QUALITY SUMMARY: GERB L2 ARG: 3 scan average Edition 1 product

GERB project team, last update 23 May 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 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 2 ARG 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. Similarly the effect to the GERB products of possible drifts and trends in the SEVIRI calibration can not be determined until a full survey of the Edition data has been made. 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 can not be 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. User are also directed to the level 1.5 anomaly flags copied into the level 2 products which indicate instrument anomalies affecting the data. In general, poducts affected by major anomalies will be processed to level 2 NRT products but excluded from the Edition dataset. Users of the NRT products should be aware that observations subject to major instrument anomalies are considered seriously compromised (erroneous) data. 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 2 user guide with further information in the level 1.5 user guide. Stray light anomaly flags are discussed in more detail below.

Geolocation. The mean geolocation accuracy should be sufficient for most purposes, however the **geolocation accuracy of an individual image 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 grid spacing (GERB sample grid spacing 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 or fluxes that have been separated according to scene type. For example, geolocation errors will occasionally cause GERB pixels identified as clear sky to actually be cloudy. For example in the SW, for dark surfaces such as ocean, the occasional cloud contamination will elevate the radiance or flux determined for the scene, leading to a systematic bias in the inferred average quantity.

<u>ARG grid</u>: For the ARG products GERB measurements have been interpolated to a regular grid, the spacing of which corresponds to the GERB sampling distance. However, the native resolution of the GERB products, which is larger than this sampling distance and a function of wavelength, is retained, and no correction for the spatial variation in the instrument response is made. Thus **each measurement represents a non-uniform spatial average at the native GERB resolution** centred on that grid point. The spatial variation of the weighting is determined by the average of the point spread functions (PSFs) of the pixels that contribute to that point. Pixel PSFs are available on request from the GERB team. The effect of the PSF is removed in the GERB level 2 BARG (Binned Averaged Rectified Geolocated) products.

<u>Pixel to pixel variation in shortwave response</u>: 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 the unfiltering of the radiances for the first edition of the GERB products uses an average pixel spectral response. Whilst we do not expect significant differences in the spectral response of the pixels, 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.

<u>Night-time SW data</u>: The error flag is present in the GERB products whenever SW data is unavailable. Thus both missing SW data and night-time SW observations are indicated by this flag. Users should consider both the flag and the incoming solar flux to determine whether it is night-time or the SW data is missing.

<u>GERB flux reference level</u>. GERB fluxes are top of the atmosphere energy densities referenced at the Earth reference ellipsoid surface. Users are reminded that when comparing these fluxes to model or other measurements an adjustment to allow for different reference levels may be necessary.

<u>Angular range of flux calculation</u>: Fluxes are not determined for radiances observed at viewing zenith angles > 80° (applies to both reflected solar fluxes and emitted thermal fluxes) or when the solar zenith angles > 80° or sunglint angles < 15° (applies to reflected solar fluxes only). The user is reminded to bear in mind these limits of available data when constructing averages.

<u>Fluxes observed at viewing zenith angles > 70°</u> Users should be aware that whilst fluxes are calculated from radiances for viewing zenith angles up to 80°, values determined from data acquired at **view zenith angles greater than 70° will be subject to increased errors**. For these higher viewing angles the three dimensional nature of clouds and the increased atmospheric path for Rayleigh scattering cause a growth in apparent cloudiness and increasing scene identification errors (Diekmann and Smith, 1988; Smith and Manalo-Smith, 1995). Thus, the wrong angular dependency model (ADM) is selected for computing flux from radiance. Also, the footprint of the pixel on the Earth grows rapidly beyond 70 degrees, so that scenes and ADMs are highly mixed.

It should also be noted that the large footprints associated with these larger view angles do not average well over Earth grids. GERB uses an instrument-oriented grid system, but when one maps the fluxes to Earth, the problem inevitably arises.

<u>Other view angle dependent errors in radiance to flux conversion</u>: Because GERB observes from a geostationary orbit the viewing geometry of each point of the surface is fixed with respect to the satellite and the relative solar angles are a function of time of day and year. This means that **errors in the radiance to flux conversion due to a specific radiance viewing angle or solar angle occur systematically in the dataset and can not be assumed to reduce with averaging**. The results of the flux comparison with CERES shown in section 4 provide an indication of the extent to which differences remain after averaging.

<u>Aerosol:</u> Edition 1 GERB data contains no special treatment of aerosol and does not use an aerosol specific radiance to flux conversion. Optically thin aerosol gets treated as clear sky and thicker aerosol

can be identified and treated as cloud. Thus **fluxes in the presence of aerosol are likely to be less accurate** than for other scene types. LW flux errors are expected to be within 10 W m^{-2} but SW errors in the presence of significant aerosol loading may be subject to more significant errors. **Extreme caution is therefore recommended before using the Edition 1 GERB shortwave fluxes to study the radiative effect of aerosol.** It suggested that users wishing to use these data for such an application consult with the GERB project team.

An aerosol treatment is currently under development to address this issue. As a first step an estimation of aerosol optical depth has been included in the GERB ARG products (Brindley and Ignatov, 2006). Whilst experimental in nature and currently only available over ocean, this field can be used to identify significant aerosol contamination (optical depth >~0.4) which is likely to result in less accurate fluxes. As the problem with aerosol relates to the radiance to flux conversion, SW radiances in the presence of aerosol should still provide useful information on the broadband effect of the aerosol present.

Thin cloud **A problem is known to exist in the radiance to flux conversion for thin (0.5< optical depth at 0.55μm < 3) high (>6km) level cloud**. It is estimated from simulations that this can result in a relative error on the LW flux of up to 20%. These worst case errors occur for fluxes derived from nadir and grazing angle observations. Conversely errors become small for fluxes derived from observations at viewing zenith angles of about 52°. Therefore except for fluxes derived from observations over a small viewing zenith angle range [50°:55°], **extreme caution is recommended before using the GERB Edition1 flux data to study cirrus cloud radiative effect in the LW**. It is suggested that users wishing to use these data for such an application consult with the GERB project team.

It should be noted that both the aerosol and thin cloud problems relate to the radiance to flux conversion not the GERB SW and LW radiances. GERB LW radiances may be used to for studying cirrus and the GERB team can provide support to help users to obtain the best estimate of the flux and associated error from the GERB radiance in case of cirrus cloud, or similar semi-transparent atmospheric components such as desert dust.

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 level 2 Edition products but exist in the level 1.5 data and the near real time level 2 products. These scans occur during the hours 22:28 to 01:32 GMT from 30-Jam to 12-May and 01-Aug to 11-Nov. This contamination is identified by the level 1.5 flags, a summary of which is contained in the level 2 products.

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 in the level 1.5 data and can be identified from the summary of the level 1.5 flags contained in the level 2 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 in the level 1.5 data and can be identified from the summary of the level 1.5 flags contained in the level 2 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.

LW non-repeatability: The daytime longwave signal is determined by subtraction of SW from TOTAL observations. The sampling of TOTAL and SW data is not exactly repeatable and occasionally, interpolation of the TOTAL channel radiances to the shortwave locations results in significant errors.

High frequency variations in the GERB LW, for regions which SEVIRI observations indicate to be homogenous in the LW but highly variable SW, are considered to be the product of such errors. The spurious variability is corrected by using the GERB radiometric level in conjunction with the LW spatial variability estimated from SEVIRI.

A difference between the longwave ratio and the longwave correction factors contained in the level 2 ARG product indicates where this technique has been applied to the GERB LW data.

2. Overview:

The level 2 ARG (Averaged Geolocated Rectified) products are 3 scan averages nominally covering a period of 14.1 minutes[1] presented on a regular grid. They contain unfiltered radiances (broadband reflected solar and emitted thermal) and associated top of the atmosphere fluxes and related information. The native resolution of the GERB observations are retrained, each measurement is thus a weighted regional average, centred on the grid point location with spatial weighting determined by the instrument point spread function. Times contained in the level 2 ARG product names indicate the nominal start of the integration period and are copied from the prime level 1.5 NANRG (Non-Averaged Non-Rectified Geolocated) product from which they are derived. In the document below the term shortwave (SW) is used to refer to reflected solar components, and the term longwave (LW) to denote emitted thermal components.

Some issues with the data mean that the edition 1 GERB ARG products do not meet all of their accuracy targets. Specific problems are known to exist with geolocation accuracy; detector spectral response information and radiance to flux conversion factors. 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 as 2.25% for the SW and 0.96% for the LW unfiltered radiances. The primary causes of the reduced SW accuracy are uncertainties associated with the detector response measurements, and the possible impact on the unfiltering of SEVIRI inter-channel calibration. The issues with the spectral response are in the process of being resolved. Once these are known, further comparisons between different unfiltering methods will be used to reduce the uncertainty due to the SEVIRI channel calibration. 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 broad band radiances and fluxes in a similar manner to GERB. Their products have been extensively validated and have stated absolute accuracy of 1.0% for the shortwave 0.5% for the longwave 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 and fluxes with CERES SSF rev1 radiances and fluxes. The resulting average GERB/CERES ratios are shown in the table below: more detail and additional comparison results are provided in section 4 of this document.

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[1] Data is interpolated to SW acquisition times to allow derivation of LW from subtraction of SW from TOTAL. The 3 SW scans are obtained over a period of 14.1 minutes. TOTAL channel data is interpolated from 4 TOTAL channel scans spanning a total period of 19.74 minutes.

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

Data compared	CERES instrument	FM2 Edition 2 GERB V998/CERES SSF rev1	FM3 Edition 1b GERB V998/CERES SSF rev1
SW 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 radiance	Night	0.989 +/- 0.003	0.982 +/- 0.001
	Day	0.993 +/- 0.001	0.982 +/- 0.003
SW flux	All sky	1.066 +/-0.006	1.082 +/- 0.004
	Overcast	1.049 +/- 0.006	1.067 +/- 0.005
	Clear sky	1.074 +/- 0.004	1.093 +/- 0.007
	Clear ocean	1.085 +/- 0.018	1.072 +/- 0.014
LW flux	Night	0.987 +/- 0.001	0.982 +/- 0.001
	Day	0.991 +/- 0.001	0.985 +/- 0.001

Table 1. Summary of GERB CERES comparison results, GERB/CERES ratio. 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.

Unfiltered radiances

The magnitude of systematic errors in the unfiltered radiances has been determined from the uncertainties provided for calibration sources and spectral response measurements. In addition the effect of un-flagged stray light and the theoretical accuracy of the SEVIRI inter-channel comparison are considered. 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 unfiltered radiances. 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 unfiltered 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.

Random errors are considered in table 3. This table includes contributions from detector noise, interpolation and unfiltering. 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, and additional errors due to a mismatch with SEVIRI in the unfiltering factor and the radiance to flux conversion factors. Whilst random in origin, unfiltering and geolocation errors can lead to systematic errors in radiances and fluxes ascribed to a particular scene type.

Error source	Reflected solar	Emitted thermal (night)	Emitted thermal (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
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	
SEVIRI inter-channel calibration[8]	<1%	<0.1%	<0.1%
RMS combination of above errors	**2.25%**	**0.96%**	**0.96%**

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

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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.

We note that spot measurements on the flight spare detector obtained post launch with an improved measurement technique show a response that would lower the unfiltered shortwave radiances by approximately 3.5% across all scenes compared to the response currently in use. The difference may be due to a real variation between the in-obit and flight spare detector arrays; however an ongoing investigation is underway to determine if the difference indicates an unaccounted for systematic error in the original data.

[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 processed to level 2, but flagged to indicate diffuse stray light contamination. Data with stray light contamination greater than ~ 3.5 $Wm^{-2}sr^{-1}$ is not processed to level 2 products.

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

[8] Unfiltering the GERB radiances relies on SEVIRI observations. The effect on the GERB unfiltered radiances of the worst case SEVIRI inter-channel calibration error at a ±5% level is considered here. For SW a worst case effect is an overestimation of the unfiltering factor by 0.8% if the errors on SEVIRI 0.6μm is +5% and on 0.8μm and 1.6μm is –5%. For the longwave the worst case is found to be an overestimation of the unfiltering factor by 0.09% for –5% on 6.2μm, 7.3μm, 12μm and 13.4μm SEVIRI channels and +5% on 8.7μm and 10.8μm.

Error source	Reflected solar	Emitted thermal (night)	Emitted thermal (day)
Instrument noise	0.13% of typical full scale	0.4% of typical full scale	0.6% of typical full scale
Geolocation[9]	0.25 pixel		
Interpolation[10]	0.63% of typical full scale	1% of typical full scale	1% of typical full scale
Spectral overlap correction	0.02% of typical full scale	None	0.08%
Unfiltering	0.3% of typical full scale	0.05% of typical full scale	0.05% of typical full scale

Table 3. Estimates of the random errors on the unfiltered radiance.

Fluxes

GERB SW fluxes are derived from the GERB SW radiances using the CERES TRMM ADMs as the basis of the radiance to flux conversion. Users are referred to the relevant CERES documentation and quality summaries for validation results details on the accuracy of the ADMs themselves (see Loeb et al. 2003, and documentation available from http://eosweb.larc.nasa.gov/PRODOCS/ceres/table_ceres.php).

Users should note that the implementation of the SW radiance to flux conversations for the Edition 1 GERB products is not identical to their application to the CERES data. CERES has different ADM versions derived from their TRMM, Terra and Aqua satellite instruments. GERB Edition 1 data uses the CERES TRMM ADM’s. The CERES data used in the comparison studies shown in section 4 (edition 2b FM1 and FM2 data and edition 1b FM3 and FM4 data) use the Terra ADM’s. Additionally, GERB Edition 1 fluxes do not include an adjustment for apparent aerosol optical depth and use interpolation of the monthly climatology to determine the wind speed for selection of the appropriate ocean ADM. In addition no interpolation for cloud optical depth and fraction is made. Comparison of co-angular fluxes between GERB and CERES indicates that these differences, in addition to differences in scene ID due for example to SEVIRI calibration bias, results in an average 1% offset between the GERB and CERES radiance to flux conversion factors. Thus all other difference aside, GERB fluxes are elevated by 1% compared to CERES for the same unfiltered radiance.

The ADMs which are the basis of the radiance to flux conversions are statistical in nature and thus a random error will be associated with the instantaneous flux estimates, the 1SD values of these errors are shown below. In addition SEVIRI measurements are employed both for the scene identification required to choose the appropriate SW radiance to flux conversion factor, and in determining the longwave radiance to flux conversion. Thus, the effect of 5% calibration errors on the SEVIRI radiances and inter-channel calibration is also considered. Flux errors which are additional to the radiance errors already discussed are shown in table 4 below.

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

[10] Errors quoted are 1SD for the maximum interpolation distance of 0.5 of a pixel, determined from high resolution scans over the central 100 columns of the Earth.

Error source	Reflected solar	Emitted thermal
SW ADM	~10 $Wm^{-2}sr^{-1}$ random error	
LW anisotropy		2.3% random error (of typical full scale)
SEVIRI channel calibration and inter-channel calibration[11]	< 0.5% bias < 2.3% random error (of typical full scale)	< 1.3% bias (of typical full scale)

Table 4. Addition error sources and approximate magnitudes to which the SW and LW fluxes are subject (see Loeb et al. 2003 for validation results on the CERES TRMM ADMs).

4. Validation result summary:

The GERB ARG unfiltered radiances and fluxes have been compared to the CERES rev 1 unfiltered radiances and fluxes. Results shown here are for the GERB V998 validation reprocessing data set, consisting of 21-27th June and 11th-17th December 2004. This processing version has the same science processing as the Edition 1 release GERB data. These data are available to all registered users from the GERB GGSPS archive.

In this section we report on two different radiance level comparisons which both matched GERB and CERES observations for viewing geometry, location and time. The first compares the CERES SSF rev1 radiances and the GERB level 2 ARG SW and LW radiances. GERB SW radiances were found to be on average 5% higher than CERES FM2 (Edition 2) and 7% higher than CERES FM3 (Edition 1b), whilst GERB LW radiances were seen to be 1% lower than FM2 (Edition 2) and 2% lower than FM3 (Edition 1b). Some scene dependent differences in the comparison are also discussed below.

The second comparison used a special GERB validation product (directly unfiltered level 1.5 NANRG radiances) and the CERES FM2 ES8 edition 2 rev 1 reflected solar radiances to compare observations for each individual GERB pixel. This study found the directly unfiltered GERB SW radiances to be around 5.5% higher than CERES, with around 2% standard deviation in the result across the pixels.

A comparison between the CERES SSF rev1 fluxes and GERB Level 2 ARG fluxes matched for location and time, found the GERB reflected solar fluxes to be on average 7% higher than CERES FM2 (Edition 2) and 8% higher than CERES FM3 (Edition 1b). GERB emitted thermal fluxes were similar to those for the LW radiance comparison, with GERB LW radiances being 1% lower than FM2 (Edition 2) and 2% lower than FM3 (Edition 1b).

Comparison of angularly matched GERB and CERES SW fluxes indicates a 1% difference in radiance to flux conversion factors due to differences in scene ID and the way the conversions are applied, resulting in a 1% elevation, in addition to the radiance difference, of the GERB fluxes compared to CERES for the same filtered radiance. Scene and viewing geometry dependent effects are discussed below.

Further details of the level 2 ARG radiance and flux comparisons can be found at the following link: http://gerb.oma.be/gerb/Validations/ARG_CERES_SSF_Comparison/

Radiances: level 2 ARG comparison

GERB and CERES SSF rev 1 radiances matched for time, location and viewing angle are compared with CERES FM2 and FM3 instruments, for data obtained during June 21st-27th and December 11th-17th 2004.

Matched data have viewing angles within 5° of each other and the CERES acquisition time must be no more 170 seconds from the acquisition time for the relevant GERB ARG column. Only data with GERB viewing zenith angles <65° for the SW and <80° for the longwave are retained and solar zenith angles are also required to be <80° for the SW comparison.

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[11] Simulated effect on the derived fluxes of a 5% calibration error in the SEVIRI radiances used for scene identification in the SW. LW error determined as worst case effect of 5% inter-channel calibration errors in the LW on the determination of LW anisotropy factor.

Resulting GERB / CERES ratio values are shown in table 5 for the SW and table 6 for the LW. In each case the mean radiance for each day of GERB and CERES points is derived and the ratio of these two mean values determined. The mean and standard deviation of the ratio is then calculated from the daily ratios. Table 5 shows the mean ratio and an associated 99% confidence uncertainty determined as 3 time the standard deviation divided by the square root of the number of days.

SW radiance data	FM2 (Edition 2) GERB/CERES	FM3 (Edition 1b)
All points June Dec	1.058 ± 0.005 1.048 ± 0.005	1.067 ± 0.013 1.075 ± 0.006
Overcast June Dec Cloud cover = 100% τ>7.4	1.041 ± 0.013 1.032 ± 0.005	1.039 ± 0.016 1.050 ± 0.017
For Clear GERB pixels (GERB cloud cover 0%)		
Ocean	1.144 ± 0.043	1.084 ± 0.052
Dark Vegetation	1.070 ± 0.017	1.089 ± 0.039
Bright Vegetation	1.062 ± 0.010	1.086 ± 0.013
Dark Desert	1.073 ± 0.019	1.101 ± 0.035
Bright Desert	1.059 ± 0.006	1.082 ± 0.012

Table 5. Results of SW radiance comparison for angularly matched and co-located GERB CERES radiances. SSF rev1 radiance data from FM2 (Edition 2) and FM3 (Edition 1b) are used. Rev1 all sky correction factor is applied to the CERES data except for the clear ocean comparison where the rev1 clear ocean correction factor is employed.

Data	FM2 GERB/CERES	FM3
All daytime points June Dec	0.993 ± 0.001 0.993 ± 0.001	0.985 ± 0.003 0.979 ± 0.002
All night time points June Dec	0.990 ± 0.003 0.988 ± 0.005	0.982 ± 0.002 0.981 ± 0.002

Table 6. Results of LW radiance comparison for angularly matched and co-located GERB CERES radiances. SSF Edition 2, rev1 radiance data from FM2 (Edition 2) and FM3 (Edition 1b) are used.

Some scene dependence is seen in the radiance comparisons. For the SW agreement between GERB and CERES (in percentage terms) is better for bright scenes than for dark scenes. This is exhibited by a higher SW ratio for ocean than for cloud or bright desert, for example. Separating the GERB SW radiances up into percentiles before making the comparison also illustrates the scene dependence of the comparison results, as shown in table 7 below.

	GERB/CERES FM2 (Edition 2)		GERB/CERES FM3 (Edition 1b)	
GERB radiance percentile	June	Dec	June	Dec
0.0-0.1	1.136 ± 0.012	1.141 ± 0.020	1.132 ± 0.027	1.142 ± 0.014
0.1-0.2	1.073 ± 0.009	1.086 ± 0.032	1.072 ± 0.011	1.102 ± 0.018
0.2-0.3	1.045 ± 0.015	1.060 ± 0.021	1.036 ± 0.010	1.062 ± 0.022
0.3-0.4	1.028 ± 0.008	1.042 ± 0.020	1.029 ± 0.009	1.049 ± 0.008
0.4-0.5	1.014 ± 0.014	1.014 ± 0.026	1.024 ± 0.009	1.041 ± 0.029
0.5-1.0	1.013 ± 0.009	1.014 ± 0.021	1.015 ± 0.014	1.027 ± 0.017

Table 7. Results of SW radiance comparison for angularly matched and co-located GERB CERES radiances, resulting ratios shown as a function of GERB radiance percentile bin.

In the LW a scene dependence is also observed. The results of a similar breakdown of the LW radiance ratio by radiance bin is shown in figure 1. This shows that for warmer scenes with radiances above 60 $Wm^{-2}sr^{-1}$ the GERB LW radiance is about 1% lower than the FM2 radiance and 2% lower than the FM3. For cold scenes (radiances < 60 $Wm^{-2}sr^{-1}$) the GERB/CERES ratio increases strongly becoming greater than 1 for radiances below than < 50 $Wm^{-2}sr^{-1}$.

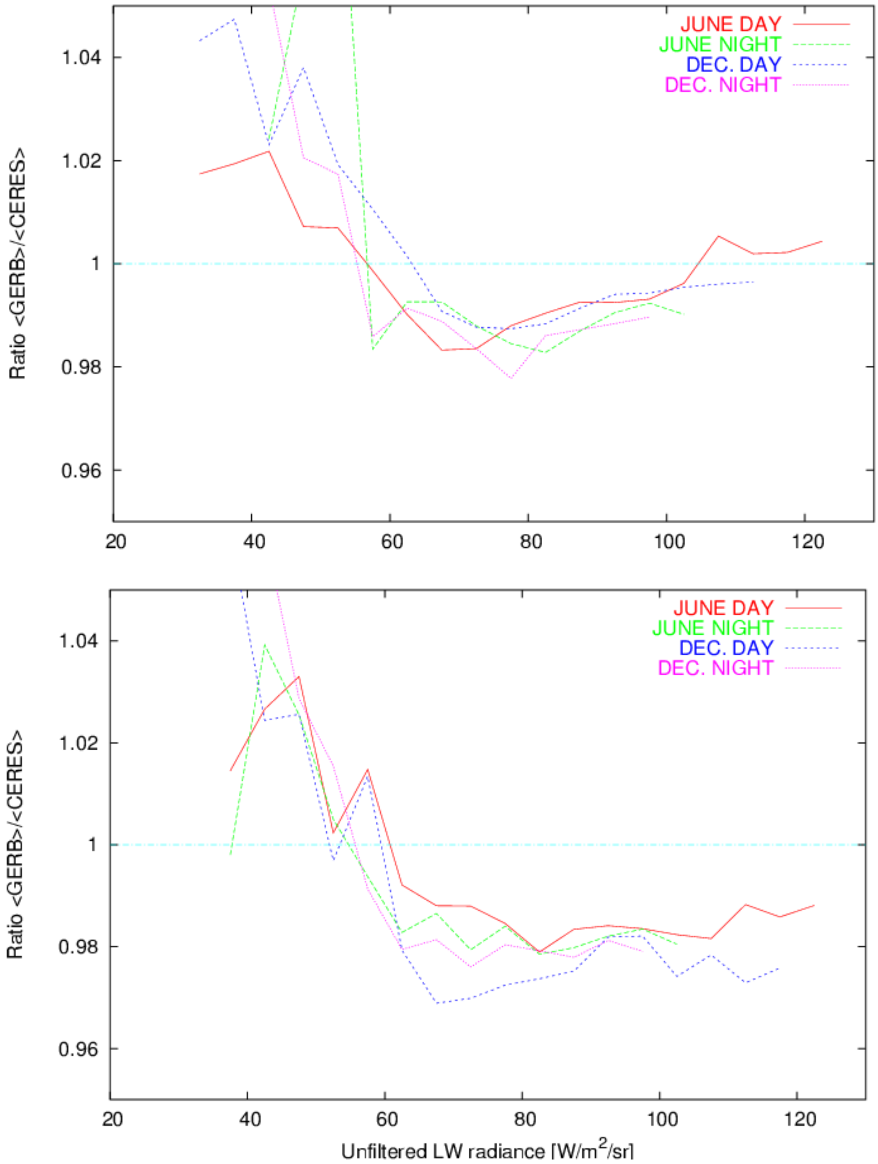

Figure 1. GERB/CERES ratio as a function of GERB unfiltered LW radiance. Results shown for comparisons between GERB and CERES FM2 (upper plot) and FM3 (lower plot).

It should be noted that the scene dependent differences seen in the LW and SW comparisons may be affected by the comparison methodology and geolocation errors. For the extreme scenes geolocation errors can lead to systematic effects on the inferred average radiance. For example geolocation errors can lead scenes identified as ocean to occasionally contain some cloud; in the SW these cloud points will always be brighter than the dark ocean and therefore act to elevate the average SW radiance inferred. However, the scene dependent differences can also be due to systematic uncertainties in the spectral response of the instrument, as bluer scenes tend to darker scenes, and colder scenes will have a greater proportional of the radiance at longwave wavelengths.

Radiances: pixel level comparison

Similar comparisons between the GERB reflected solar radiances and the CERES ES8 edition 2 rev1 data from FM2 have been made on an individual pixel basis. These comparisons use a special GERB validation product (directly unfiltered Version 998 GERB L1.5 NANRG) which is not interpolated to a regular grid, to enable each individual GERB pixel to be compared separately. The CERES data were obtained during a period of special operation when FM2 employed a “GERB mode” programmable azimuth scan which increases the number of angularly-matched measurements between the two instruments.

The GERB unfiltered radiances compared in this study differ slightly from the level 2 ARG radiances as they do not use SEVIRI in their unfiltering, but are unfiltered based solely on the filtered radiance observed. This different unfiltering method is expected to increase the random error associated with the unfiltering but should not significantly affect the bias except to the extent that SEVIRI inter-channel calibration errors may introduce a bias (estimated to be less than 1%) into unfiltered level 2 ARG radiances.

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 2 shows the number of matched points as a function of GERB pixel number, used in the June and December comparison. Figure 3 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.

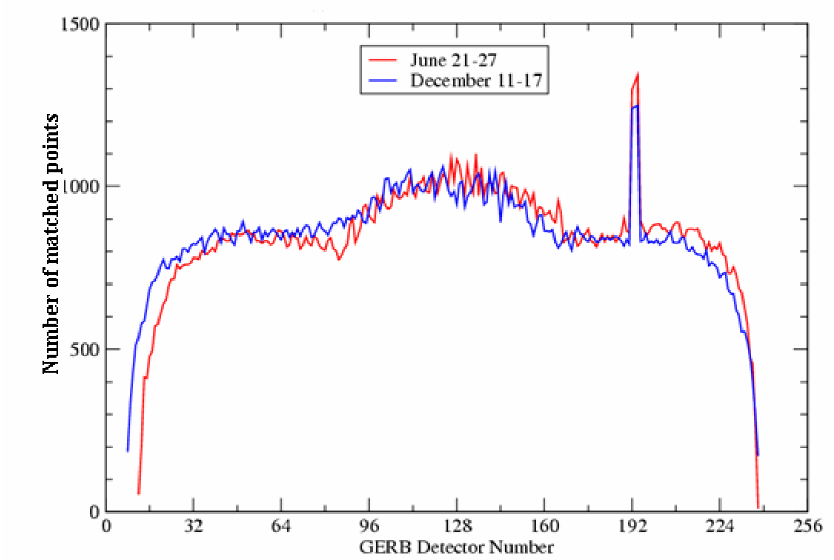

Figure 2. Number of matched GERB CERES points as a function of GERB detector number obtained from the special scan data used in the pixel level comparison for June (red) and December (blue) datasets.

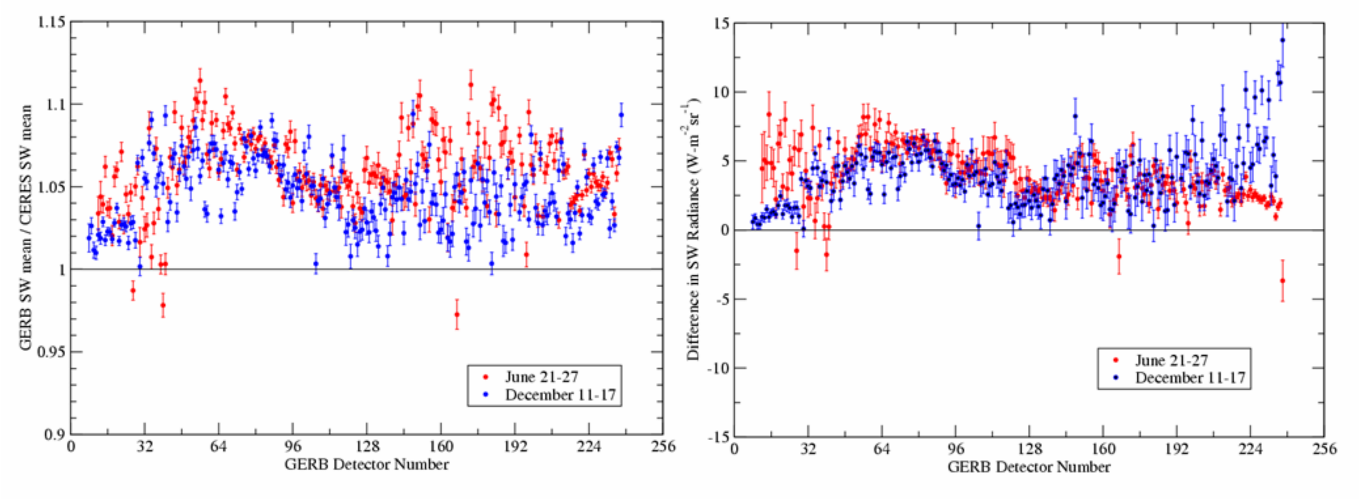

Figure 3. Results of the comparison between GERB V998 directly unfiltered and CERES FM2 Edition 2 rev1 ES8 reflected solar radiances. Left hand panel shows mean GERB/CERES SW radiance ratio as a function of GERB detector number, and right hand panel shows mean GERB – CERES SW radiance difference as a 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.

Fluxes

The GERB V998 level 2 ARG fluxes have also been compared to the CERES SSF rev 1 fluxes for the periods 21-27th June and 11th-17th December 2004. All CERES flux measurements, within 170 seconds of acquisition time of the relevant ARG column, falling within the GERB footprint are used (note: as fluxes are now compared there is no need to match viewing geometry). Prior to comparison the CERES SSF fluxes are adjusted from a 20km reference level to a surface reference level.

Each day the mean of GERB and CERES fluxes are determined and the ratio of these means derived. The mean and standard deviation of the ratio is then calculated from the daily ratios. The mean ratio and an associated 99% confidence uncertainty determined as 3 time the standard deviation divided by the square root of the number of days is displayed in table 8 for the SW and table 9 for the LW.

In addition in order to analyse viewing angle dependent and scene dependent differences an average of the matched points is constructed for each location and smoothed using a 5x5 ARG pixel moving average before being compared to construct a map of the GERB/CERES ratio over the GERB viewing region. The results of these comparisons are shown in figures 4 and 5 for the SW all sky and clear sky fluxes respectively and figures 6 and 7 for the LW day-time and night-time fluxes.

Over the several days used to accumulate the averages, the CERES data contributing to the average at a given location will have been acquired from a range of viewing angles, whereas due to its geostationary orbit, the GERB viewing geometry remains relatively invariant for each point on the Earth. Thus whilst view angle dependent errors in the radiance to flux conversion will be much reduced in the CERES average, they are expected to remain in the GERB data at a level comparable to that present in the instantaneous measurements. The results thus highlight the view angle dependent errors in the radiance to flux conversion. It should be noted that each CERES instrument has a different overpass time and hence the comparison obtained corresponds to the time of day of the overpass of the relevant instrument. Thus differences between the comparisons for different instruments can indicate variations in the errors through the day or for different solar angles.

SW Flux comparison results

Overall the SW flux comparison shows a 1-2% increase in the GERB/CERES ratio compared to the radiance results. The discrepancy between the SW radiance comparison and SW flux comparison results can be attributed to a combination of differences in the ADMs (GERB uses the TRMM ADMs and the CERES fluxes used here are derived using the TERRA ADMs) and possible discrepancies in the scene identification. This is evidenced by the fact that comparison of the co-angular GERB CERES flux measurements results in, on average, a 1% difference between the two instruments in the SW anisotropy factors assigned to the SW radiances, which alone would result in an elevation of the GERB/CERES flux ratio by 1% compared to the radiances.

SW flux data	FM2 (Edition 2) GERB/CERES	FM3 (Edition 1b) GERB/CERES
All points June Dec	1.073 ± 0.004 1.059 ± 0.004	1.083 ± 0.004 1.079 ± 0.003
Overcast June Dec Cloud cover = 100% τ>7.4	1.054 ± 0.007 1.044 ± 0.004	1.065 ± 0.008 1.066 ± 0.005
For Clear GERB pixels (GERB cloud cover 0%)		
Ocean	1.085 ± 0.018	1.076 ± 0.018
Dark Vegetation	1.072 ± 0.007	1.080 ± 0.017
Bright Vegetation	1.082 ± 0.005	1.105 ± 0.012
Dark Desert	1.081 ± 0.009	1.105 ± 0.010
Bright Desert	1.068 ± 0.007	1.091 ± 0.007

Table 8. Results of SW flux comparison for co-located GERB CERES fluxes. SSF rev1 flux data from FM2 and FM3 are used. Rev1 all sky correction factor is employed except for clear ocean where rev1 clear ocean factor is employed.

The geographical distribution of the GERB/CERES average flux ratio is shown in figure 4 for the SW all-sky and figure 5 for the SW clear sky observations. Results are shown for FM2 (upper plots) and FM3 (lower plots) for June (left hand plots) and December (right hand plots). A red ring indicates the GERB viewing zenith angle of 70°, fluxes derived from observations beyond this limit are expected to be of reduced accuracy.

For the all-sky plots, the GERB/CERES SW flux ratio over much of the disk is relatively uniform. Exceptions are seen towards the edge of the disk, particularly for fluxes derived from observations with viewing zenith angles greater than 70°. Enhanced ratios are seen at the edges of the sunglint region (indicated by a roughly circular black region of missing data). Depressed ratios are seen off the West coast of Africa. As discussed in section 1, fluxes in the presence of aerosol are expected to be of reduced accuracy, and as this region of depressed flux is an area where significant aerosol effects are likely, aerosol contamination is a possible cause of the observed signature. In the clear sky the region of depressed ratios is clearly visible. In addition, enhanced ratios are seen for ocean points close to coastlines. These enhanced ratios are likely the result of geolocation errors causing land observations to be occasionally included in the average determined for the GERB ocean locations.

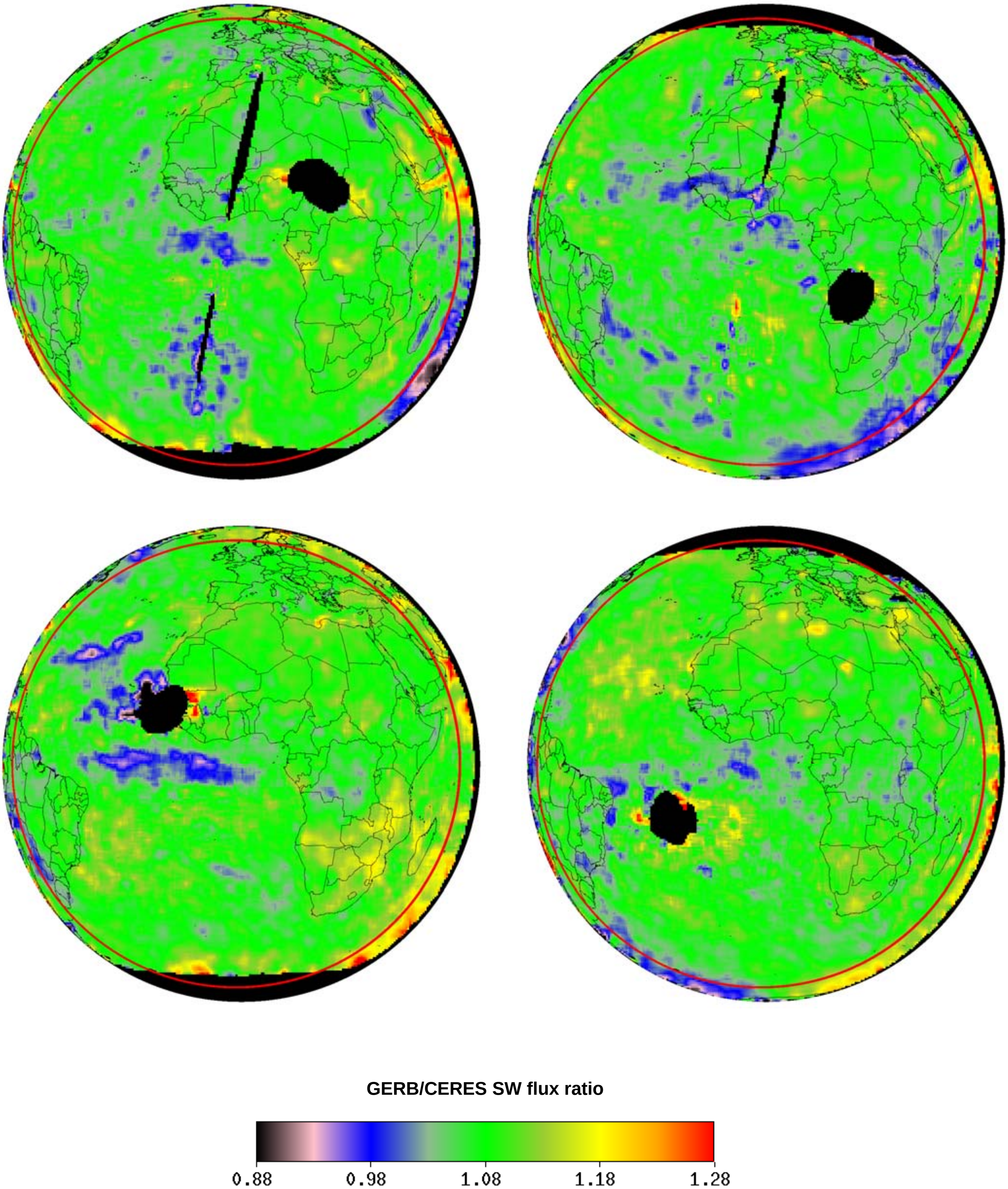

Figure 4. All sky SW flux comparison for June (left) and December (right). GERB/FM2 ratio shown in upper panels and GERB/FM3 ratio in lower panels. Ring in red shows limit of VZA = 70°.

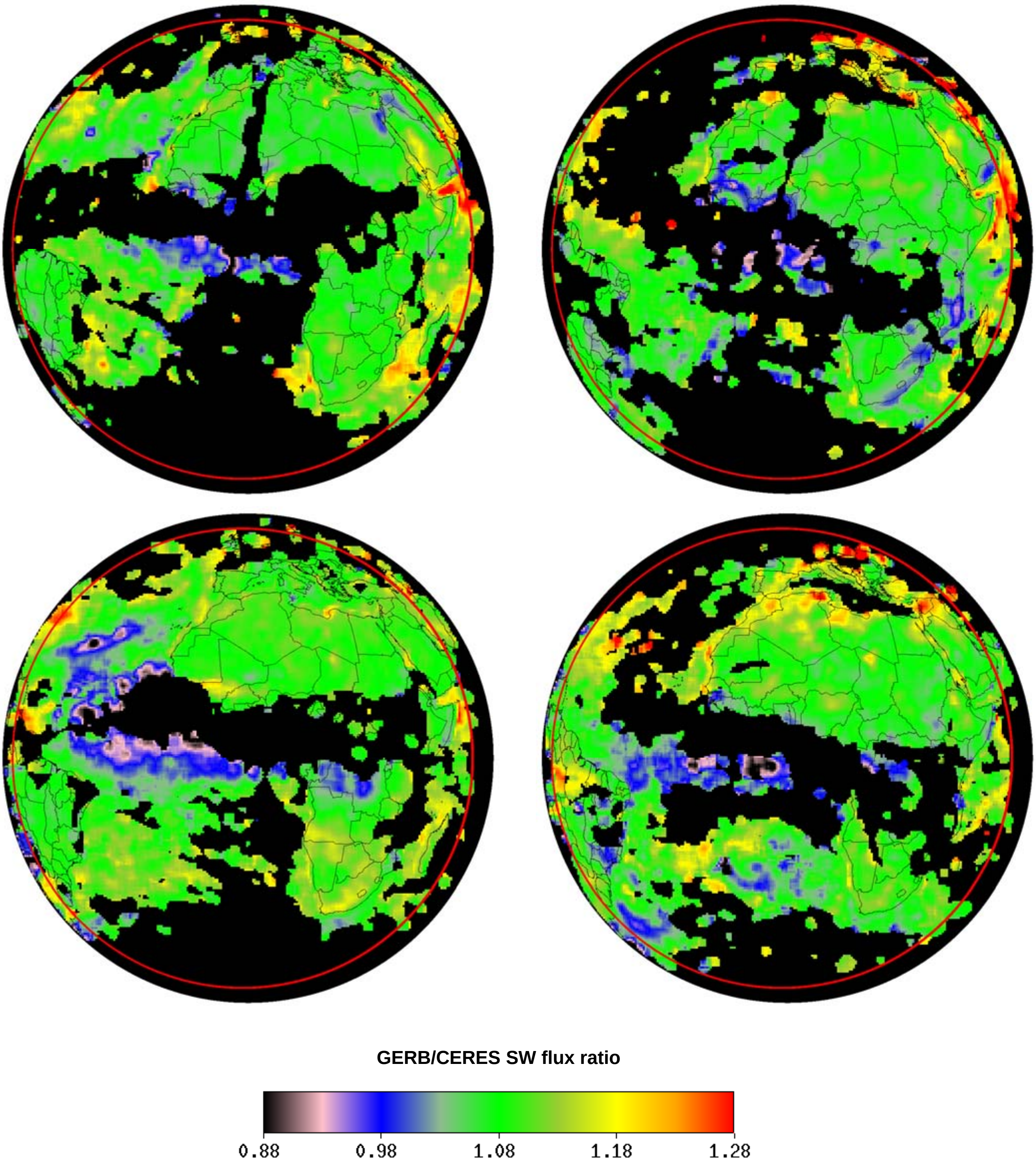

Figure 5. Clear sky SW flux comparison for June (left) and December (right). GERB/FM2 ratio shown in upper panels and GERB/FM3 ratio in lower panels. Ring in red shows limit of VZA = 70°.

LW flux comparison

The GERB/CERES longwave flux ratios, shown in table 9 below, are similar to the radiance ratios.

LW flux data	FM2 (Edition 2) GERB/CERES	FM3 (Edition 1b) GERB/CERES
All day time points June Dec	0.991 ± 0.001 0.992 ± 0.001	0.986 ± 0.001 0.984 ± 0.001
All night time points June Dec	0.987 ± 0.001 0.987 ± 0.001	0.982 ± 0.001 0.981 ± 0.001

Table 9. Results of LW flux comparison for co-located GERB CERES fluxes. SSF flux data from FM2 and FM3 are used.

The geographical distribution of the GERB/CERES average LW flux ratio is shown in figure 6 for the daytime comparisons and figure 7 for the night-time comparisons. Results for FM2 (upper plots) and FM3 (lower plots) for June (left hand plots) and December (right hand plots) are shown in each figure, with the GERB viewing zenith angle of 70° indicated by a red ring on each plot. Fluxes outside this line (closer to the edge of the disk) are expected to be of reduced accuracy for the reasons explained in the section 1.

A limb darkening effect is apparent in the LW flux comparisons, with GERB fluxes derived from observations at higher viewing angles producing lower ratios than those derived from low view angles. Enhanced ratios are also seen in regions associated with cloud; this is believed to be related to the problem in the GERB data of correctly modelling the anisotropy of semi-transparent cloud, as discussed in section 1.

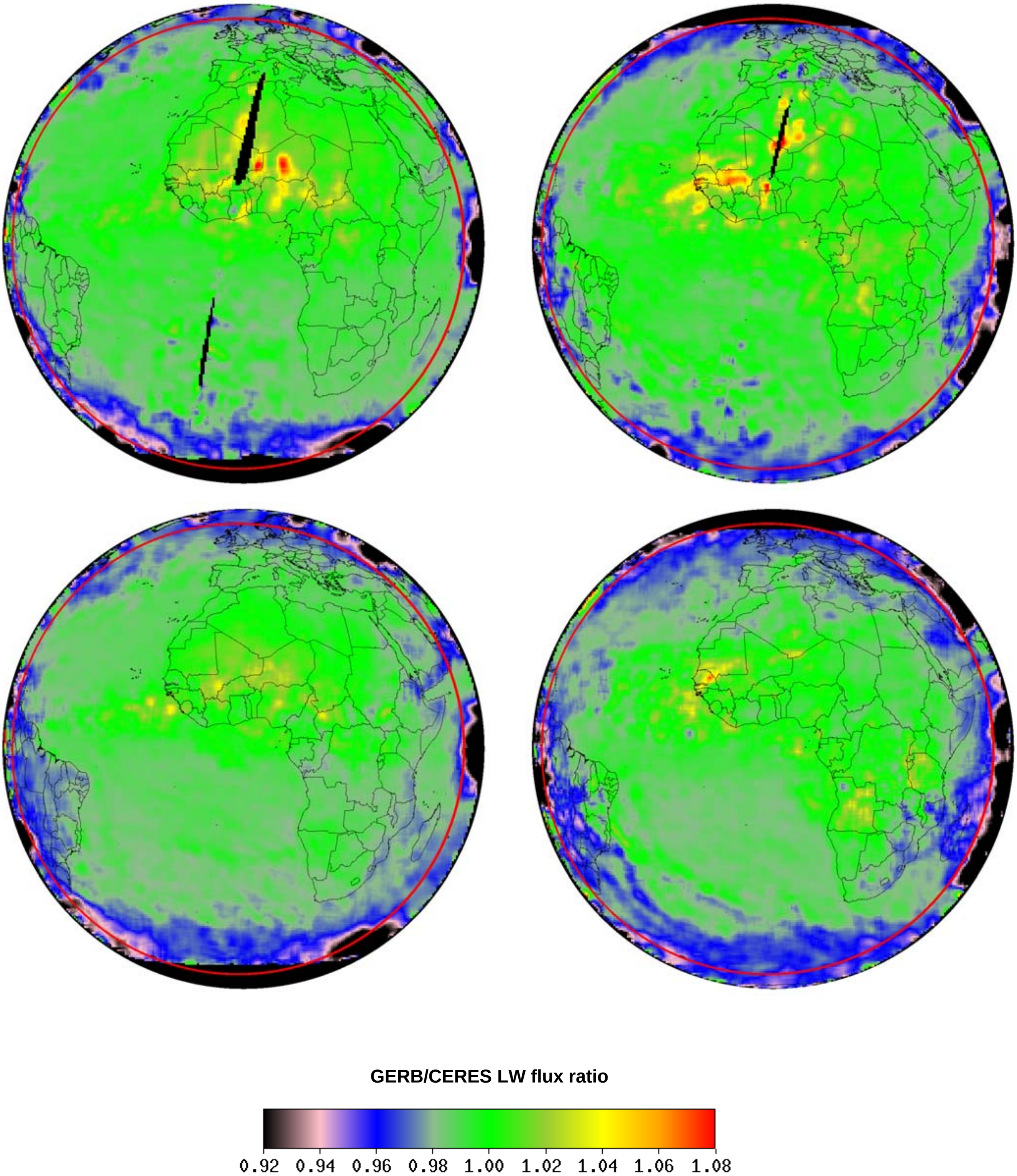

Figure 6. Daytime LW flux comparison for June (left) and December (right). GERB/FM2 ratio shown in upper panels and GERB/FM3 ratio in lower panels. Ring in red shows limit of VZA = 70°.

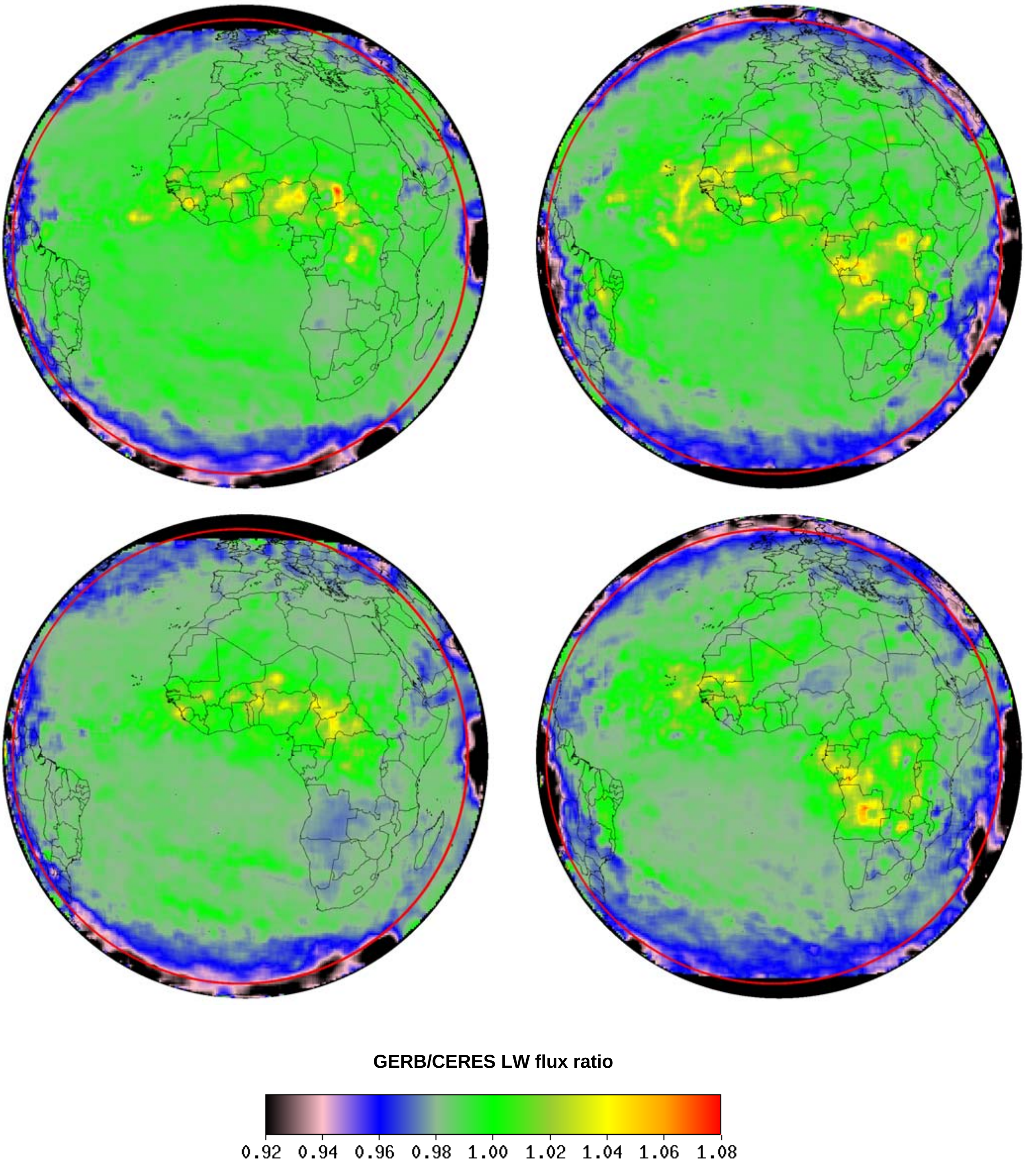

Figure 7. Night time LW flux comparison for June (left) and December (right). GERB/FM2 ratio shown in upper panels and GERB/FM3 ratio in lower panels. Ring in red shows limit of VZA = 70°.

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

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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

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Diekmann, F. J. and G. L. Smith, 1988: Investigation of scene identification algorithms for radiation budget measurements, J. Geophys. Res., 94, 3395-3412.

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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