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

GERB project team, last update January 2011

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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 designed to inform users of the accuracy of the GERB Edition 1 level 2 ARG 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. The document relates to the METEOSAT 8 and METEOSAT 9 GERB datasets. The Edition 1 record from these two instruments is processed with the same algorithms but the independence of the two instrumental records is maintained and any offsets between the calibration of the two instruments are not rectified. Separate validation results are therefore included as well as an inter-comparison. The operational data record from the GERB instrument on METEOSAT 8 (GERB-2) covers the period March 2004 to May 2007. From May 2007 the GERB on METEOSAT 9 (GERB-1) is the operational instrument.

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

Absolute accuracy and calibration:

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

User applied SW calibration update 2004-May 2007: A correction of around 2.4% to the calibration curve of the shortwave ground calibration source used for GERB 2 (on METEOSAT-8, operational record March 2004-May 2007) has been advised by NPL. The correction implies the GERB 2 shortwave needs to be adjusted, to apply the correction ***users need to multiply the shortwave radiances and fluxes in all GERB 2 level 1.5 and level 2 products by 0.976***. When using data employing this adjustment it should be denoted at GERB 2 Edition 1 SWupdate.

Instrument switchover May 2007: The Edition 1 version of the data preserves the independence of the individual instrument calibrations. ***At the point of transition (May 2007) a step change in the Edition 1 data record is expected due to the differences between GERB 1 and GERB 2***. Slight differences in the viewing position of the satellite and in the different SEVIRI instrument used for scene identification also introduces spatial and temporal variation into the differences between the two instruments (see section 4). ***Extreme caution is advised in treating the data prior to May 2007 and post May 2007 as a single record***.

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 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, which will result in subtle differences between the accuracy of the observations in different latitude regions. We anticipate that that this issue will be resolved in future editions of the GERB products.

Gridding and geolocation:

ARG grid: 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.

Geolocation. The mean geolocation accuracy should be sufficient for most scientific purposes, however the ***geolocation accuracy of an individual image pixel is not guaranteed***. Edition 1 GERB geolocation is achieved by a statistical matching between the GERB and SEVIRI data which is subject to random error. In general ***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 pixel. Effects on the products are most significant at high contrast edges, such as cloud and coastline.

In addition to this statistical error GERB measurements are obtained by means of a rapidly rotating mirror on the edge of the rotating MSG spacecraft, this mechanism is subject to occasional mispointing events which are normally identified and removed from the data if serious. However ***occasional mirror mispointing events may remain introducing a further source of geolocation error***. This issue is more significant for the METEOSAT-9 data record (from May 2007).

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 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.

Flux accuracy and limitations

Aerosol: 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*** and 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% in the worst cases which 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***, and 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 these problems relate to the radiance to flux conversion not the GERB SW and LW radiances. Thus 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 LW flux and associated error from the GERB radiance in case of cirrus cloud, or similar semi-transparent atmospheric components such as desert dust.

GERB flux reference level: 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.

Angular range of flux calculation: Fluxes are not determined for viewing zenith angles > 80° (applies to both reflected solar fluxes and emitted thermal fluxes) or 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.

Fluxes observed at viewing zenith angles > 70°: Users should be aware that whilst fluxes are calculated up to viewing zenith angles of 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.

Other view angle dependent errors in radiance to flux conversion: 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.

Missing data and data flags

Eclipse operations and Stray light: ***For a few months centred on each equinox the amount of GERB data available is reduced*** by variable amounts. In all cases no science data can be collected from 23:00 to 02:30 UTC from approximately mid February to end of April and from Mid September to end of November as the Sun is within the instrument FOV. 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***, which leads to flagging or removal of the products from the Edition record. In some instances (the whole METEOSAT-9 record) the performance of the GERB mirror makes the probability of accidental exposure to the sun too great a risk to enable science observations at any time from mid February to end of April and from Mid August to end of October.

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 22:45 to 01:15 GMT from 03-Feb to 04-May and 09-Aug to 07-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. 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. 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.

Night-time SW data: The error flag is present to indicate all unavailable SW observations. 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.

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 copied into the level 2 products which indicate GERB instrument anomalies affecting the data. Products affected by major anomalies are 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 which seriously compromise the data will occasionally be present. 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.

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. Product 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. 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.

The original aims for absolute accuracy, defined as the accuracy after sufficient averaging to remove any random component of the error, of the SW and LW unfiltered radiances was 1% of the typical full scale signals which were considered 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, and once 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.

3. Processing and calibration uncertainty

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 1 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 1. 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.

[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.

Error source	Reflected solar	Emitted thermal (night)	Emitted thermal (day)
Calibration sources absolute accuracy (1 SD uncertainty values)	~0.22%[2]	<0.05%[3]	
Calibration sources uniformity (full range over region used)	< 0.5%	Small	
Spectral response [4]	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 $Wm^{-2}sr^{-1}$ [5]	
	<0.1% of typical full scale	<0.3% of typical full scale	
Polarisation	<0.4%[6]	Small	
SEVIRI inter-channel calibration[7]	<1%	<0.1%	<0.1%
RMS combination of above errors	**2.25%**	**0.96%**	**0.96%**

Table 1. Estimates of the ground determined unfiltered radiance bias error sources and magnitudes.

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[2] 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.

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

[4] 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.

[5] 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.

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

[7] 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.

Random errors are considered in table 2. 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)
Instrument noise	0.13% of typical full scale	0.4% of typical full scale	0.6% of typical full scale
Geolocation[8]		0.25 pixel	
Interpolation[9]	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 2. Estimates of the random errors on the unfiltered radiance.

Fluxes

GERB SW fluxes use the CERES TRMM ADMs for their 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).

Users should note that in the implementation of the SW radiance to flux conversions 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. GERB Edition 1 fluxes do not include an adjustment for the 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.

[8] Pixel error quoted is determined from the stability of the geolocation in the GERB 2 validation data set (V998) and represents approximately 1SD excluding the edge pixels.

[9] 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.

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 used both for the scene identification used 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.

Error source	Reflected solar	Emitted thermal
SW ADM	~14 $Wm^{-2}sr^{-1}$ random error	
LW anisotropy		2.3% random error (of typical full scale)
SEVIRI channel calibration and inter-channel calibration[10]	< 0.5% bias < 2.3% random error (of typical full scale)	< 1.3% bias (of typical full scale)

Table 3. 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).

[10] 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.

4. Validation result summary:

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.

Calibration offsets:

Validation studies have compared the GERB ARG radiances and fluxes with CERES SSF rev1 radiances and fluxes. In addition an extensive inter-comparison of the GERB 1 and GERB 2 data has been made. The resulting average GERB/CERES and GERB 2/ GERB 1 ratios are shown in the figures below. The CERES data used was the SSF Edition 2 dataset with the rev 1 allsky corrections applied. Data points are matched temporally (within 15minutes) and spatially and in the case of radiances viewing geometry is also matched to within 5°. Daily averages of all the matched points are calculated and then the ratio determined from the daily average values. The average ratio over all days of the comparison period and associated standard deviation is calculated. Values shown in figures 1 and 2 are these average ratios, the error bars indicate $3\sigma / \sqrt{ndays - 1}$. More detail on the comparison methodology and further results for the GERB 2 CERES 2004 comparisons are provided in Clerbaux et al. (2009). Note in the table below the SW calibration update has been applied to the GERB 2 Edition 1 data, this was not applied in the comparisons shown in Clerbaux et al. (2008).

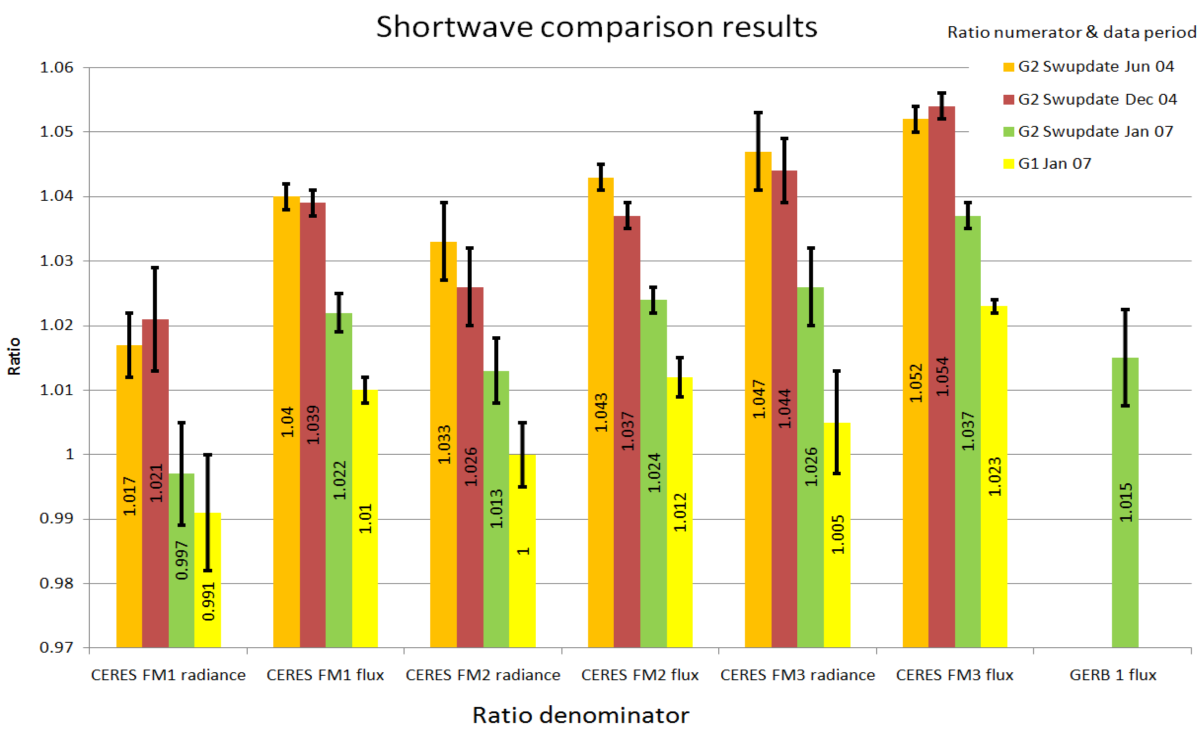

Figure 1. Summary of comparison results average shortwave ratios shown, data used denominator and whether flux or radiance is compares is shown on the x-axis, data used in the numerator and the time period of the comparison is indicated in the legend. Ratios are calculated from the mean of matched points each day, the mean ratio is then determined over the whole period and its associated standard deviation calculated. Error bars show the 3σ uncertainty based on the variability in the individual ratios calculated. All GERB 2 data have the SW calibration update applied, results shown for GERB 2 for June and December 2004 are taken from Clerbaux et al. 2008 and adjusted to account for the GERB 2 SW calibration update.

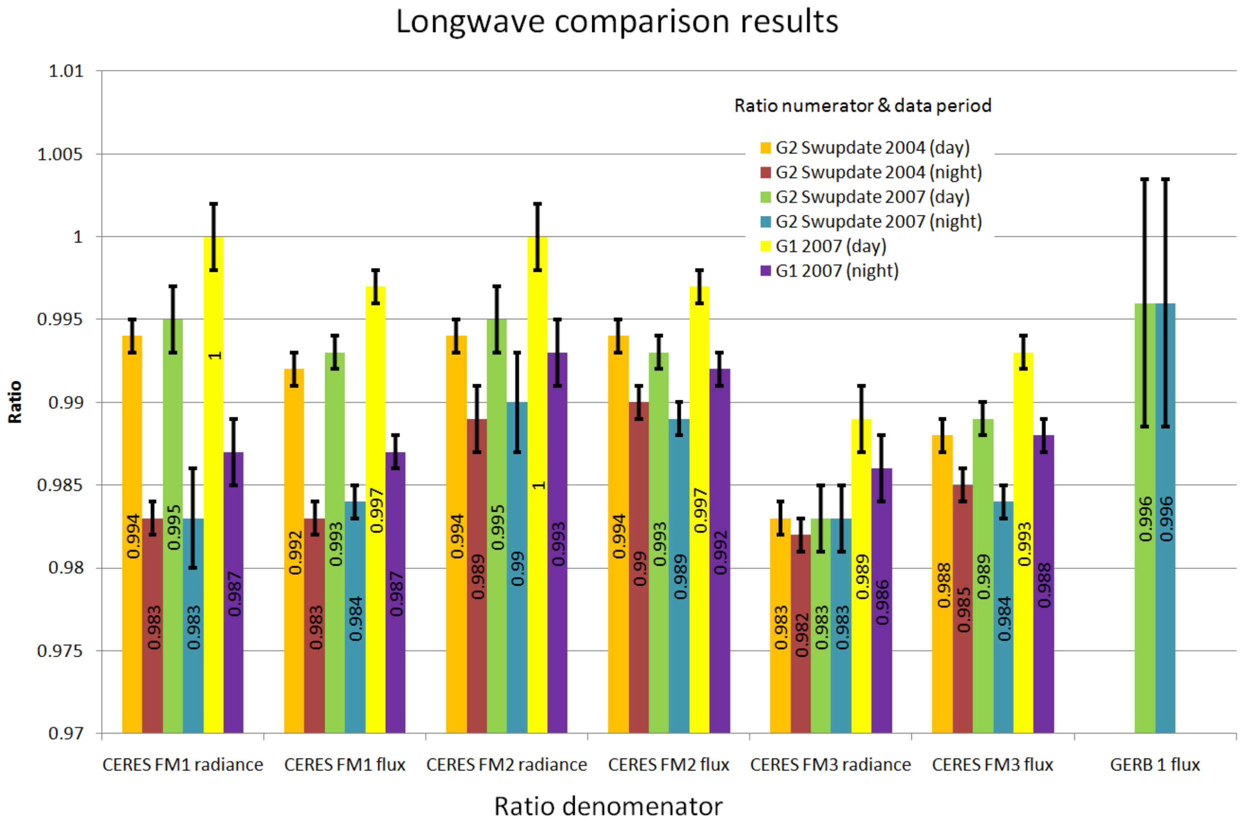

Figure 2. Summary of comparison results average longwaye ratios shown, data used denominator and whether flux or radiance is compares is shown on the x-axis, data used in the numerator and the time period of the comparison is indicated in the legend. Ratios are calculated from the mean of matched points each day, the mean ratio is then determined over the whole period and its associated standard deviation calculated. Error bars show the 3σ uncertainty based on the variability in the individual ratios calculated. All GERB 2 data have the SW calibration update applied, results shown for GERB 2 for June and December 2004 are taken from Clerbaux et al. 2008 and adjusted to account for the GERB 2 SW calibration update.

The shortwave ratios shown in figure 1, display a difference between the radiance and flux ratios which implies that there are two aspects to the GERB / CERES ratio. The first, indicated by the co-angular radiance comparison relates to a calibration difference between the instruments and the second, resulting in around an extra 1% elevation is due the effect of differences between the scene identification and radiance to flux conversion.

In 2007 the calibration difference between GERB 1 and CERES is seen to within the uncertainty of the comparison (<1%). The GERB 2 / GERB 1 difference in 2007 shows GERB 2 to be about 1.5% higher in the shortwave. However the GERB 2 CERES comparisons shows an evolving picture. The difference between GERB 2 and CERES in 2007 varies with CERES flight model from 0 to 2.6%. The 2004 comparisons between GERB 2 and CERES show GERB 2 to be around an extra 2% higher than each CERES flight model on top of the difference found in 2007, implying a change in the relative calibration of the two instruments over time.

From the longwave ratios in figure 2 we see consistent results for GERB 2 in 2004 and 2007. Daytime comparisons for both GERB 1 and GERB 2 radiance and flux show agreement to within 1% between GERB and CERES (apart from FM3) and between the two GERB instruments. Night-time differences are slightly larger but still within 1.5% for FM2 and within 2% for FM1 and FM3. When considering the cause of the discrepancy between the day night results two things must be borne in mind. Firstly in the day the longwave is obtained by a subtraction of the shortwave channel measurement from a total observation for both GERB and CERES. This process must account for a calibration difference between the channels which if not done correctly will result in differing day night errors. However during the night there is a greater proportion of cold scenes comprising the average and thus a variation of the calibration offset between the two instruments with scene temperature can also result in a day night difference. Decomposing the day-night comparisons according to the scene radiance indicates that it is a combination of these effects. Ratio tend to reduce with reducing scene radiance during both day and night and the greater prevalence of colder scene at night reduces the overall ratio, however even for the same scene temperature ratios are generally lower at night than in the day.

Spatial comparisons:

Comparison maps of the ratio for averages over all the matched data for both radiance and flux have been made where there is sufficient data. The radiance comparisons allow spatial patterns due to a calibration variation as a function of pixel and viewing angle to be highlighted. In addition to this the flux comparisons highlight deficiencies with the angular modelling of the radiance to flux conversion. It should be noted that these maps are not comparison of monthly average products but are averages of instantaneously matched data points and thus subject to the time constraints of the CERES overpasses.

In figure 3 we can see the problems with the longwave radiance to flux conversion associated with thin cloud (see specific cautions) in the GERB 2 / CERES all sky flux ratios shown in the third column, whereas no such effect is seen in the radiance comparisons and is much reduced in the clear sky flux comparisons shown in this figure.

Figure 4 shows the same for the shortwave comparisons. Here some spatially varying calibration differences are observed which is likely a combination of GERB pixel to pixel variability in calibration (~2%) and the effect of different calibration offsets as a function of scene (a spectral response effect). The flux results show some coherent patterns associated with differences in scene ID and consequently radiance to flux conversion. The different treatment of aerosol between GERB and CERES in the radiance to flux conversion is also likely contributing tot he differences seen particularly off the West Coast of Africa.

GERB 1 / CERES spatial flux ratio plots are shown in figure 5 and indicate similar effects to those already discussed for GERB 2.

For the GERB 2 GERB 1 comparisons the increased matches allow us to decompose the results further according time of day. This is shown in figure 6 for the longwave and figure 7 for the shortwave. The longwave shows little variation outside the ±1% range except in the northern extreme in the day where the cold bright scenes highlight the effect of differing accuracy of the subtraction of the shortwave component and at all times of day across the ITCZ where the variation of the calibration offset with scene temperature results in reduced ratios. The shortwave comparisons which are further decomposed into all sky, overcast and clear sky. Here variations with scene and time of day particularly in the clear sky highlight the limitations of the radiance to flux conversion and the effects of the subtly differing viewing position of the instruments. The overcast comparisons also indicate a difference between the scene identification particularly at more extreme solar angles. These effects will all introduce a step in the data record at the point of transition. They will be considered within the planned Edition 2 improvements, until that time extreme caution is advised in using these two data records in combination.

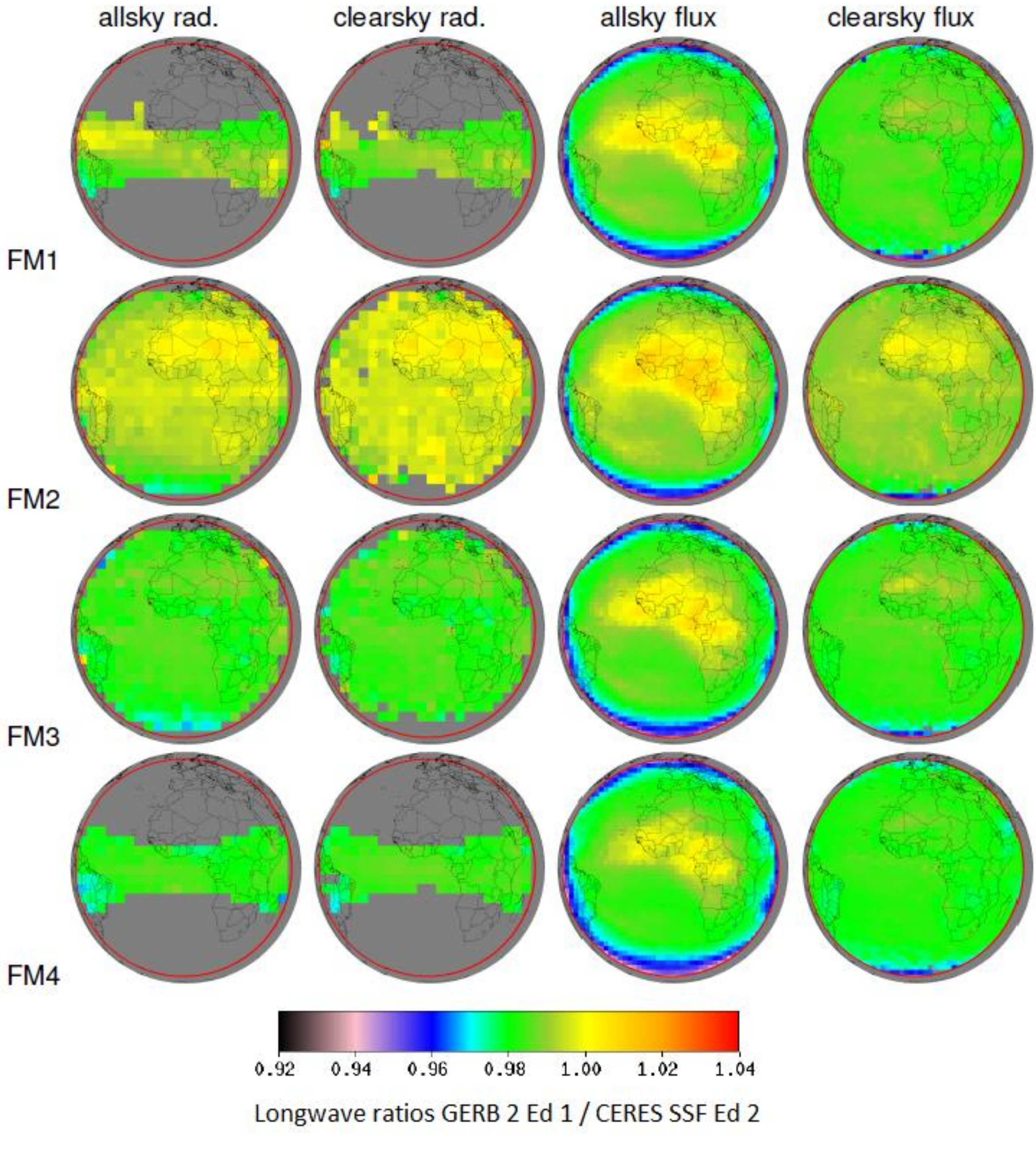

Figure 3: GERB 2 Ed 1 / CERES SSF Ed 2 longwave flux ratio for June and December 2004 temporally and spatially matched points plus angular matching for radiances. First and third columns show all sky comparisons for radiance and flux respectively, second and forth columns clear sky matches for radiance and flux. Reproduced from Clerbaux et al. 2009, see paper for methodology.

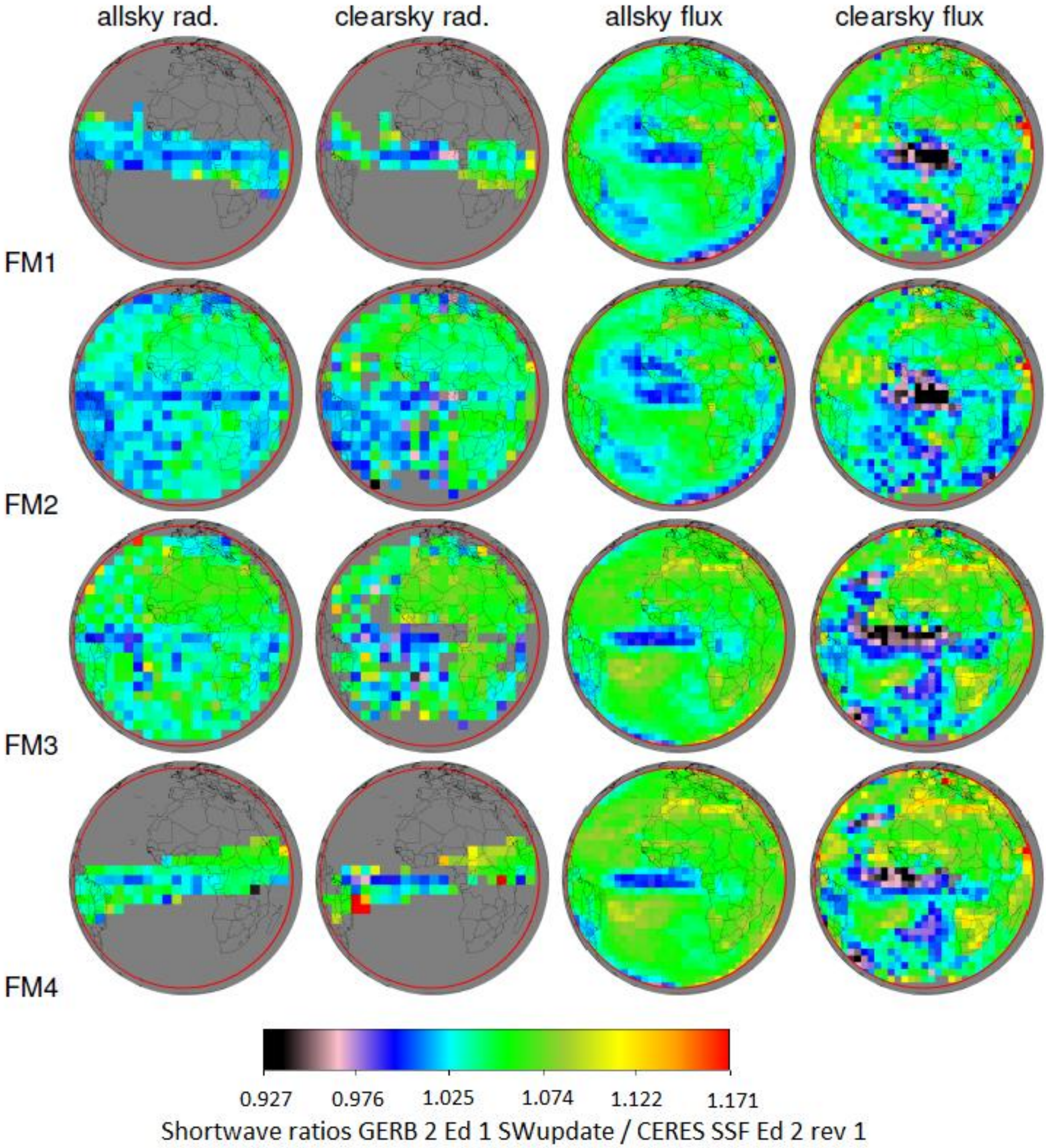

Figure 4: GERB 2 Ed 1 / CERES SSF Ed 2 longwave flux ratio for June and December 2004 temporally and spatially matched points plus angular matching for radiances. First and third columns show all sky comparisons for radiance and flux respectively, second and forth columns clear sky matches for radiance and flux. Reproduced from Clerbaux et al. 2009 but scale adjusted here to account for the GERB 2 shortwave calibration update, see paper for methodology.

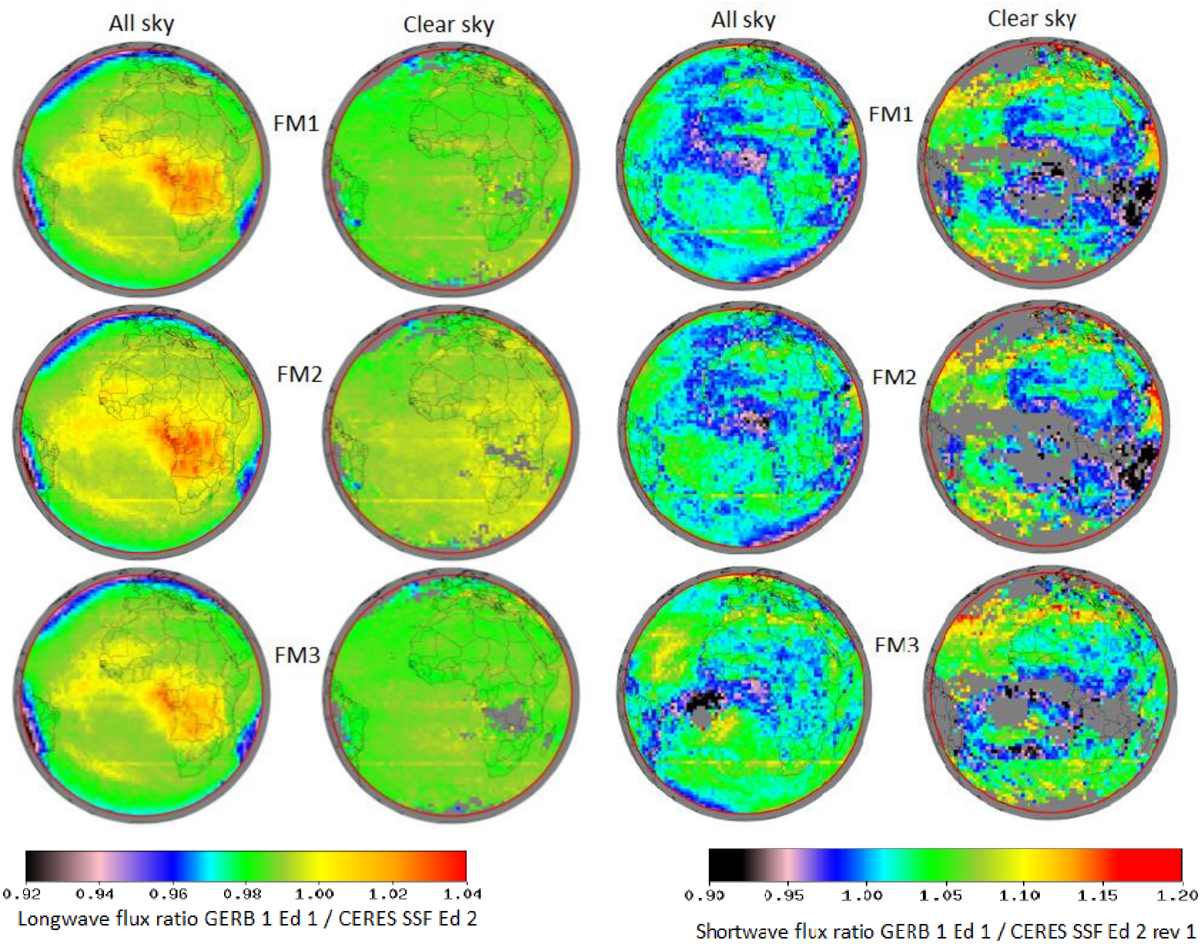

Figure 5: GERB 1 Ed 1 / CERES SSF Ed 2 longwave (first and second column) and shortwave (third and forth column) flux ratio for January 2007 temporally and spatially matched points. First and third columns show all sky, second and forth columns clear sky, tow row are CERES FM1, middle row CERES FM2 and bottom row CERES MF3. Methodology follows that described for GERB 2 comparisons shown by Clerbaux et al. 2009.

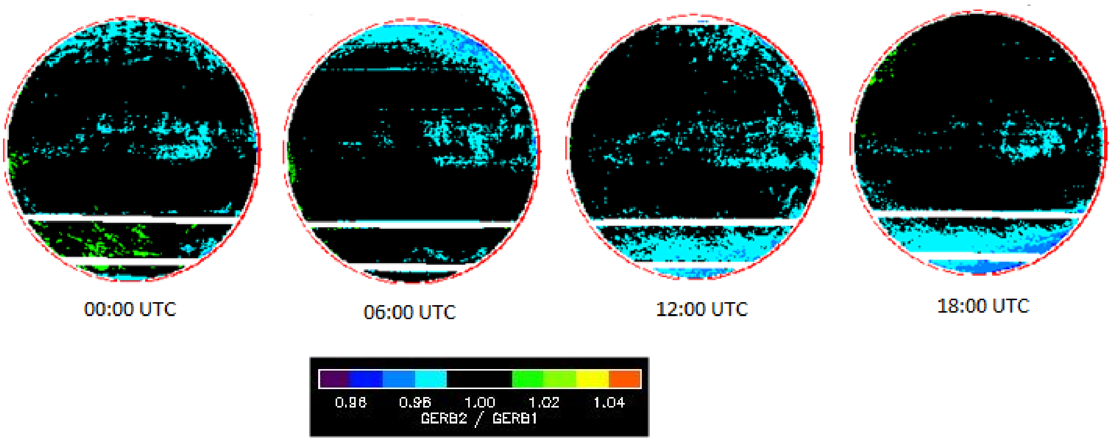

Figure 6. Longwave G2/G1 average ratio plots for May 2007, for 4 times of day.t

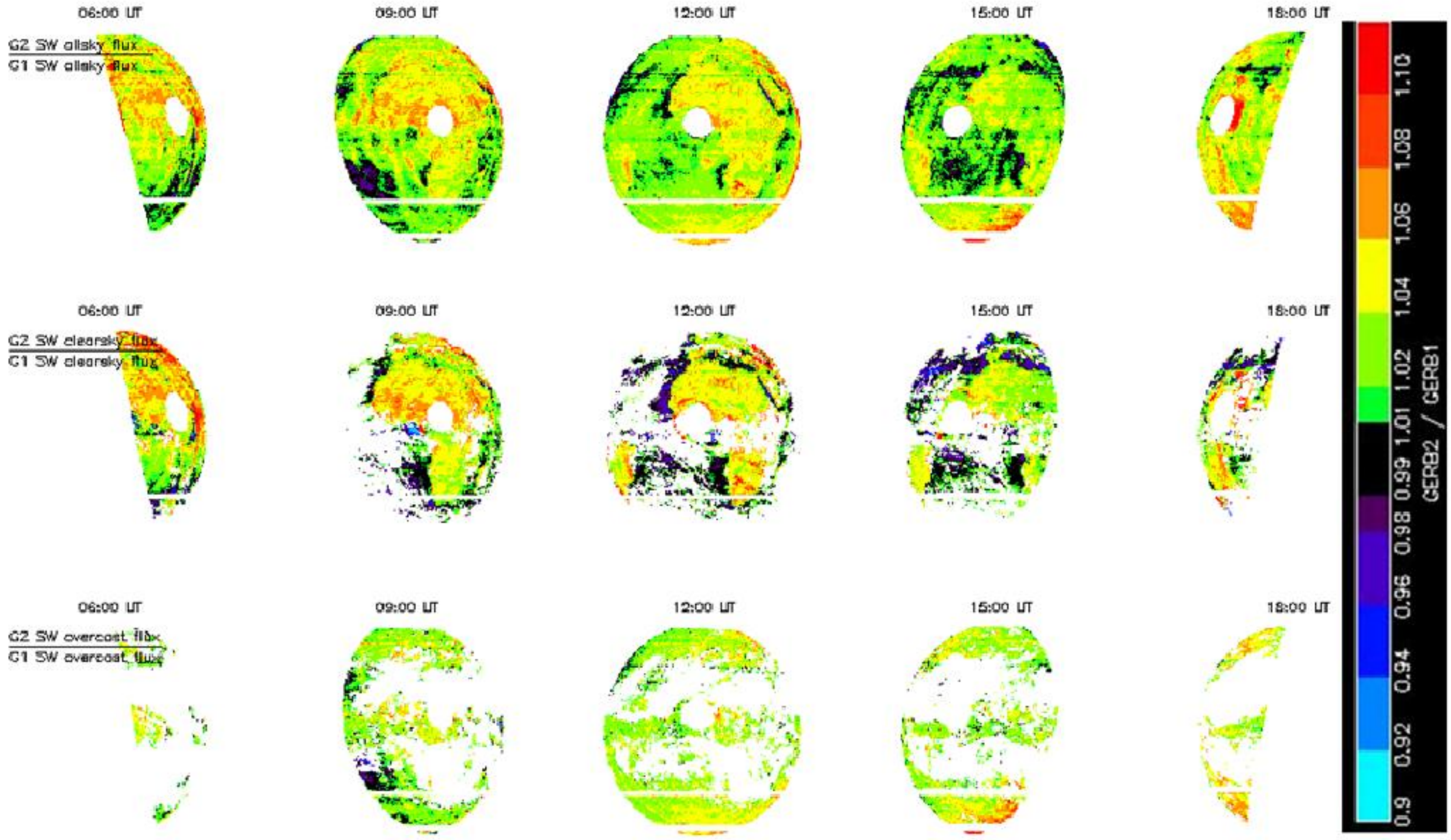

Figure 7. Shortwave G2/G1 average ratio plots for May 2007, for 5 times of day, decomposed according the GERB scene ID into allsky, clearsky and overcast.

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

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7. References

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