MTG-FCI: ATBD for GSICS Corrections

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1 INTRODUCTION

1.1 Purpose of this Document

The Global Space-based Inter-Calibration System (GSICS) is an initiative of CGMS and WMO, which aims to ensure consistent calibration and inter-calibration of operational meteorological satellite instruments. For MTG-FCI this will be realised by comparisons of observations with reference instruments, such as Metop/IASI and Aqua/MODIS, to generate *GSICS Corrections* which can be applied to L1c data to make its calibration consistent with the references'.

This document is intended to provide advice on scoping the requirements for algorithm development and processing hardware needed to generate GSICS Corrections for MTG-FCI.

For the infrared channels this is based on the current generation of the GSICS Correction of MSG, which is now running routinely in prototype form on the TCE and in pre-operational form on the Cal/Val facility. At the current time we are still awaiting the procurement of new hardware for operational use. A comprehensive ATBD for this is available in Ref [1].

For the solar band channels, the algorithm is still under development. It is expected to be based on a combination of methods, following the current operational algorithm for the vicarious calibration of the solar channels of MSG [2].

1.2 Applicable and Reference Documents

The following documents have been used to establish this document:

Doc ID	***Title***	***Reference***
[1]	ATBD for EUMETSAT's Inter-Calibration of SEVIRI-IASI	EUM/MET/TEN/09/0774
[2]	Y. M. Govaerts, A. Arriaga and J. Schmetz, 2001: *Operational vicarious calibration of the MSG/SEVIRI solar channels*, Adv. in Space Res., Vol. 28, Issue 1, pp 21-30	doi:10.1016/S0273-1177(01)00269-1
[3]	GSICS Wiki, accessed 2010-06-25	https://cs.star.nesdis.noaa.gov/bin/view/GSICS/WebHome
[4]	GSICS Data and Products Server User Guide	EUM/OPS/MAN/09/1146
[5]	GSICS Meteosat IR Inter-Calibration, (EUMETSAT's webpage for GSICS Bias Monitoring)	http://www.eumetsat.int/Home/Main/DataProducts/Calibration/Inter-calibration/index.htm?l=en

1.3 Acronyms and Definitions

The following table lists definitions for all acronyms used in this document.

Acronym	*Full Name*
CLARREO	Climate Absolute Radiance and Refractivity
FCI	Flexible Combined Imager
FCI-FDSS	FCI Full Disc Scanning Service
FCI-RSS	FCI Rapid Scanning Service
FDHSI	Full Disc High Spectral Resolution Imagery
GEO	Geostationary orbiting satellite
GSICS	Global Space-based Inter-Calibration System
HRFI	High Spatial Resolution Fast Imagery
HRV	High Resolution Visible Channel of SEVIRI
IASI	Infrared Advanced Sounding Interferometer
IR	Infrared
LEO	Low Earth Orbit (satellite)
MODIS	Moderate-resolution Imaging Spectro-radiometer
MSG	Meteosat Second Generation
MTG	Meteosat Third Generation
NWP	Numerical Weather Prediction
RTM	Radiative Transfer Model
RTTOV	Radiative Transfer for TOVS
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SSD	Spatial Sampling Distance
VIS	Visible (solar)

2 OVERVIEW

2.1 Relevant Instrument Characteristics

The mission of the Meteosat Third Generation (MTG) System is to provide continuous high spatial, spectral and temporal resolution observations and geophysical parameters of the Earth / Atmosphere System derived from direct measurements of its emitted and reflected radiation using satellite based sensors from the geo-stationary orbit to continue and enhance the services offered by the Second Generation of the Meteosat System (MSG) and its main instrument SEVIRI.

The meteorological products described in this document will be extracted from the data of the Flexible Combined Imager (FCI) mission. The FCI is able to scan either the full disk in 16 channels every 10 minutes with a spatial sampling distance in the range 1 – 2 km (Full Disk High Spectral Resolution Imagery (FDHSI) in support of the Full Disk Scanning Service (FCI-FDSS)) or a quarter of the earth in 4 channels every 2.5 minutes with doubled resolution (High spatial Resolution Fast Imagery (HRFI) in support of the Rapid Scanning Service (FCI-RSS)).

FDHSI and HRFI scanning can be interleaved on a single satellite (e.g. when only one imaging satellite is operational in orbit) or conducted in parallel when 2 satellites are available in orbit. Table 1 provides an overview over the FCI spectral channels and their respective spatial resolution.

The FCI acquires the spectral channels simultaneously by scanning a detector array per spectral channel in an east/west direction to form a swath. The swaths are collected moving from south to north to form an image per spectral channel covering either the full disc coverage or the local area coverage within the respective repeat cycle duration. Radiance samples are created from the detector elements at specific spatial sample locations and are then rectified to a reference grid, before dissemination to the End Users as Level 1 datasets. Spectral channels may be sampled at more than one spatial sampling distance or radiometric resolution, where the spectral channel has to fulfil FDHSI and HRFI missions or present data over an extended radiometric measurement range for fire detection applications.

Table 1: Channel specification for the Flexible Combined Imager (FCI)

Spectral Channel	*Central Wavelength, $\lambda 0$*	*Spectral Width, $\Delta\lambda 0$*	*Spatial Sampling Distance (SSD)*
VIS 0.4	0.444 µm	0.060 µm	1.0 km
VIS 0.5	0.510 µm	0.040 µm	1.0 km
VIS 0.6	0.640 µm	0.050 µm	1.0 km 0.5 km #1
VIS 0.8	0.865 µm	0.050 µm	1.0 km
VIS 0.9	0.914 µm	0.020 µm	1.0 km
NIR 1.3	1.380 µm	0.030 µm	1.0 km
NIR 1.6	1.610 µm	0.050 µm	1.0 km
NIR 2.2	2.250 µm	0.050 µm	1.0 km 0.5 km #1
IR 3.8 (TIR)	3.800 µm	0.400 µm	2.0 km 1.0 km #1
WV 6.3	6.300 µm	1.000 µm	2.0 km
WV 7.3	7.350 µm	0.500 µm	2.0 km
IR 8.7 (TIR)	8.700 µm	0.400 µm	2.0 km
IR 9.7 (O_3)	9.660 µm	0.300 µm	2.0 km
IR 10.5 (TIR)	10.500 µm	0.700 µm	2.0 km 1.0 km #1
IR 12.3 (TIR)	12.300 µm	0.500 µm	2.0 km
IR 13.3 (CO_2)	13.300 µm	0.600 µm	2.0 km

#1: The spectral channels VIS 0.6, NIR 2.2, IR 3.8 and IR 10.5 are delivered in both FDHSI sampling and a HRFI sampling configurations.

2.2 Generated GSICS Products

The range of routinely generated GSICS products includes the *GSICS Correction* and *GSICS Bias Monitoring*:

1. **GSICS Corrections** are functions, which users can choose to apply to correct the calibration of operationally-generated L1c datasets from the *Monitored Instrument* (in this case MTG-FCI) to be consistent with that of the *Reference Instrument*. GSICS Corrections are produced from the same algorithm for both *Near-Real-Time* and *Re-Analysis* applications, with different latencies. For example, an MTG L2 processing facility may decide to apply the GSICS Near-Real-Time Correction as

part of its processing chain if its products are sensitive to calibration errors. Coefficients for the GSICS Corrections shall be published in netCDF format from the GSICS Data and Products Server.

2. **GSICS Bias Monitoring** allows users to visualise the relative biases between the monitored and reference instruments for standard radiances. These take the form of time series plots in which the latest results can compared with recent trends. GSICS Bias Monitoring plots shall be routinely published on the GSICS pages of the EUMETSAT website.

For MTG-FCI, these GSICS products shall be generated independently for channels in the reflected-solar and thermal infrared bands.

Additionally, reports of GSICS Analyses may be generated on request to assist the diagnosis of specific instrument anomalies and to support any recommendations for changes in operational procedures. These reports shall necessarily be generated manually and require skilful analysis of the above GSICS products in conjunction with detailed knowledge of the instruments and the processing of their data.

3 ALGORITHM DESCRIPTION

3.1 Overview of GSICS Correction Algorithm

The algorithm for the inter-calibration of the infrared channels of MTG-FCI is based on the comparison of thousands of observations of the two instruments, collocated in space, time and viewing geometry, taken within 15 days from the observation time. These observations are transformed spatially and spectrally to allow direct comparison by weighted linear regression to estimate the coefficients of the correction function, together with the covariance of their uncertainties. This regression provides the coefficients for the GSICS Correction, which is a function to convert the calibration of issued dataset to be consistent with those of the reference. A full description of the algorithm for MSG is given in Ref [1].

The reference instrument for the infrared channels is currently the hyperspectral Infrared Advanced Sounding Interferometer (IASI) on Metop-A.

The algorithm for the inter-calibration of the solar band channels of MTG-FCI will also be based on that used for MSG. Although, this is still under development, it is expected to be based on a combination of other methods in the same way developed for the vicarious calibration of MSG [2], but applied to both MSG and a LEO reference instrument. These methods include the direct comparison of ray-matched radiances as well as comparison of BDRFs constructed from a series of observations of "invariant scenes", such as deep convective clouds, selected desert scenes and the ocean surface in clear conditions.

The reference instrument for the solar band channels for MSG is still being defined – however, it is likely to be a well characterised instrument such as MODIS.

In the MTG era it was hoped that the reference instruments would be supplemented by the use of CLARREO to provide absolute calibration, traceable to SI standards. However, it now appears that such an absolute reference is unlikely to be available in-orbit at the start of the MTG era. Therefore, the traceability concept of GSICS will only be realised by comparison back to a common reference – initially Metop/IASI for the thermal infrared, and later its EPS-SG successor – and a successor of Aqua/MODIS for the reflected-solar band.

3.2 Overview of GSICS Bias Monitoring

The GSICS Bias Monitoring product allows near real-time monitoring of the calibration of the infrared channels of Meteosat's SEVIRI imager. It is based on the same analysis and generated by the same process as the GSICS Correction. This product comprises plots of the difference in radiance of standard scenes, allowing the most recent result to be compared to the long-term trend. These plots are delivered to a publically accessible web page.

3.3 Algorithm Input

These are specified in the ATBD for MSG [1].

3.3.1 Primary Sensor Data

The GSICS Correction shall be calculated from a series of MTG-FCI data at the processing level issued for operational applications – i.e. geo-located and radiometrically calibrated data. Only those portions of the data near the time and location of overpasses of the reference instrument are needed, e.g. from images near the nominal overpass time of the Metop for IASI and Aqua for MODIS. These can be further subset to only include data near within ~50° of the MTG sub-satellite point.

3.3.2 Ancillary Dynamic Data

Data from the reference instruments on LEO are also required in the same temporal/spatial domain as for MTG-FCI (see above) at the processing level issued for operation applications – i.e. level 1c for geo-located and radiometrically calibrated data.

3.3.3 Ancillary Static Data

Some additional data are required in the form of pre-calculated look-up-tables generated from Radiative Transfer Models, which are used to account for any spectral deficiencies of the reference instrument. These are specified in the full ATBDs.

3.4 Output Description

The inter-calibration algorithm generates small files containing the coefficients of the GSICS Correction, which are updated on a daily basis. Their format is specified on the GSICS Wiki [3]. These files are uploaded to EUMETSAT's GSICS Data and Products Server [4], where they are available for download by registered users and other GSICS developers.

The GSICS Bias Monitoring generates graphics images showing the time evolution of the instruments' relative bias. These are updated daily and transferred to a web server, where they are integrated into a dedicated webpage, similar to that developed for MSG [5].

4 SCALABILITY FROM MSG TO MTG

The hardware needed to implement the GSICS algorithms on MTG-FCI can be estimated from the current requirements for MSG, by considering the differences between the instruments and following some simple scaling arguments.

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	MSG IR	MTG-FCI IR	Data I/O multiplier	CPU multiplier	Memory multiplier
Number of Channels	8	8	1	1	1
Number of Detectors per channel	3	300	1	1	1
Repeat Cycle/min	15	10	1.5	1	1
Spatial Sampling/km	3	2	2.25	2.25	2.25
Total multiplier			5.75	5.25	5.25

	MSG Solar	MTG-FCI solar	Data I/O multiplier	CPU multiplier	Memory multiplier
Number of Channels	3	8	2.67	2.67	2.67
Number of Detectors per channel	3	300	1	1	1
Repeat Cycle/min	15	10	1.5	1	1
Spatial Sampling/km	3	1	9	9	9
Total multiplier			14.17	13.67	13.67

The underlying assumption in the GSICS Correction is that small differences in calibration against a references instrument can be accounted for empirically by inter-calibration. If these changes are not small then additional predictors will need to be added to the correction function to account for them. In the case of MTG-FCI, it is anticipated that the differences between the calibration of each of the detectors (e.g. due to different spectral responses) will be sufficiently small that they can be empirically corrected in this way. This is the case for MSG. However, if it is not the case for MTG-FCI, additional data will be needed to account for the mix of different detectors used to generate each radiance in the geo-located level 1c data.