are part of the edition release and these should not be used for scientific purposes.

This document must be read prior to using GERB data, and all users should determine if their use of the data is appropriate by consideration of the information contained here.

This document is intended as a high-level summary for scientific users of the product. It will be updated as necessary to reflect the current knowledge of the quality of the data products. Users should re-check this document for the latest status before publication of any scientific paper using these data.

More detailed information and validation results will be made available in supplementary documentation as appropriate. Users are also referred to the product user guide for additional information concerning the product contents.

Users are asked to pay particularly careful attention to section 1 of this document which contains 'Specific Cautions' regarding the use of the GERB level 1.5 NANRG data.

1. Specific cautions

Instrument calibration: In the Edition 1 data instrument gain is determined in orbit and updated every 5 minutes. However all other calibration coefficients are kept static using ground measured values. Whilst no change to these values is expected, this can not be verified until the full edition dataset is available for survey. Therefore until such time as this is completed, the user is cautioned that **subtle variations trends and cycles may be present in the Edition 1 data**. **The stability of the Edition 1 data record is not guaranteed beyond the level of the absolute accuracy.**

Bad data flags: Users should be aware of the error values for each dataset and the calculation limits applied to the products. Users are also directed to the level 1.5 anomaly flags which indicate instrument anomalies affecting the data. In general, products affected by major anomalies will be excluded from the Edition dataset. Users may also wish to exclude products affected by some or all minor anomalies. A list of the anomalies flagged is included in the level 1.5 user guide. Stray light anomaly flags are discussed in more detail below.

Geolocation. **The geolocation information contained within the Edition 1 NANRG files themselves is not accurate and is not suitable for scientific use, users requiring geolocation information should download and use the appropriate L15_GEO file**. There should be one L15_GEO file for each of the 6 scans within a NANRG. The date and time indicated in the name of the L15_GEO file corresponds to the 'UTC_TIME__PER_COLUMN_' value within the 'TIMES' part of the HDF structure for the NANRG. For shortwave scans the time in the GEO file corresponds to the UTC time for column 0 and for total scans to that for column 281

The mean geolocation accuracy of the L15_GEO should be sufficient for most purposes, however the **geolocation accuracy of an individual pixel is not guaranteed**. This is because problems with the stability of the MSG geolocation signal and a delay in obtaining spin-structure axis misalignments for the satellite has required the geolocation for the edition 1 GERB products to rely on a match between each individual GERB image and the SEVIRI observations. The matching process, based on a minimisation of the differences between the observations, is statistical in nature and thus the accuracy of the geolocation for any given pixel is subject to random errors.

The stability of the edition 1 geolocation is best for low viewing zenith angles, becoming worse for viewing angles above 40-50° and for extreme solar zenith angles. Over the nominal GERB region (60°E to 60°W, 60°S to 60°N), we estimate the standard deviation of the geolocation to be around a quarter of a GERB sampling distance (GERB sample distance is approximately 50 km at nadir). Effects on the products are most significant at high contrast edges, such as cloud and coastline.

Users should note that although the geolocation error is random, it can produce systematic effects in average radiances that have been separated according to scene type or location. For example, for points close to coasts geolocation errors will occasionally cause GERB pixels with a longitude and latitude that would imply they should be ocean to occasionally actually be land. In the SW this will always lead to an elevation of the radiance compared to the dark ocean surfaces leading to a systematic bias in the inferred average quantity.

NANRG grid: Each NANRG point measurement is an instantaneous observation of the broadband TOTAL or SW radiance filtered by the instrument response. **No correction has been made for the spectral or spatial variation in the instrument response**. Each measurement represents a non-uniform spatial average centred on that location where the spatial variation of the weighting is determined by the pixel point spread function. Each measurement is a broadband observation weighted by the spectral response of the instrument in that channel. The TOTAL channel covers the range 0.3 to 500μm and the SHORTWAVE is sensitive to the spectral range 0.3 to 4μm (with a small 'leakage' contribution wavelengths longer than about 65μm). Average pixel spectral response is shown in figure 2 and the text files containing this information can be accessed from the ggsps information page: http://ggsps.rl.ac.uk/information.html. Point spread function data for each pixel is available on request from gerb@imperial.ac.uk.

Pixel to pixel variation in shortwave response: GERB obtains measurements with 256 distinct detectors arranged approximately North-South with respect to the Earth. The shortwave and longwave gain of each pixel is independently determined, but an average detector response is assumed to apply to each pixel for the Edition 1 release. Whilst we do not expect significant differences in the spectral response of the detectors, there may be a variation in their response with a standard deviation of around 2% in the shortwave. If present **this can result in biases in the radiances and fluxes which vary subtly with pixel number**. Because of the north-south orientation of the pixel array this can translate into latitude dependent biases. To quantify the possible magnitude of this effect a per-pixel comparison between the GERB and CERES radiances has been made and the results are presented in section 4 of this document. We anticipate that that this issue will be resolved in future editions of the GERB products.

Eclipse operations and stray light: Being a wide field of view instrument it is impossible to avoid stray light affecting the data during some periods. GERB is unable to make science observations for a few hours around midnight for a period stretching from a little more than a month before to a month after the spring and autumn equinoxes. This is because the Sun enters the GERB field of view at these times and exposing the detectors to direct solar illumination would result in pixel damage. Approaching these times **as the Sun comes close to the edge of the GERB field of view, stray illumination can cause contamination of the data products**.

Contamination of the data by stray light is a function of solar declination and time of day. Significant levels are limited to the hours around midnight and to a lesser extent midday. Severity of stray light contamination peaks at the spring and autumn equinoxes.

Scans containing severe stray light contamination (above 3.5 $Wm^{-2}sr^{-1}$ in the filtered radiances, termed direct stray light) are excluded from the Edition products. These scans occur during the hours 22:28 to 01:32 GMT from 30-Jan to 12-May and 01-Aug to 11-Nov.

Scans containing stray light contamination less than 3.5 $Wm^{-2}sr^{-1}$ but above the noise level (~0.3%, termed diffuse stray light) are flagged as a minor anomaly in the level 1.5 products (**please see addendum for a correction related to this statement**). These flags occur in products between the hours of 23:00 and 01:00 GMT from 15-Jan to 23-May and 21-Jul to 26-Nov.

Scans affected by stray light contamination of the internal black body view, used to subtract the offset from each measurement, are also flagged as a minor anomaly in the level 1.5 products (**please see addendum for a correction related to this statement**). These flags occur in products between the hours 10:05 to 12:30 GMT from 15-Jan to 23-May and 21-Jul to 26-Nov. Whilst normally a small effect, effects of stray light in the black body are visibly noticeable in the data for about three weeks centred on each equinox.

2. Overview:

The level 1.5 NARG (Non Averaged, Non Rectified, Geolocated) products contain 6 consecutive scans (3 SW and 3 TOTAL) obtained over a period of 16.92 minutes. Each scan contains the instantaneous calibrated filtered radiances for SW or TOTAL channel as appropriate, in a 282 by 256 array. Each array element corresponds to an individual instantaneous measurement, the y dimension of the array corresponds to pixel number (0 to 255) and the x dimension to column (0 to 281). Times contained in the level 1.5 NANRG product names indicate the nominal UTC start time of data contained within the file (NB the 'TIMES' values within the products may differ by a few seconds due to differences in the conversion between clock times and UTC, in all cases the 'TIMES' values can be considered to be more accurate). Figure 1 shows how the GERB scanning mechanism builds up a scan of the Earth in each channel. Further details of the data acquisition can be found in the GGSPS user guide available from http://ggsps.rl.ac.uk/docs/UserGuide.pdf.

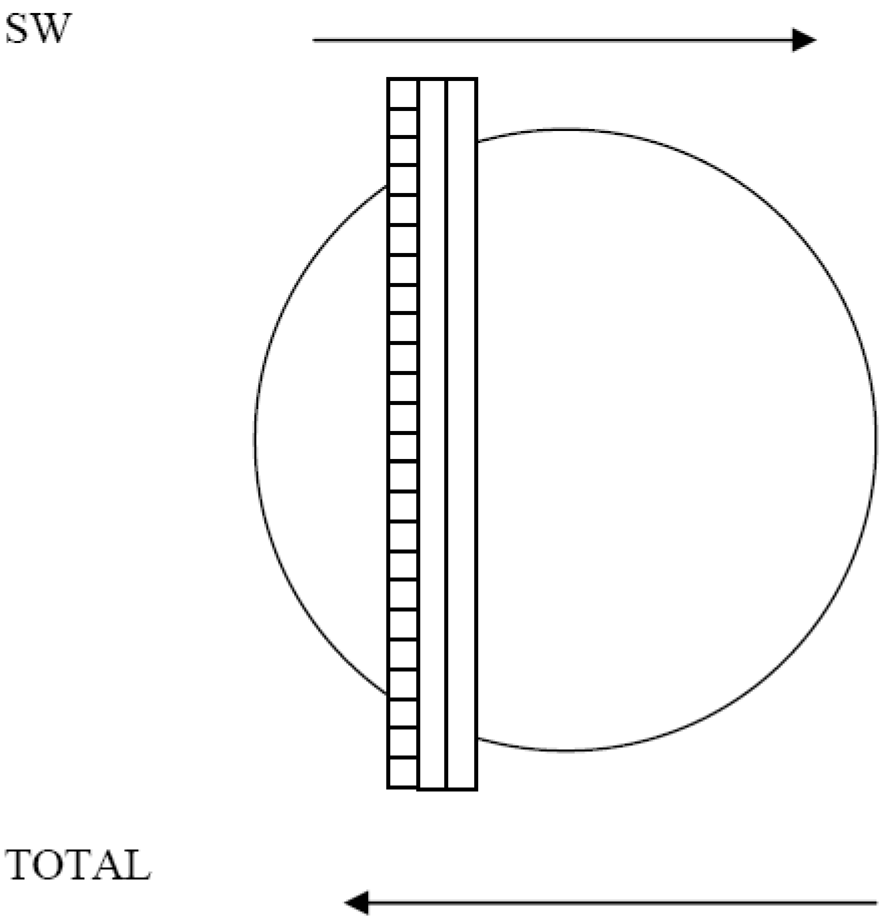

Figure 1: GERB builds an image of the Earth by scanning using a linear array of 256 individual detector elements or pixels which is oriented roughly N-S with respect to the Earth,. Each column in a NANRG is observed during one rotation of the spinning MSG satellite and consists of simultaneous observations from each of the 256 detectors. Successive columns are obtained on subsequent rotations, at approximately 0.6s intervals by stepping the observed region by 0.07° in viewing azimuth (roughly due East in the case of the SW channel and due West for the TOTAL channel). 282 columns each containing observations from 256 pixels comprise a complete scan in one of the two GERB channels. Once on 282 column scan is complete the channel is altered (by inserting or removing the quartz filter) and the process repeated in the opposite direction.

Each NANRG point measurement is an instantaneous observation of the broadband TOTAL or SW radiance filtered by the instrument response. **No correction has been made for the spectral or spatial variation in the instrument response**. Each measurement represents a non-uniform spatial average centred on that location where the spatial variation of the weighting is determined by the pixel point spread function. Each measurement is a broadband observation weighted by the spectral response of the instrument in that channel. The TOTAL channel covers the range 0.3 to 500μm and the SHORTWAVE is sensitive to the spectral range 0.3 to 4μm (with a small 'leakage' contribution wavelengths longer than about 65μm).

Constructing a synthetic LW observation during the day

A synthetic longwave observation (uncorrected for filter leakage and not accounting for overlap between the reflected solar and emitted thermal components) can be constructed from the SW and TOTAL channel observations. In order to achieve this, the gain correction factor (*B*) which has been applied to the SW radiances and the transmission of the quartz filter (*T*) needs to be accounted for, this is done by application of the calibration '*A*' factor to the shortwave radiance before subtraction from the total radiances:

$$L^F_{LW} = L^F_{TOT} - AL^F_{SW}$$

Where L^F denotes filtered radiance and SW, TOT and LW refer to the shortwave total and synthetic longwave channels respectively. The approximate value for the factor $A \left(= \frac{B}{T_{ref}} \right)$ can be found in the BAT parameter tables available on the ggsps website (http://ggsps.rl.ac.uk/docs/TableVersions.html). The *A* in this table is for a typical solar spectrum, strictly speaking the adjustment for the effect of the quartz filter is a function of the observed Earth spectra, however, because the quartz filter is relatively spectrally flat over the wavelength range containing the majority of the SW energy, the transmission adjustment factor and hence *A* is found not to vary significantly from scene to scene. For, example for a mean pixel for solar and view zenith angles less than 70° and non-glint conditions (glint angle[1] < ±5°) the difference between using the approximate *A* (= 1.0734) and the ideal one is less than 0.3$Wm^{-2}sr^{-1}$ for 99.99% of the 4.6 million simulated cases, and for no cases meeting these angle criteria was the difference greater than 1.4 $Wm^{-2}sr^{-1}$. Thus the approximate *A* can be used to contract a synthetic LW filtered radiance that will have had the solar component removed to within the noise of the measurements. It should be noted that even though the reflected solar energy is effectively removed the LW filtered radiance is not exactly an emitted thermal component or identical to the TOTAL channel measurements at night as it is filtered by the LW spectral response and so contains negligible energy (including any thermal component) from wavelengths shorter than 3.5μm.

Figures below show average pixel SW, TOTAL and synthetic LW spectral responses, text files containing the numerical values can be accessed from http://ggsps.rl.ac.uk/information.html

NOTE: the construction of the longwave observation will require spatial and temporal interpolation of the shortwave observation to the total (or visa versa), the interpolation process will introduce some additional random error into the final longwave filtered radiance.

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[1] The glint angle is defined as $\cos^{-1}(\cos\theta_{view}\cos\theta_{sun} + \sin\theta_{view}\sin\theta_{sun}\cos\phi_{rel})$, where θ_{view} is the view zenith angle θ_{sun} is the solar zenith angle and ϕ_{rel} is the relative azimuth angle between the solar and viewing directions.

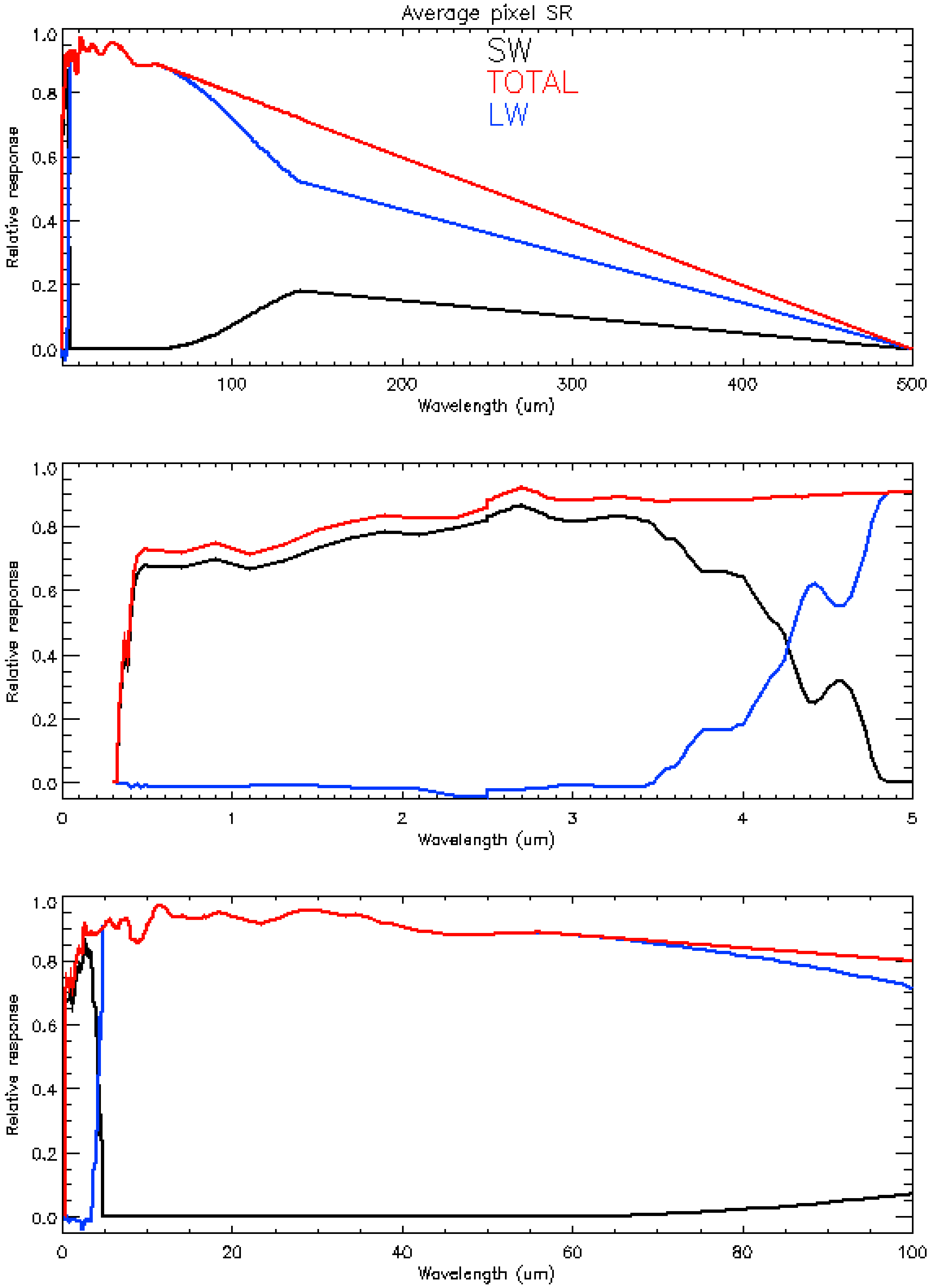

Figure 2. Average pixel spectral response for shortwave (black) total (red) and synthetic longwave (blue) channels, displayed over three different spectral ranges.

Accuracy of the Edition 1 NARG products

Some issues with the data mean that the Edition 1 GERB NARG products do not meet all of their accuracy targets. Most importantly the **geolocation information within the Edition NANRG files are not accurate and should not be considered part of the Edition release or used for scientific purposes**. **Where product geolocation is required this should be obtained from separate geolocation L15_GEO files which are named G2_SEV1_L15_GEO_SW_* and**

G2_SEV1_L15_GEO_TW_* for the SW and TOTAL channel respectively. More information on the accuracy of the replacement geolocation files is given in section 4. Specific problems are also known to exist with the accuracy of the instrument spectral response information, which may have consequences for the accuracy of the filtered radiances in the NANRG products. We anticipate further information and improvements that will address these issues for future editions.

Targets for the absolute accuracy[2] of the SW and LW unfiltered radiances were 1% of the typical full scale signals (typical full scale signals are taken to be 240 $Wm^{-2}sr^{-1}$ for the SW and 77 $Wm^{-2}sr^{-1}$ for the LW). For the Edition 1 GERB products we have determined the absolute accuracy of the filtered radiances to be 2.02% for the SW and 0.95% for the LW at night (from the TOTAL channel) and 1.07% from the LW during the day (from TOTAL minus A*SW). A more detailed breakdown of the ground determined uncertainties is given in section 3 of this document.

The CERES instruments (Wielicki et al. 1996) flying on the low Earth orbit AQUA and TERRA satellites measure the outgoing longwave and reflected shortwave broadband radiances in a similar manner to GERB. Their products have been extensively validated and have stated absolute accuracy of 1.0% for the shortwave (reflected solar) 0.5% for the longwave (emitted thermal) unfiltered radiances.

Whilst GERB and CERES have different spatial and temporal coverage and resolution, matched observations can be selected and compared as part of the GERB validation. Validation studies have compared the GERB ARG radiances with CERES SSF rev1 radiances with the observations being matched for viewing geometry pixel centre and time. The resulting average GERB/CERES ratios are shown in the table below: more detail and additional comparison results are available in the level 2 ARG quality summary (http://ggsps.rl.ac.uk/docs/GERBED1_ARG_QS.pdf) and section 4 of this document includes additional GERB CERES comparison results specific to the NANRG.

Data compared	CERES instrument	FM2 Edition 2 GERB V998/CERES SSF rev1	FM3 Edition 1b GERB V998/CERES SSF rev1
SW (reflected solar) unfiltered radiance	All sky	1.053 +/- 0.005	1.072 +/- 0.008
	Overcast	1.036 +/- 0.008	1.046 +/- 0.012
	Clear sky	1.065 +/- 0.006	1.087 +/- 0.007
	Clear ocean	1.146 +/- 0.043	1.086 +/- 0.053
LW (emitted thermal) unfiltered radiance	Night	0.989 +/- 0.003	0.982 +/- 0.001
	Day	0.993 +/- 0.001	0.982 +/- 0.003

Table 1. Summary of GERB CERES comparison results, GERB/CERES unfiltered radiance ratios. GERB V998 validation data set used for this study, these data have the same science processing at the GERB Edition 1 data.

3. Processing and calibration accuracy

Accuracy aims of the GERB products are 1% (of the typical full scale radiance) absolute accuracy of LW and SW radiances, and 0.1 GERB pixel absolute accuracy of the geolocation. The theoretical accuracy of the Edition 1 GERB products does not meet all of these targets due to known issues which we plan to resolve in future releases. Below is a summary of our current understanding of the theoretical accuracy of the GERB radiances and geolocation.

Filtered radiances

The magnitude of systematic errors in the filtered radiances has been determined from the uncertainties provided for calibration sources and spectral response measurements and the additional effect of un-flagged stray light. Table 2 summarises the approximate magnitudes of these effects and determines an RMS combination of the contributions to derive an overall accuracy assessment of the filtered radiances.

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[2] Absolute accuracy is considered to be defined as the accuracy after sufficient averaging to remove any random component of the error.

It should be noted that no random errors, including those that may be systematic for a particular scene type, are considered in table 2. Errors are quoted as a percentage where a fixed error in the quantities corresponds to a fixed fractional error in the unfiltered radiances, independent of the magnitude of the unfiltered radiances. Where a fixed error causes a fixed radiance error on the filtered radiances errors are quoted as a percentage of the typical full scale radiances which are taken to be 240 $Wm^{-2}sr^{-1}$ for the SW and 77 $Wm^{-2}sr^{-1}$ in correspondence to the accuracy requirements.

Error source	**SW**	**LW (TOTAL at night)**	**LW (Synthetic LW day)**
Calibration sources absolute accuracy (1 SD uncertainty values)	~0.22%[3]	<0.05%[4]	
Calibration sources uniformity (full range over region used)	< 0.5%	Small	
Spectral response [5]	1.9% of typical full scale	<0.9% of typical full scale	<0.9% of typical full scale
'A' factor	N/A		0.5%
Stray light (maximum effect in unflagged data)	<0.25 $Wm^{-2}sr^{-1}$ [6]		
	<0.1% of typical full scale	<0.3% of typical full scale	
Polarisation	<0.4%[7]	Small	
RMS combination of above errors	**2.02%**	**0.95%**	**1.07%**

Table 2. Estimates of the ground determined filtered radiance bias error sources and magnitudes.

Random errors are considered in table 3. This table includes contributions from detector noise, geolocation and possible smear or jitter in the observation pointing. Uncertainties due to these sources are stated as percentages of the typical full scale radiances are before. The estimated 1SD random error in geolocation accuracy is stated in terms of GERB pixels. It should be noted that geolocation errors will lead to errors in the assigned filtered radiances for a given location. Whilst random in origin, unfiltering and geolocation errors can lead to systematic errors in radiances and fluxes ascribed to a particular scene type or location.

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[3] GERB 2 VISCS data implies errors on integrated quantities of between 0.13% (spectrally uncorrelated errors) and 1.08% (worst case spectrally correlated errors). As no separation of the spectrally correlated and uncorrelated errors are currently available for the GERB 2 VISCS calibration the value given above was determined from the GERB 3 VISCS calibration for which spectrally uncorrelated and spectrally correlated errors were provided separately.

[4] Linear sum of temperature probe calibration, drift and chamber radiation.

[5] Values indicate the largest effect over a wide variety of scene types. Uncertainty is determined as a linear sum of the effects of spectrally correlated and spectrally uncorrelated errors (1SD level) on the instrument spectral response.

[6] Error indicates the maximum impact of unidentified stray light. Data with stray light contamination between approximately 0.25 $Wm^{-2}sr^{-1}$ and 3.5 $Wm^{-2}sr^{-1}$ is included in the Edition products, but flagged to indicate diffuse stray light contamination. Data with stray light contamination greater than ~ 3.5 $Wm^{-2}sr^{-1}$ is not included in the Edition products.

[7] Worst case error for a completely linearly polarised source.

Error source	**SW**	**LW (TOTAL at night)**	**LW (Synthetic LW day)**
Instrument noise	<0.19% of typical full scale	<0.65% of typical full scale	<1.0% of typical full scale
Geolocation[8]	0.25 pixel		
Interpolation	N/A		~2.5%
Jitter & smear	Under assessment		

Table 3. Estimates of the 1SD level random errors on the instantaneous filtered radiances.

4. Validation result summary:

Instrument noise

Pixel noise, in counts, was assessed in orbit by considering the standard deviation over the course of a scan in the quantity V(IBB) – V(space) for either the shortwave and/or total channel. V(IBB) – V(space) is the difference between the instrument response, in counts, for observations of the internal black body and deep space readings obtained during a single rotation of the instrument mirror, these two readings are separated in time by approximately 0.3s. Factors other than noise affecting the constancy of this quantity are variation in the black body output, i.e. temperature, changes to the instrument gain or contamination of either signal, for example by stray light. The first two of these sources of additional variation are not expected to be significant over the course of one scan (< 3 minutes) and the third factor, stray light, can be avoided by excluding data for the times of day when stray light is present. Pixel noise is not expected to be related to the signal strength as it is an electronic noise present even for a zero reading. Ground measurements confirm that this is the case. Pixel readings are in counts and contain a time varying electronic offset, which is removed by the subtraction of the space view data used for this analysis. It is a requirement for this analysis that the space view be representative of the instrument zero level.

The standard deviation of the above quantity gives an indication of the 1SD noise in counts. It can be compared to a similar measure of the noise obtained on ground and monitored through the life of the instrument. Such an analysis shows, when time-periods affected by stray light are excluded, that the noise level has remained constant over the life of the instrument and is similar to that measured on ground. The 1SD noise for most pixels on the quantity V(IBB) – V(space) is found to be 8 counts. Translating this into a noise equivalent radiance (NER), which is the required quantity, depends on the instrument gain and throughput. The conversion can be directly made for the total channel by considering the instrument response in counts to the known input signal (unfiltered radiance) from the internal black body. This differs from the instrument gain, in that it considers the unfiltered radiances rather than the filtered radiance, and thereby also includes the transmission of the instrument optical and absorption efficiency of the detector. This is important because we want to know how the noise in counts corresponds to the signal we wish to measure, the unfiltered or incident radiance.

We thus determine the conversion factor *f* from counts to radiance we use:

$$R(IBB) = \frac{\sigma t(IBB)^4}{\pi}$$

$$f = \frac{R(IBB)}{V(IBB) - V(space)}$$

Except for a few anomalous and damaged pixels *f* is between 0.05 and 0.065 in the total channel for the pixels on GERB-2, which makes 8 counts equivalent to between 0.40 and 0.52 $Wm^{-2}sr^{-1}$. Thus the noise

[8] Pixel error quoted is determined from the stability of the geolocation in the V998 and represents approximately 1SD excluding the edge pixels.

on V(IBB) – V(space) in the total channel is equivalent to 0.4-0.5 $Wm^{-2}sr^{-1}$, this would be the NER on the longwave measurements at night[9].

Figure 3 shows the standard deviation in counts of V(IBB) – V(space) the total channel conversion factor and the resulting NER determined from the in-orbit data for the total channel for each of the GERB pixels.

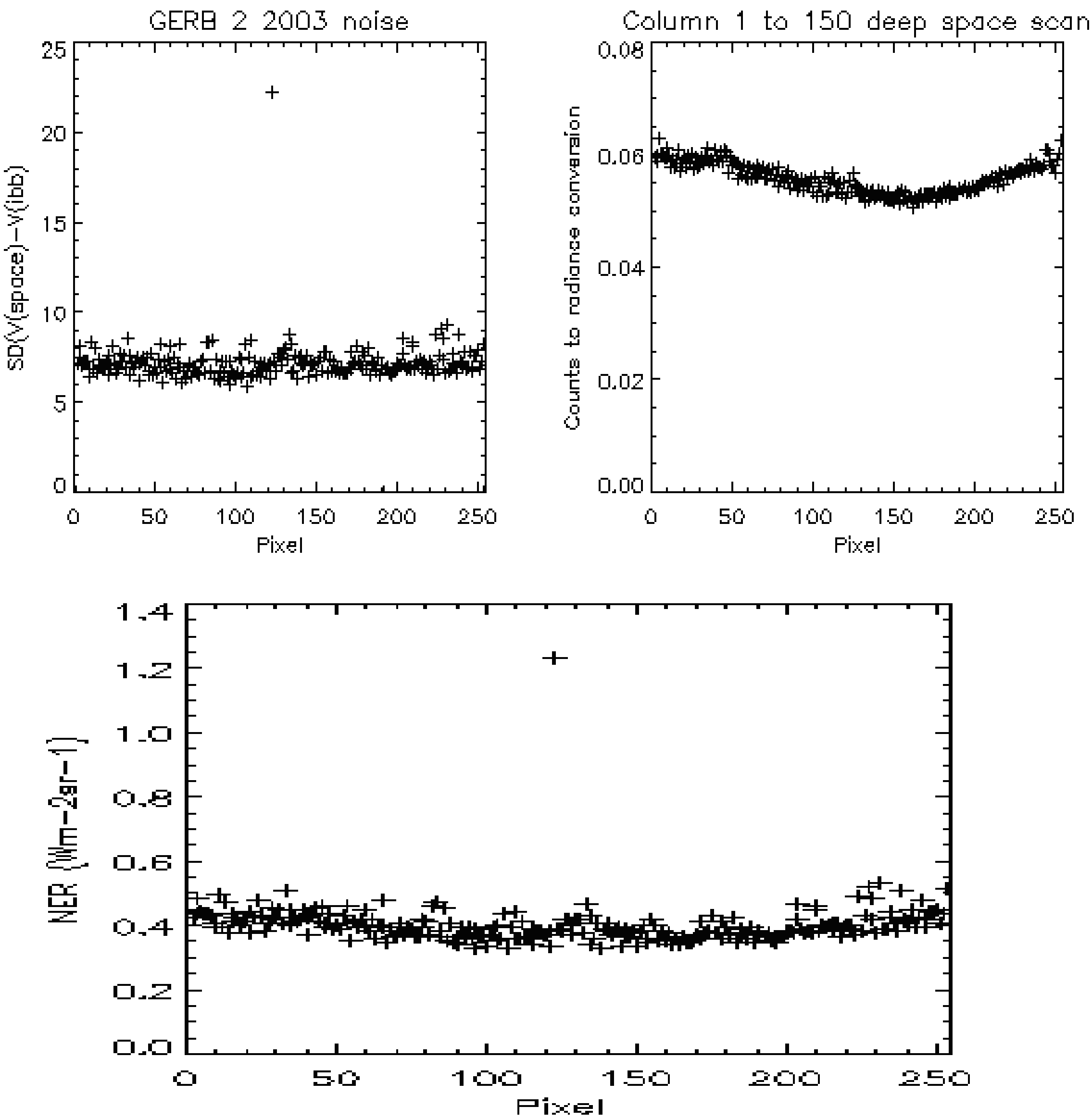


Figure 3 GERB 2 noise determined from deep space scan data in obtained in 2003. Upper left plot shows SD in count of V(space) – V(ibb), upper right plot shows the counts to radiance conversion and the lower plot the noise equivalent radiance for the instantaneous measurement for longwave during the day.

In the shortwave channel the instrument response differs, both because of the effect of the quartz filter and because of spectral variation in the reflectivity of the mirrors and detector absorption. To find the conversion factor to go from counts to radiance for the shortwave we need to use ground calibration measurements which can relate the instrument response to a known shortwave source in the shortwave channel, to that for a known longwave source, like the black body, in the total channel. This exercise indicates that the instrument response to a given incident energy is larger in the shortwave portion of the spectrum, even when the quartz filter is included. In ground calibration the instrument views a shortwave source (known as the visual calibration source or VISCS) and a longwave source (a warm black body or

[9] We neglect the noise contribution from the in-orbit determined gain as negligible as it is determined as a running average over many internal black body minus space views.

WBB). The incident radiances from the shortwave source is 2.6 times that from the longwave source, but the instrument response, in counts is between 2.95 and 3.15 greater in the shortwave channel for the shortwave source than it is in the total channel for the longwave source. This indicates that for these shorter wavelengths the shortwave channel is between 1.14 and 1.2 times more sensitive to incoming radiance than the total, that is it has a higher throughput. Thus the factor *f* for the shortwave would be between 0.04 and 0.057. Thus the NER in the shortwave channel, resulting from the 8 counts standard deviation in the signal, is between 0.32 and 0.46 $Wm^{-2}sr^{-1}$.

During the day when the longwave is obtained by subtraction of the shortwave from the total channel, noise contributions on both the filtered total radiance and the filtered shortwave radiance contribute to the overall noise, with the shortwave noise modified by the quartz filter correction factor. This makes the noise on the synthetic LW 11.8 counts, as this is a longwave signal the same conversion factor should be applied as for the TOTAL channel, resulting in a NER of between 0.59 to 0.77 $Wm^{-2}sr^{-1}$.

The results are summarised in the table below.

	In orbit determined (per scan)
NER (shortwave)	0.32 to 0.46 $Wm^{-2}sr^{-1}$
NER (Total/longwave night)	0.40 to 0.52 $Wm^{-2}sr^{-1}$
NER (synthetic longwave day)	0.59 to 0.77 $Wm^{-2}sr^{-1}$

Table 4: Noise equivalent radiance in the instantaneous filtered radiances for each of the channels determined from in-orbit deep space and internal black body observations. Note: in orbit values are determined in counts for the total channel and converted to radiance for each of the channels based on their radiance to counts conversion factors for a standard source; the synthetic longwave values consider rms combination of the noise contribution from the shortwave and total channels, however additional random error from the interpolation necessary to determine this measurement will be incurred on top of this for the synthetic LW.

Geolocation

As previously mentioned the geolocation within the level 1.5 NANRG files themselves is not accurate, and geolocation data available in the additional L15_GEO files should be used. The information in these files is obtained by matching the GERB radiances to geolocated SEVIRI data. The accuracy of the matching is statistical in nature so the geolocation accuracy of any particular pixel can not be guaranteed.

As the SEVIRI image is the reference for the GERB geolocation it is not possible to obtain an independent estimate of any bias present in the L15_GEO geolocation, however its stability or noise can be assessed. The pointing directions of the pixels relative to each other are not expected to change with time as this is a function of the optical structure of the instrument. This pointing can be derived from the longitude and latitude if the satellite position and orientation are known; although it should be noted that time varying errors in the assumed satellite position could cause the relative values of inferred pixel azimuth and elevation to vary.

Thus by combining the longitude and latitude information in the L15_GEO files with the satellite and axis orientation information in the level 1.5 NANRGs, pixel pointing directions can be derived in terms of azimuth and elevation,. The mean azimuth of each column is determined by the time of acquisition of that column relative to the satellite spin, this quantity may vary and is one of the pieces of information which is poorly measured due to variations in the MSG satellite timing signal. What is expected to be stable are pixel azimuth relative to the azimuth of pixel 128 for each column. Similarly variations in the overall elevation are possible, and even gross shifts in the N-S position of the Earth have been observed which are not traceable to measured variations in satellite position or orientation, however pixel elevation relative to the elevation of pixel 128 within each column should be stable.

Therefore the variation in a pixel's relative azimuth (azimuth minus pixel 128 azimuth for the same column) and relative elevation (elevation minus the average pixel 128 elevation in the scan, as studies show that pixel 128 elevation does not vary systematically with a scan), provides a measure of the statistical noise in the geolocation matching procedure. However it should be noted that noise or systematic biases that affect pixel 128 column azimuth and average pixel 128 elevation in each scan will not be diagnosed by this study.

This analysis was applied to the NANRGs and associated L15_GEO geo files from the V998 GERB validation reprocessing data set, consisting of 21-27th June and 11th-17th December 2004. The relative spacing of the pixels was seen to remains quite stable through the dataset. More variability was apparent in the SW geolocation than the TOTAL; for pixels towards the ends of the pixel array and for columns towards the edge of the Earth. From this we deduce that the SW geolocation is noisier than the TOTAL channel geolocation and geolocation becomes nosier at higher viewing zenith angles.

For each pixel a frequency distribution of relative azimuth and elevation can be determined for the dataset studied. Figure 4 shows and example relative position frequency distribution determined from the total channel observations in the reprocessed V998 data for June 2004 for pixel 186.

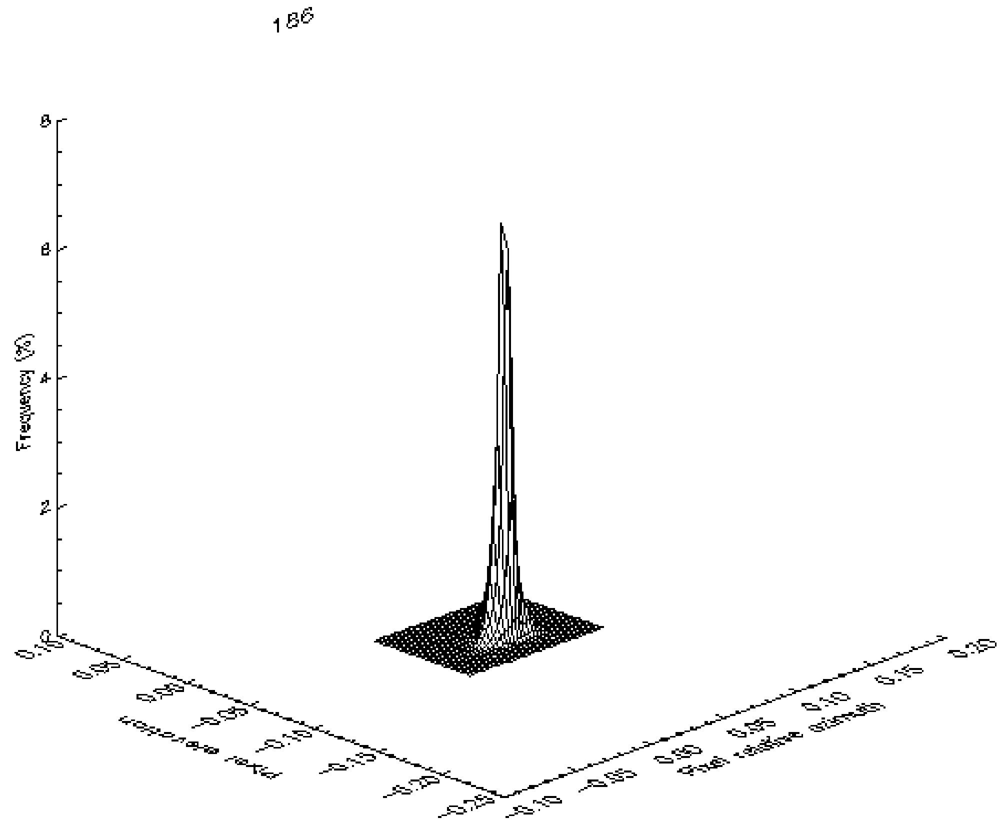
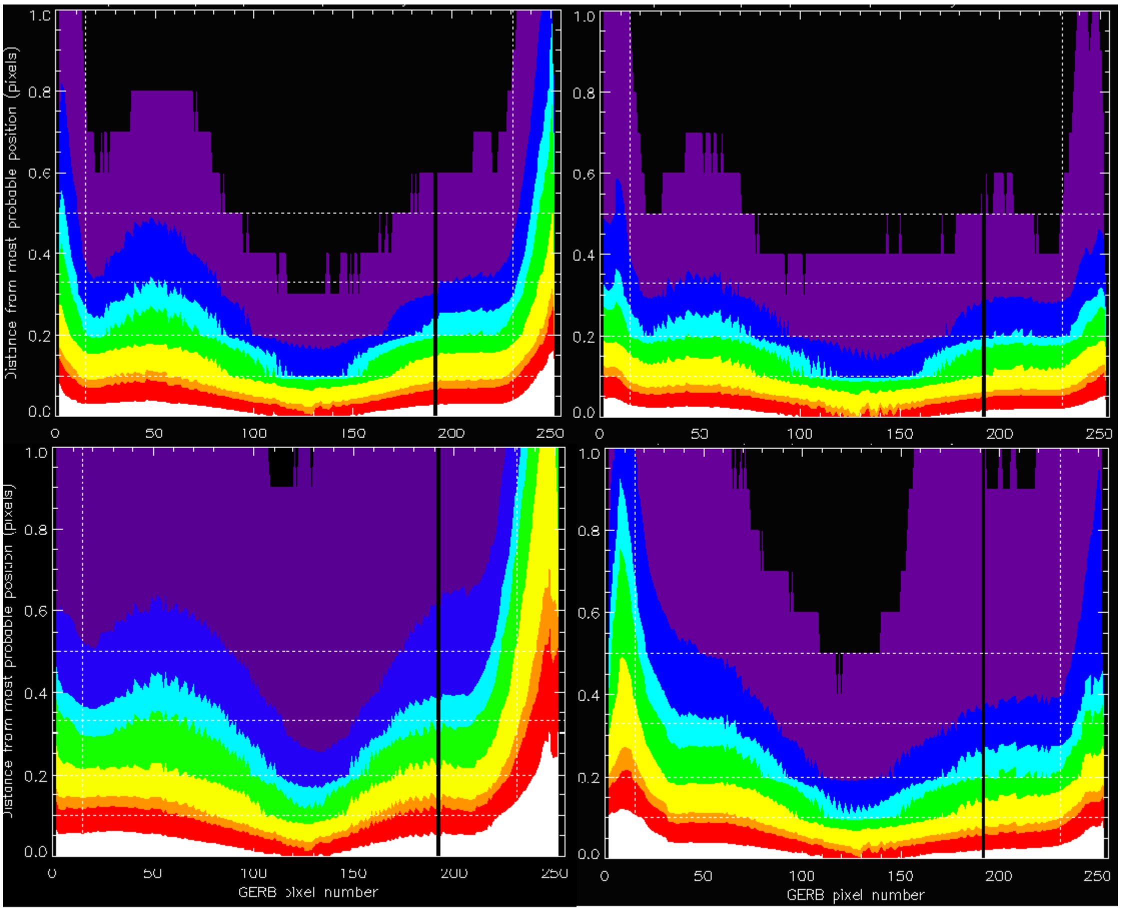


Figure 4: Example relative pixel position probability distribution for V998 total channel data for June 2006. Frequency distribution of relative pixel elevation and azimuth is show. Actual pixel azimuth is subtracted from pixel 128 azimuth for the same column and actual pixel elevation from average pixel 128 elevation for the same scan..

These results can be analysed to determine how probable it is for the relative position of each pixel to deviate from its most likely value by a given amount. The results of this analysis are displayed in the figure 5 below.

From figure 5 it is clear that pixels towards the ends of the array (for these data the first 15 and last 25 pixels) show more variation in terms of their location relative to the pixel 128. We interpret this to mean that their geolocation is noisier. For the June data the variation is more extreme for the Southern most pixels and in December for the Northern most pixels (although the December asymmetry is less dramatic) where illumination conditions are less favourable, although there in a feature around pixel number 50 of elevated variability, probably associated with geographical or meteorological features here. Excluding the first 15 and last 25 for the TOTAL channel observations 99% of the cases have relative pixel positions within 0.5 of a pixel to the most probable pixel location, 95% are within 0.33 of a pixel and 75% vary by less than 0.2 of a pixel from the most probable relative position. For the SW 99% are within 0.7 of pixel, 95% are within 0.45 of a pixel and 75% vary by less than 0.25 of a pixel.



Purple: Maximum deviation observed, occurs 1% of the time

Blue: 4% of cases; 99% of cases have deviations within upper limit of this bound

Cyan: 5% of cases; 95% of cases have deviations within the upper limit of this bound

Green: 15% of cases; 90% of cases have deviations within the upper limit of this bound

Yellow: 25% of cases; 75% of cases have deviations within the upper limit of this bound

Orange: 10% of cases; 50% of cases have deviations within the upper limit of this bound

Red: 20% of cases; 40% of cases have deviations within the upper limit of this bound

White: 20% of cases; 20% of cases have deviations within the upper limit of this bound

Fig 5. Contours showing probability as a function of pixel number of a given deviation in pixels (where one pixel is taken to be 0.07°) from the most likely position of the pixel. Pixel positions are calculated relative to the azimuth for pixel 128 in the same column and the average elevation of pixel 128 is the same scan. Results are for V998, left hand plots are for June 2004, right hand plots for Dec 2004 total scan results are shown in the upper panels, shortwave scan results in the lower panels. Probability are for columns 50 to 232 only.

Radiances

As filtered radiance depends on instrument response, which differs between instruments, it is not informative to directly compare filtered radiance observations from two different instruments. The process of unfiltering the measurements, that is, correcting for the instrument spectral response, is necessary before comparison.

Unfiltering is performed as part of the level 2 GERB processing and the unfiltered radiances are included the level 2 ARG (Averaged Rectified Geolocated) GERB data product. As part of the GERB validation these unfiltered radiances have been compared to the CERES rev 1 unfiltered radiances which have been extensively validated and have stated absolute accuracies of 1% in the SW and 0.5% in the LW.

Results of these comparisons for the V998 GERB validation reprocessing data set, consisting of 21-27th June and 11th-17th December 2004 are reported in the level 2 ARG quality summary, which can be accessed from http://ggsps.rl.ac.uk/docs/GERBED1_ARG_QS.pdf, and are summarised in table 1 of this document.

It should be borne in mind that the level 2 ARG products have undergone considerably more processing that the level 1.5 NANRG radiances, and the comparison results will reflect the effects of this, including the effect of interpolation, unfiltering with SEVIRI observations and the model assumptions used to derive the unfiltering factors. Overall, for the LW (emitted thermal) these results show agreement within the expected uncertainties of the two instruments (1% GERB and 0.5% CERES) and the comparison method, and no significant difference is seen between the daytime and night-time LW comparisons or between different scene types. For the SW (reflected solar) the GERB unfiltered radiances are several percent higher than CERES and this difference is greater than the combined theoretical uncertainties on the two instruments' absolute accuracy (2.25% GERB and 1% CERES) and the uncertainty of the comparison method. The percentage difference is smallest for bright scenes such as overcast conditions and higher for dark scenes such as clear ocean.

The cause of these discrepancies is under investigation, and it is presently unclear if it indicates a problem with the calibration of either instrument, or arises from differences in the models used to unfilter the two measurement sets or even if it results from problem with the comparison method.

Some factors, such as the use of SEVIRI to aid in the unfiltering, can be eliminated by comparing 'directly unfiltered' level 1.5 NANRG radiances with the CERES unfiltered radiances. In the SW, direct unfiltering, that is, unfiltering the radiances based solely on their filtered values, is possible (although expected random errors are expected to be larger than when SEVIRI is used as for the normal GERB processing). The same model calculations used to determine the unfiltering factors in the standard GERB processing which utilises the SEVIRI narrow band radiances can be used to derive a relation between the GERB filtered and unfiltered radiances. This was done for a special GERB validation product and not only enables a comparison independent of SEVIRI radiances (although still dependent on the SEVIRI derived geolocation), but also allows the comparison to be made individually for each of the 256 GERB pixels.

Comparison between directly unfiltered level 1.5 NANRG SW radiances and CERES FM2 ES8 edition 2 rev 1 reflected solar radiances on an individual GERB pixel basis are broadly consistent with the level 2 ARG comparison results shown in table 1. The directly unfiltered GERB SW radiances are found to be around 5.5% higher than CERES, with around 2% standard deviation in the result across the pixels.

For the comparison GERB and CERES pixels are matched after adjusting for the fact that the CERES ES8 locations are at 30 km altitude and the GERB locations are at the surface. Using data obtained during the special 'GERB scan' mode employed by FM2, points are matched when the view zenith angle and azimuth angle between the CERES and GERB pixels are within 5° and the view zenith angle is less than 70°. The operation of CERES in the programmed azimuth plane mode assures that the azimuth angles agree well within the five-degree range. When Terra flies nearly under GERB, however, the azimuth angle can vary considerably due to the polar singularity, so if the angle between the ray from the Earth scene to CERES and the ray from the Earth scene to GERB is less than ten degrees, the match is accepted. This treatment is justified by the fact that the reflected solar radiation does not vary significantly within these angle ranges. Thus the error due to the increased angular difference is small, whereas the increased number of measurements obtained with this treatment greatly reduces the scatter in the results.

Figure 6 shows the number of matched points as a function of GERB pixel number, obtained for the June and December V998 comparison dataset. Figure 7 shows as a function of GERB pixel number the resulting average GERB/CERES SW radiance ratio and GERB-CERES SW radiance difference determined by this comparison.

Averaged over all pixels the pixel level comparison shows V998 GERB SW directly unfiltered radiances to be 5.5% higher than CERES. A standard deviation of 2% in the GERB/CERES ratio is seen across the pixel array and a noticeable broad scale structure across the pixels is apparent. As the pixel array is oriented roughly north-south with respect to the Earth this structure will be similar to the variation in the GERB CERES ratio with latitude.

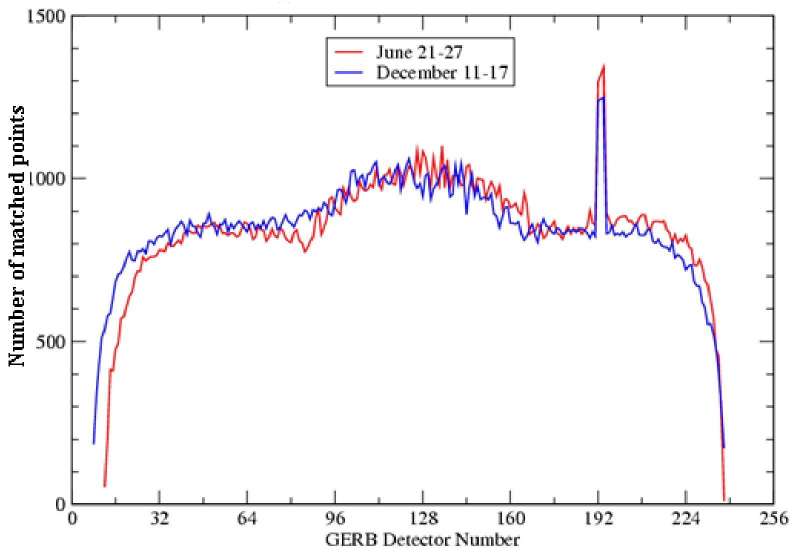


Figure 6. Number of matched GERB CERES points as a function of GERB detector number obtained from the special scan data used in the pixel level comparison for June (red) and December (blue) datasets.

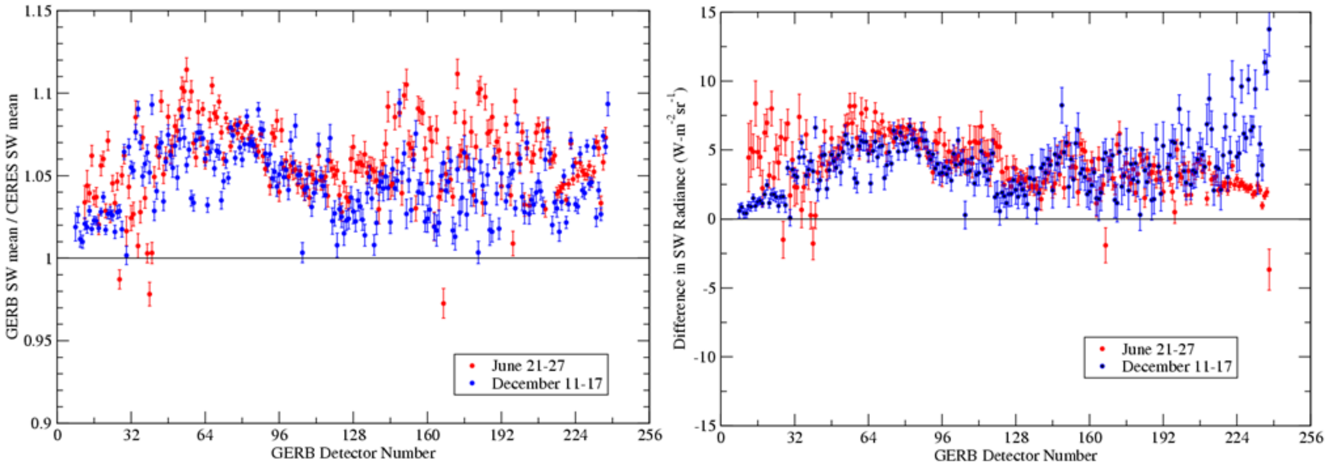


Figure 7. Results of the comparison between GERB V998 directly unfiltered and CERES FM2 Edition 2 rev1 ES8 reflected solar radiances. Left hand panel shows mean GERB/CERES SW radiance ratio as a function of GERB detector number, and right hand panel shows mean GERB – CERES SW radiance difference as a function of GERB detector number. Both plots show results for June (red) and December (blue) comparison datasets.

The Edition 1 data uses an average pixel spectral response, and a variation of around 2% in the unfiltered radiances due unaccounted for pixel to pixel variation in spectral response are consistent with the level of possible pixel to pixel variation in spectral response. However, it should also be noted that the relative occurrence of particular scene types also varies with latitude and thus any scene dependent differences in the GERB/CERES ratio can contribute to the variation with pixel number seen in these results.

5. Referencing data

All users are asked to reference the following publication when referring to GERB data:

The Geostationary Earth Radiation Budget Project. J E Harries, J E Russell, J A Hanafin, H Brindley, J Futyan, J Rufus, S Kellock, G Matthews, R Wrigley, A Last, J Mueller, R Mossavati, J Ashmall, E Sawyer, D Parker, M Caldwell, P M Allan, A Smith, M J Bates, B Coan, B C Stewart, D R Lepine, L A Cornwall, D R Corney, M J Ricketts, D Drummond, D Smart, R Cutler, S Dewitte, N Clerbaux, L Gonzalez, A Ipe, C Bertrand, A Joukoff, D Crommelynck, N Nelms, D T Llewellyn-Jones, G Butcher, G L Smith, Z P Szewczyk, P E Mlynczak, A Slingo, R P Allan and M A Ringer. Bulletin of the American Meteorological Society, 2005, Volume 86, No. 7, pp 945-960.

6. Acknowledgements

This summary was produces by the GERB project team and includes results of studies performed by RMIB, LaRc and Imperial College, London.

7. References

Mlynczak, P. E., G. L. Smith, Z. P. Szewczy, J. Russell, J. Harries, S. Dewitte and N. Clerbaux, 2006: Comparisons of GERB and CERES Measurements, Proc. 13-th Sat. Met. & Ocean

Smith, G.L., Z.P. Szewczyk, P.E. Mlynzak, R.B. Lee III, B.A. Wielicki, K.J. Priestley, J. Harries, S. Dewitte, and Nicolas Clerbaux, 2003: Method for comparison of GERB and CERES radiances, Proc., 10-th Internat. Symp. SPIE.

Wielicki, B. A., B. R. Barkstrom, E. F. Harrison, R. B. Lee III, G. L. Smith, and J. E. Cooper, 1996: Clouds and the Earth's Radiant Energy System (CERES): An Earth Observing System Experiment, Bullietin of the American Meteorological Society, 77, 853-868.

8. Addendum

Stray light flags: An error has been found in the calculation of the equation of time. This results in the daily time range for which data is flagged as affected by "diffuse stray light" (stray light contamination of the filtered radiances of between 0.25 $Wm^{-2}sr^{-1}$ and 3.5 $Wm^{-2}sr^{-1}$) and "stray light in black body" is slightly shifted from the ideal. The periods currently flagged in the products and those that should be treated with caution are indicated below. Users should be aware that all data in the caution periods may be of reduced accuracy because of stray light effects.

	Spring date range	Autumn date range	Flagged time range (GMT)	Caution time range (GMT)
Diffuse stray light	15 Jan – 23 May	21 Jul - 26 Nov	23:00 - 01:00	22:26 - 01:34
Black body stray light			10:05 - 12:30	09:31 - 13:04