EUMETSAT

User Guide for EUMETSAT GSICS Corrections for inter-calibration of Meteosat-SEVIRI with Metop-IASI

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1 WHAT IS THIS GSICS PRODUCT USER GUIDE FOR?

1.1 Purpose

This manual is intended to provide potential users with guidance in the application of the EUMETSAT GSICS Corrections for inter-calibration of Meteosat-SEVIRI with Metop-IASI:

1. It aims to help users understand what these GSICS products are for and their limitations.
2. It also provides information to assist users in the decision of whether they can or should use these products for their applications, based on an analysis of the resulting biases that can be corrected, and the uncertainties with which this can be achieved.
3. This guide then provides users with practical details of how to apply these GSICS Products. Finally it documents the changes between different product versions.

1.2 Scope

This manual covers the Near Real-Time and Re-Analysis Corrections, which are generated as part of EUMETSAT's operational GSICS products for the infrared channels of Meteosat/SEVIRI, using a single reference instrument. The products may be extended in future to combine results from multiple reference instruments as part of *Prime GSICS Corrections*.

1.3 Applicable Documents

AD-1	*GSICS Product Format Templates*	*EUMETSAT Technical Note [EUM/OPS/TEN/12/1447](EUM/OPS/TEN/12/1447)*
AD-2	*The Conversion from Effective Radiances to Equivalent Brightness Temperatures*	*EUMETSAT Technical Note EUM/MET/TEN/11/0569*
AD-3	*MSG Level 1.5 Image Data Format Description*	*EUMETSAT Technical Note EUM/MSG/ICD/105*
ATBD	*ATBD for EUMETSAT Operational GSICS Inter-Calibration of Meteosat-IASI*	*EUMETSAT Technical Note EUM/TSS/TEN/15/803179 doi:10.15770/1001.80319*

1.4 Reference Documents

Hewison et al., 2013	*GSICS Inter-Calibration of Infrared Channels of Geostationary Imagers using Metop/IASI*	*IEEE Trans. Geosci. Remote Sens., vol. 51, no. 3, Mar. 2013, doi:10.1109/TGRS.2013.2238544*
Hewison, 2013	*An Evaluation of the Uncertainty of the GSICS SEVIRI-IASI Inter-Calibration Products*	*IEEE Trans. Geosci. Remote Sens., vol. 51, no. 3, Mar. 2013, doi:10.1109/TGRS.2012.2236330*

2 WHAT IS THIS GSICS PRODUCT FOR?

2.1 Scope/Applicability/Limitations

These GSICS Corrections can be used to correct the calibration of the operational Level 1.5 data from the infrared channels of Meteosat/SEVIRI instruments to be radiometrically consistent with a specified reference instrument, the IASI on Metop-A, -B, or -C. The corrections can also be used to evaluate the bias in channels of the monitored instrument (SEVIRI), with respect to the reference (IASI) for any given scene radiance. The coefficients of the corrections are provided with uncertainties, which can be propagated to estimate the uncertainty in the inter-calibrated radiance or bias.

These GSICS corrections are applicable to both SEVIRI's full disc and rapid scanning modes. When SEVIRI is operating in Full Disc Imaging mode, the inter-calibration results are derived over the geographical domain of ±35°N/S, ±35°E/W. This domain is restricted to latitude north of 15°N while SEVIRI provides the Rapid Scan Service. These GSICS Corrections are derived using only night-time observations. Although strictly only applicable to these conditions, an analysis [Hewison *et al.*, 2013] suggest they are generally applicable, although diurnal variation in the bias of the IR3.9 channel is possible.

2.1.1 Re-Analysis Correction

The Re-Analysis Correction (RAC) is intended for reprocessing type analysis, as it has a longer latency time (15d) to allow more smoothing of the results by combining more collocations over a longer period.

Because the RAC is intended to support the analysis of extended time series of observations for convenience it is provided with results covering a range of dates in a single file. New files are only generated following major version changes in the algorithm.

2.1.2 Near Real-Time Correction

The Near Real-Time Correction (NRTC) is intended for near real-time applications, as it has a shorter latency time (<1d) to allow more rapid response to any calibration changes.

The NRTC is not intended to be applied in the analysis of extended time series, so a new file is generated every time the algorithm is run (typically daily).

3 DO YOU NEED THIS GSICS PRODUCT?

You can judge the importance of this inter-calibration product for your application, based on the typical results presented below. These are followed by a discussion of the GSICS Correction's uncertainties.

3.1 Typical Results

The biases of the infrared channels of Meteosat-10 relative to Metop-A/IASI were calculated from the pre-operational GSICS Re-Analysis Correction for a standard scene radiance over an 8-month period while it was operating in full disc scanning. Summary statistics over this period are shown in Table 1, where they are expressed as brightness temperature differences (in kelvin). These results are typical of the performance of all SEVIRI instruments.

Table 1 Summary Statistics of Pre-Operational GSICS Re-Analysis Correction for Meteosat-10/SEVIRI in Full Disc Scanning in the period 2014-12-20/2015-07-20 (All uncertainties are for coverage factor k=1)

Meteosat/ SEVIRI Channel IR	*3.9*	*6.2*	*7.3*	*8.7*	*9.7*	*10.8*	*12.0*	*13.4*	*μm*
Standard Radiance (as Tb)	284	236	255	284	261	286	285	267	K
Mean Bias (SEVIRI-IASI) for Standard Radiance Scenes	+0.60	-0.15	+0.08	-0.05	+0.05	+0.05	+0.04	-0.86	K
Standard Deviation of Bias for Standard Radiance Scenes	0.04	0.03	0.04	0.03	0.04	0.03	0.02	0.10	K
Median Uncertainty of Bias for Standard Radiance Scenes	0.008	0.006	0.006	0.006	0.009	0.006	0.007	0.008	K
Random Uncertainty estimated as rolling standard deviation of Bias over 29d	0.011	0.007	0.007	0.012	0.015	0.009	0.006	0.010	K
Total Systematic Uncertainty from [Hewison, 2013]	0.008	0.003	0.002	0.002	0.002	0.003	0.003	0.004	K

3.2 How big are the biases? How stable are they?

Table 1 confirms that the operational calibration of most of the infrared channels of Meteosat-10/SEVIRI is very good for this period, with mean biases of ≤ ±0.2 K for standard radiance scenes, typical of clear skies over the sea. These biases are very stable in time, with standard deviations of < 0.1 K. However, the IR3.9 and IR13.4 channels showed larger biases during this period, which varied with time (hence the higher standard deviations), due to ice contamination [Hewison *et al.*, 2013].

When the corrections are evaluated for cold radiance scenes, typical of high cloud (220 K), the biases are typically larger, but still < ±1.0 K – and are more variable – with standard deviations of < 0.3 K, for most channels, except IR3.9, where the variability is amplified when expressed in brightness temperatures, with a correspondingly increased uncertainty. Nevertheless, it is recommended that the GSICS Corrections are applied to all IR channels for any applications for which spectral consistency is important.

3.3 How good are the Corrections?

3.3.1 Random Component of Uncertainty

The coefficients of the GSICS Corrections are provided with uncertainties (including their covariance), based on the error propagation through the weighted linear regression, as defined in the [ATBD]. The median value of the uncertainty evaluated for the standard scene radiances are also included in Table 1. These suggest very low uncertainties for all channels (~0.01 K) for operational RACs derived from Full Disc Imaging data.

Following a detailed analysis [Hewison, 2013], the ATBD and its operational implementation have been revised to increase the uncertainties of the offset and slope coefficients and their covariance by a factor of 2 to compensate for processes omitted in the ATBD and to ensure uncertainty estimates are consistent with the statistics of the time series. This has the effect of increasing the uncertainties on the biases calculated from the correction coefficients by a factor of ~2 relative to those calculated for the preoperational products. These are now estimated to be 0.01 K and 0.03 K for standard radiance scenes when operating in normal and rapid scan modes, respectively; and approximately 7 times larger for cold scenes (except for IR3.9, which is much larger due to its strong non-linearity).

The analysis was repeated for demonstration RACs derived when Meteosat-9 was providing the Rapid Scan Service (RSS) data during the period 2013-02-27/2015-01-01. In this case the variograms suggested the random components of the uncertainty to be ~3 times larger than for data from Full Disc Imaging, due to the reduced collocation sample size, increased viewing angles. However, these are still ~4.5 times larger than the uncertainties previously provided in the pre-operational products.

The uncertainties in the NRTC products are expected to be a factor of √2 times larger than the RAC described above, due to proportionally smaller collocation sample sizes.

The uncertainties provided with the GSICS Corrections are variable, depending on the conditions of the instruments and collocation scenes. Thus, it is recommended that users evaluate them as described below to provide valuable quality control for their correction of the SEVIRI radiances.

3.3.2 Systematic Component of Uncertainty

Also shown in the last row of Table 1 is the total systematic component of the uncertainty evaluated in [Hewison, 2013]. These are very small – less than 0.01 K for all channels – and an order of magnitude smaller than the random component of uncertainty (after adjustment described above). As such these GSICS Corrections can be considered to have negligible bias with respect to the reference instrument (in this case Metop-A/IASI).

4 HOW TO USE THIS GSICS PRODUCT?

4.1 How are the Inter-Calibration coefficients derived?

The inter-calibration process [Hewison et al., 2013] is based on the comparison of thousands of observations of the two instruments, collocated in space, time and viewing geometry, taken within 14 days of the observation date. These observations are transformed spatially and spectrally to allow direct comparison by linear regression to estimate the correction coefficients, a_r and b_r, required to convert GEO radiances, L_{GEO}, to the reference LEO radiances, L_{LEO}:

Equation 1: $$L_{GEO} = a_r + b_r L_{LEO}$$

The relationship in Equation 1 can be inverted to apply the regression coefficients, a_r and b_r, to convert GEO radiances, L_{GEO}, into radiances consistent with the LEO reference instrument, $\hat{L}_{LEO}$,

Equation 2: $$\hat{L}_{LEO} = +\frac{1}{b_r} L_{GEO} - \frac{a_r}{b_r},$$ together with the estimated uncertainty:

Equation 3: $$\left[u\left(\hat{L}_{LEO}\right)\right]^2 = \left[\left(L_{GEO} - a_r\right)u\left(b_r\right)\right]^2 + \left[\frac{u(a_r)}{b_r}\right]^2 - 2\frac{\left(L_{GEO} - a_r\right)}{b_r}u\left(a_r, b_r\right).$$

4.2 How to apply the formulae?

The GSICS Correction can be used to correct the operationally produced radiance in the GEO Meteosat/SEVIRI L1.5 data, L_{GEO}, so its calibration is consistent with that of the LEO reference instrument, Metop/IASI, L_{LEO}.

The operational radiance, L_{GEO}, is calculated from the L1.5 counts as:

Equation 4: $$L_{GEO} = a_c + b_c C,$$

where C is the pixel count, a_c and b_c are the operational offset and slope calibration coefficients, respectively, referred to as *Cal_Offset* and *Cal_Slope* in the L1.5 files [AD-3].

The GSICS Corrected radiance is then given by Equation 2, which may be re-written as

Equation 5: $$\hat{L}_{LEO} = \left(\frac{a_c - a_r}{b_r}\right) + \left(\frac{b_c}{b_r}\right)C,$$

where a_r and b_r are the coefficients of the GSICS Correction given in the netCDF file as the variables *offset* and *slope*, respectively.

This is equivalent to changing the space count and calibration coefficient in Equation 4 to a_g=(a_c- a_r)/b_r and b_g= (b_c/b_r), respectively.

4.3 Where to get this GSICS Product?

The coefficients of the GSICS Correction are available from EUMETSAT's GSICS Data and Products Server: http://gsics.eumetsat.int. This server is organised in a logical directory structure, where EUMETSAT GSICS Products are available in subdirectories under http://gsics.eumetsat.int/thredds/eumetsatProducts.html, corresponding to RAC or NRTC for each combination of monitored instrument (e.g. MSG2 SEVIRI) and reference instrument (e.g. MetOpA IASI). Operational products are provided in a further subdirectory level.

The files follow the GSICS file naming convention, and are time-stamped according to the first date of the processing period. As this is a THREDDS-based server, the files are available for direct download via HTTP, e.g.
http://gsics.eumetsat.int/thredds/fileServer/msg3-seviri-metopa-iasi-oper-rac/W_XX-EUMETSAT-Darmstadt,SATCAL+RAC+GEOLEOIR,MSG3+SEVIRI-MetOpA+IASI_C_EUMG_20130110000000_01.nc

Table 2 Equivalence Table for Meteosat Second Generation Platform Names

Platform name	Meteosat-8	Meteosat-9	Meteosat-10	Meteosat-11
Abbreviation	MSG1	MSG2	MSG3	MSG4

4.4 How to read this GSICS Product?

The RAC and NRTC files are formatted in netCDF, following the CF compliant GSICS netCDF convention and can be read by any common netCDF readers or libraries.

The regression coefficients, a_r and b_r, and their uncertainties, $u(a_r)$, $u(b_r)$ and $u(a_r, b_r)$ are given as variables *offset*, *slope*, *offset_se*, *slope_se* and *covariance*, respectively.

4.4.1 Re-Analysis Correction

The RAC files are updated each day with additional coefficients added to 2-D arrays of *number_of_channels* (8) x *date* (~1000) for the freshly calculated results with a nominal date, 15 days previous. The whole netCDF file should be read and the *date* closest to the required date used, ensuring that it is within the *validity_period*.

A new file will only be generated if a new major version of the algorithm is released. Use the most recent RAC file, where the start date in the file name precedes the period of interest, and read the coefficients for the relevant dates. Take great caution where no results are available within 14 days, as determined by the netCDF *validity_period* variable.

4.4.2 Near Real-Time Correction

Every day a new NRTC file is generated, based on collocations obtained over the previous 14 days. Each file contains the NRTC coefficients stored in 1-D arrays of *number_of_channels* (8 for Meteosat/SEVIRI). As the NRTC is intended for near real-time applications, only the most recent file should be read, which is intended to provide results applicable to a period of 14 days from the date in the filename. Take great caution where results are older than that, as determined by the netCDF *validity_period* variable.

4.4.3 GSICS Corrected Calibration Coefficients in SEVIRI L1.5 Header

The corrected calibration coefficients derived from the NRTC are also available in the L1.5 headers [AD-3], as *GSICSCalCoeff* and *GSICSOffsetCount*. (Additionally, *GSICSCalError* provides an estimate of the uncertainty on the corrected standard scene radiance.) These can then be use to convert the L1.5 count, C, into a radiance consistent with the GSICS Reference, $\hat{L}_{LEO}$ by substitution into Equation 5:

Equation 6: $$\hat{L}_{LEO} = GSICSOffsetCount \times GSICSCalCoeff \; + GSICSCalCoeff \times C.$$

n.b. *GSICSCalCoeff* and *GSICSOffsetCount* are defined for consistency with the deprecated vicarious calibration coefficients previously included in the L1.5 *MPEFCalFeedback* record. They are derived as $GSICSCalCoeff \; = b_c/b_r$ and $GSICSOffsetCount = (a_c - a_r)/b_c$.

4.5 What are the units and how do I convert them?

The units are given in the following table, which also summarises the terminology and symbols used in this document, following the Meteosat/SEVIRI convention of *effective radiance* as defined in [AD-2].

Parameter	Where used?	Variable		Uncertainty		Unit
		Symbol	Name	Symbol	Name	
Operational Calibration Coefficients	L1.5 Files	a_c	*Cal_Offset*	N/A	N/A	$mW/m^2/sr/cm^{-1}$
		b_c	*Cal_Slope*	N/A	N/A	$mW/m^2/sr/cm^{-1}$/count
GSICS Correction Coefficients	GSICS netCDF Files	a_r	*offset*	$u(a_r)$	*offset_se*	$mW/m^2/sr/cm^{-1}$
		b_r	*slope*	$u(b_r)$	*slope_se*	1
				$u(a_r,b_r)$	*covariance*	$mW/m^2/sr/cm^{-1}$
Corrected Calibration Coefficients	L1.5 Files	$\frac{a_c - a_r}{b_r}$	*GSICSOffsetCount *GSICSCalCoeff*	N/A	N/A	$mW/m^2/sr/cm^{-1}$
		$\frac{b_c}{b_r}$	*GSICSCalCoeff*	N/A	N/A	$mW/m^2/sr/cm^{-1}$/count
GSICS-Corrected Radiance	User	$\hat{L}_{LEO}$	**Equation 6**	$u(\hat{L}_{LEO})$ $u(\hat{L}_{STD})$	**Equation 3** or *GSICSCalError*	$mW/m^2/sr/cm^{-1}$

4.5.1 Radiance to Brightness Temperature Conversion

[AD-2] also describes how to convert radiance to equivalent brightness temperature. Additionally, the netCDF file contains global attributes to define the function to convert between SEVIRI effective radiances and equivalent brightness temperatures for each channel: *brightness_to_radiance_conversion_formula, radiance_to_brightness_conversion_formula*. The coefficients needed are also supplied as the variables *alpha*, *beta* and *wnc*.

4.6 Example

For example, a typical scene radiance for Meteosat-9 IR13.4 channel might be C=620 counts.

The operational calibration coefficients, a_c=-8.0376 $mW/m^2/sr/cm^{-1}$ and b_c=0.1576 $mW/m^2/sr/cm^{-1}$/count give a radiance of L_{GEO}=89.7 $mW/m^2/sr/cm^{-1}$, corresponding to a brightness temperature of 267.0 K (the GSICS *standard scene radiance* for this channel).

Applying Equation 5 with example GSICS Correction coefficients, a_r=+2.04 mW/m^2/sr/cm^{-1} and b_r=0.95, gives the GSICS Corrected radiance, $\hat{L}_{LEO}$=92.2 mW/m^2/sr/cm^{-1}, corresponding to a brightness temperature of 268.8 K. i.e. an increase of +1.8 K compared to the operational calibration, to correct the standard bias of this channel of -1.8 K.

4.7 How can I visualise the biases?

EUMETSAT have also developed an interactive *Plotting Tool* to visualise time series of the biases accounted for the GSICS Re-Analysis Correction. The server-side Java tool reads the RAC files from the GSICS server, performs the above calculation to evaluate the biases for a user-selectable scene brightness temperature (the GSICS *standard scene radiance* by default), and generates data for the client side plotting tool. This tool is available online at http://gsics.tools.eumetsat.int/plotter/.

4.8 How to reference this GSICS Product?

The product's filename provide a unique identifier for each product, which is also given in the *id* global attribute.

4.9 Who to contact for Support?

General questions about GSICS products can be directed to the GSICS Coordination Center. For enquiries specifically about this product, please contact the EUMETSAT User Service Helpdesk by email: *ops@eumetsat.int*.

5 RELEASE NOTES

The *processing_level* global attribute refers to the distribution mode of the GSICS product, and its version number, expressed as **major.minor.revision**. The changes between different product versions are documented in the following table.

Processing Level	Release Notes
Operational/ v1.1.0	First operational distribution of product. Based on software release v1.2.0 and *iasi_mon* v1.0.7. For SEVIRI-IASI, this is based on *preoperational/v1.1.0*, which included the following changes to previous versions: • Uncertainties of GSICS Correction coefficients inflated by a factor of 2, as recommended in Hewison [2013]. • Clarify case of outage of >14d should only reset smoothing for significant changes. On promotion to operational status, the following changes were introduced: • File name changed to reflect operational status. • Updated *window_period* and *atbd_doi* netCDF global attributes. • Corrected handling of discontinuities occurring caused by decontaminations.
Operational/ v2.1.0	As v1.1.0, but only for *reference_instrument*: **MetOpA IASI** after change to onboard processing implemented since 2019-09-30T14:45Z. All processing as v1.1.0.