GSICS-RDGUG

Global Satellite   
Inter-Calibration System

GSICS USER GUIDE  
*Using GSICS Products and Services*

tional logo of the entity providing/ maintaining the document

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# GSICS User Guide

Using GSICS Products and Services

## Purpose of the document

The present document describes the products and services delivered by the Global Satellite Inter-calibration System (GSICS) for satellite data users.

## Scope of GSICS

GSICS was established in 2005 by WMO and the Coordination Group for Meteorological Satellites (CGMS). Its aim is to coordinate the production of satellite inter-calibration information enabling the use of space-based observations with improved and globally consistent accuracy for climate monitoring, weather forecasting, and environmental applications.

Within GSICS, satellite operators and science teams are collaborating to develop community-agreed best practices, standard procedures and tools. This enables to monitor, improve and harmonize the calibration of instruments aboard operational meteorological, climate and other environmental satellites of the WMO Integrated Global Observing System (WIGOS), thus contributing to ensure interoperability of their measurements.

The focus of GSICS’ activity is the systematic generation of in-orbit inter-calibration information to correct the individual calibration of Level 1 satellite data.

This routine production of in-orbit inter-calibration information is however part of a comprehensive strategy, which involves a broad range of activities including:

• In-orbit instrument Level 1 data monitoring,

• In-orbit instrument comparison with references,

• Routine generation of intercalibration corrections for near real-time applications,

• Provision of algorithms enabling recalibration of archived data,

• Traceability to absolute measurement standards,

• Prelaunch instrument characterization

• Documentation of state-of-the-art calibration techniques.

## Challenges of space-based instrument calibration

Space-based observations of meteorological variables, atmospheric composition, ocean and land surfaces, represent a large majority of observation data assimilated in NWP models or climate models, and are increasingly used in a wide range of environmental applications. The accuracy of these observations, and their suitability to be used in an interoperable manner with other observations, directly depend on the reliability of instrument calibration.

Calibration is a process by which instrument readings can be converted into measurements in physical units, units of radiance in the case of satellite radiometric instruments.[[1]](#footnote-1) In the field of satellite meteorology, the term cal/val is frequently used, where “Cal” refers to calibration of the instruments, and “val” refers to validation of the geophysical products generated from the instrument observed radiances. Satellite instrument calibration activities take place throughout the lifetime of the instrument, and beyond through retrospective calibration.

Prior to launch, instruments are calibrated in laboratories against known radiance sources. Pre-launch calibrations often need to be adjusted once in orbit because of inability to create a perfect space environment during pre-launch characterization, the effect of launch shock, and the harsh radiation environment the instruments fly in. However, despite such calibration shifts, pre-launch calibration is still critical to mission performance. Pre-launch calibration provides and validates the radiometric performance of on-board calibrators, determines filter in-band and out-of-band spectral response, detector linearity, stray light, instrument thermal response, and other performance attributes which are critical for on-orbit performance assessment and calibration correction.

Calibration continues while the instrument is in space, but it is a difficult challenge there is generally no direct way to assess how much the instrument has drifted away from its pre-launch calibration. Many space-borne radiometric instruments have on-board calibration devices, but the stability of this on-board device itself must be monitored. For those without on-board calibrators, e.g., operational visible and near infrared imagers, changes from pre-flight calibration can be monitored by viewing relatively constant external sources. Such sources include natural targets on the Earth’s surface such as deserts, deep convective clouds, and sun glint, and celestial targets such as the Moon and stars.

Complex methods must however be deployed to evaluate this indirect calibration and establish traceability. This is achieved in comparing the instrument with a measurement reference and computing the corresponding calibration correction function. A first challenge is to determine suitable measurement reference standards. A second challenge is to account for the differences between the references and the instrument to be monitored, as these instruments may have different spectral characteristics, scanning pattern, viewing geometry, orbital locations, and don’t necessarily observe the same scenes at the same time.

The satellite comparison and inter-calibration methodology implemented by GSICS is addressing these issues, in following common principles: observations are collocated, transformed, compared and analyzed to produce calibration correction functions making the observations consistent with common references.

For historical satellite data when rigorously collocated data from two satellite instruments cannot be compared scene by scene, a minimum step is to compare the large-scale spatial and temporal means of overlapping time series of the two instruments and remove the bias difference.

Furthermore, an inter-calibrated system which would not be tied to measurement reference standards based on the SI system of units would be prone to drift over time. It is an issue for climate measurements where small changes over periods of several decades are of prime interest. Therefore, development of procedures for linking the observations to the international SI system of units is highly desirable.

## GSICS users

GSICS aims to serve the needs of two main user categories:

### The satellite data user community

Primary GSICS users are the users of satellite data in applications relying on accurate and globally consistent satellite data. This includes for instance the generation of Level 2 or stable and seamless composite Level 3 satellite imagery products, or quantitative products (such as Sea Surface Temperature, or cloud analysis, aerosol or ash detection, or sea or land surface monitoring). It also supports Numerical Weather Prediction (NWP) since the assimilation of GSICS calibrated radiance provides the best conditions allowing the NWP model to apply its linear bias correction. Particular uses of GSICS products are the generation of Climate Data Records and reanalysis projects, since climate change detection and monitoring have stringent uncertainty and stability requirements as identified for instance by Ohring et al. (2005)[[2]](#footnote-2).

The User Requirements addressed by GSICS are summarized in [RDURD].

### The GSICS Member agencies

In sharing expertise, development resources, calibration references and tools within GSICS, satellite operators are contributing to, and benefitting from, capacity building, resource optimization, and ultimately improvement of calibration techniques.

## GSICS deliverables

The different functions of GSICS result in four broad types of deliverables:

* ***Inter-comparisons of space-based instruments with the GSICS references, and resulting calibration adjustments, which are commonly designated as “GSICS Products.*** The inter-comparison and calibration adjustments are performed by the GSICS member agencies in accordance with GSICS practices and standard procedures and are made available either in near real-time for current data, or as retrospective analyses or algorithms, for past data. The associated deliverables are either calibration coefficients, or correction functions to be applied by the user to the operational instrument calibration coefficients, or algorithms for the recalibration of archived data. A by-product is the monitoring of instrument Level 1 data;
* ***Documentation.***  Information is delivered through different media to assist satellite data users and GSICS member agencies in understanding GSICS activities and calibration issues, and using GSICS products and services.
* ***Best practices and standard procedures***. GSICS coordinates the definition and implementation of standard procedures and best practices for the comparison and inter-calibration of operational space-based instruments against the appropriate references. The associated deliverables include agreed procedures (such as inter-calibration algorithms), standards (such as data and metadata representation) and guidelines.
* ***Measurement references and tools.*** One of the objectives of GSICS is also to ensure the continuous availability of calibration references, either ground-based or space-based, to provide the best possible support to radiometric measurement calibration in the various spectral domains used by the WIGOS space-based component. The tools include software modules, data sets, infrastructure elements, which are shared among GSICS member agencies to support inter-comparison and calibration activities.

## Calibration references

[This section certainly needs to be reviewed and expanded. Criteria for in-orbit references. Current references, transition. Perspective of future SI traceable sensors]]

For the thermal infrared domain, a reference is chosen among the most accurate and stable of the available infrared spectrometers, in accordance with an agreed set of criteria. To the extent possible, the reference instrument should be SI traceable, for instance through the use of thermo-regulated black-bodies with phase-change cells.

For the near infrared and visible domains (solar channels) a reference is chosen among the most accurate and stable of the available short-wave spectrometers, in accordance with an agreed set of criteria. Natural targets such as the moon’s surface (together with a lunar model), deep convective clouds, ocean surface or desert targets are used as transfer standards.

For the micro-wave domain, a reference is chosen among the most accurate and stable of the available microwave radiometers, in accordance with an agreed set of criteria, using an atmospheric Radiative Transfer Model as a transfer standard.

Secondary references are defined in order to serve as transfer standards when the primary references are no longer available.

## GSICS intercalibration methodology

### Principles

The generation of calibration adjustments for Level 1 satellite sensor data is performed in accordance with the following principles:

* Calibration of satellite instruments is monitored and assessed by comparing their output with community references, using common methodologies, following international standards and community best practices, and, ultimately, tying these to SI-traceable standards.
* GSICS implements a continuous chain of comparisons, each with stated uncertainties, to ensure metrological traceability.
* Calibration corrections are generated with specified uncertainties, through well-documented, peer-reviewed procedures, based on various techniques aiming to ensure consistent and robust results, which are applicable over a broad range of observing conditions.
* These inter-calibration assessments, comparisons and corrections are delivered to users through free and open access, adopting community data standards.

### Product acceptance

The recognition of a product as a GSICS product is subject to the GSICS Procedure for Product Acceptance (GPPA) which aims to assess the relevance, maturity, and availability of the products through a comprehensive review process coordinated by the GCC and under the responsibility of the Executive Panel. The GPPA foresees different stages: demonstration, pre-operational, operational.

The GPPA requires that each GSICS Product be delivered with an Algorithm Theoretical Baseline Document (ATBD) and an uncertainty analysis. The GPPA was established in accordance with the principles of the Quality Assurance Framework for Earth Observation (QA4EO). Details on the GPPA can be found on the GCC website.

### Intercalibration by Simultaneous Nadir Observation

Whenever possible, the main approach for comparison of contemporaneous sensors is to use Simultaneous Nadir Observations (SNO), for nadir scanning instruments. A variant of SNO is the Simultaneous Conical Observations (SCO) for conical scanning instruments.

An ATBD describes each step of the processing for each individual GSICS product, which generally includes the following steps.

* **Subsetting**: a rough cut is done in the acquired data to select portions of data collected by the two instruments that are likely to produce collocations.
* **Collocation:** selecting relevant comparable datasets, identify the pixels that are spatially collocated, temporally concurrent, geometrically aligned and spectrally compatible and calculate the mean and variance of these radiances. To ensure that the selected collocated pixels have been observed under comparable conditions, they should view the surface at similar incidence angles (which may include azimuth and polarisation as well as elevation angles) through similar atmospheric paths.

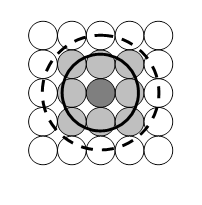
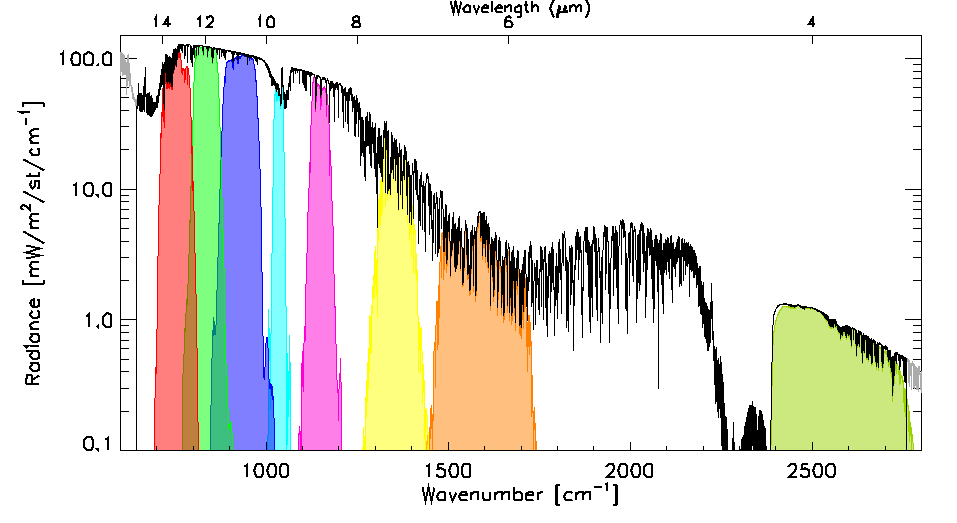


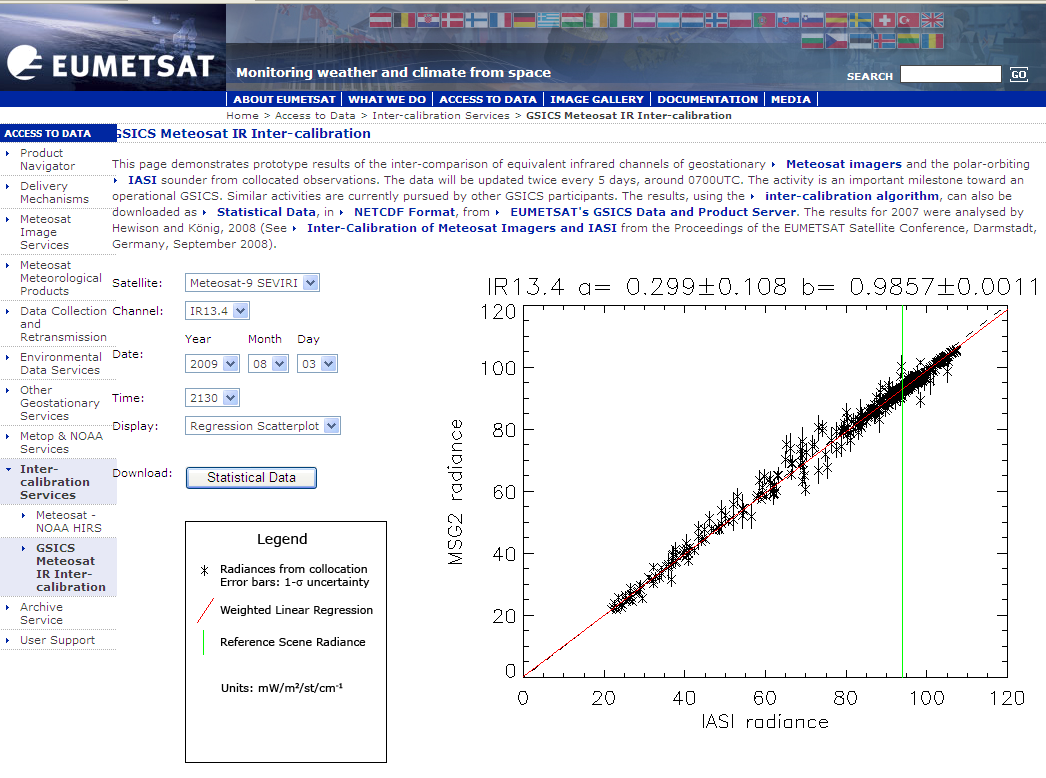
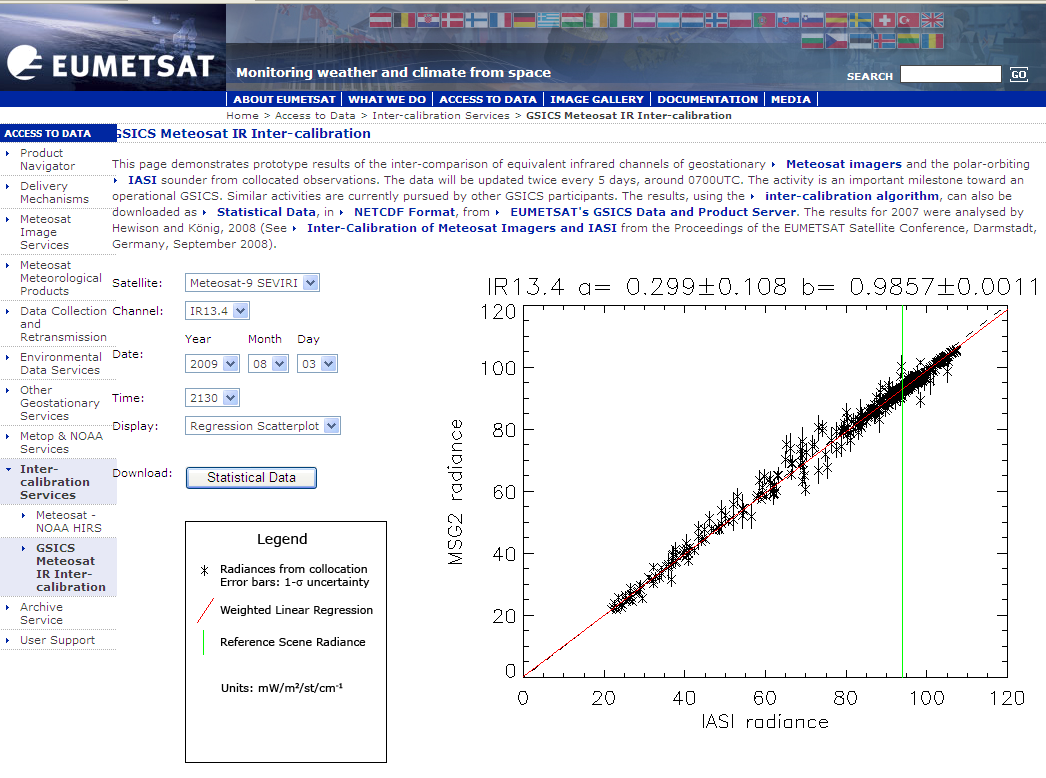
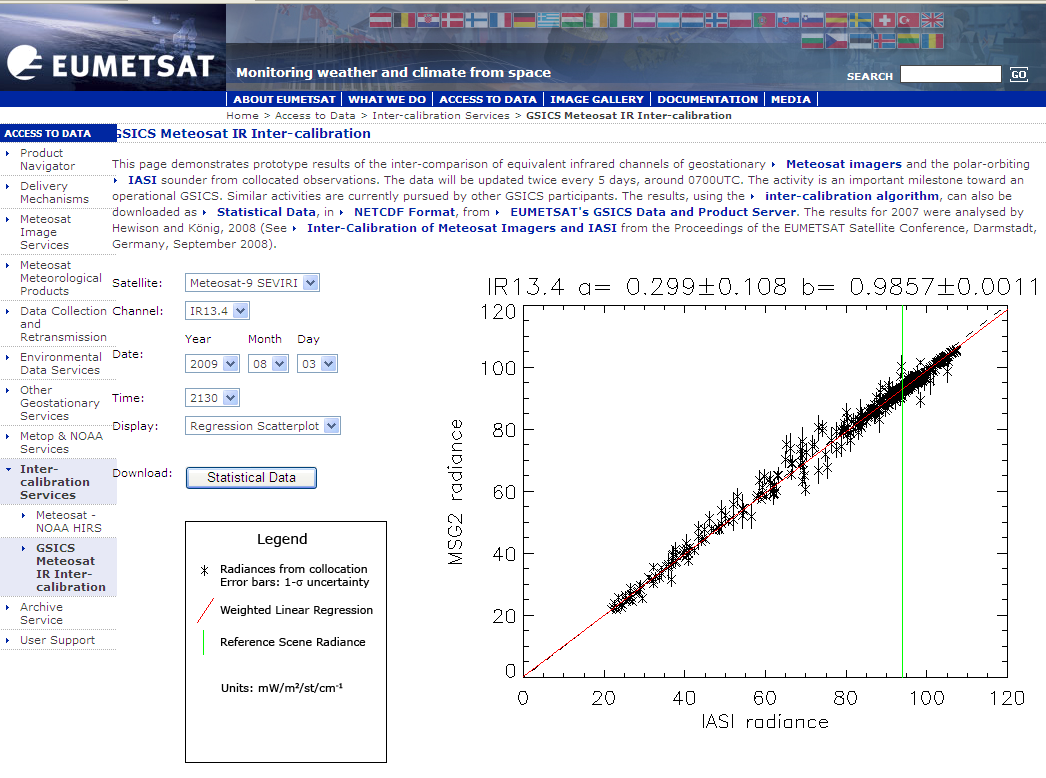
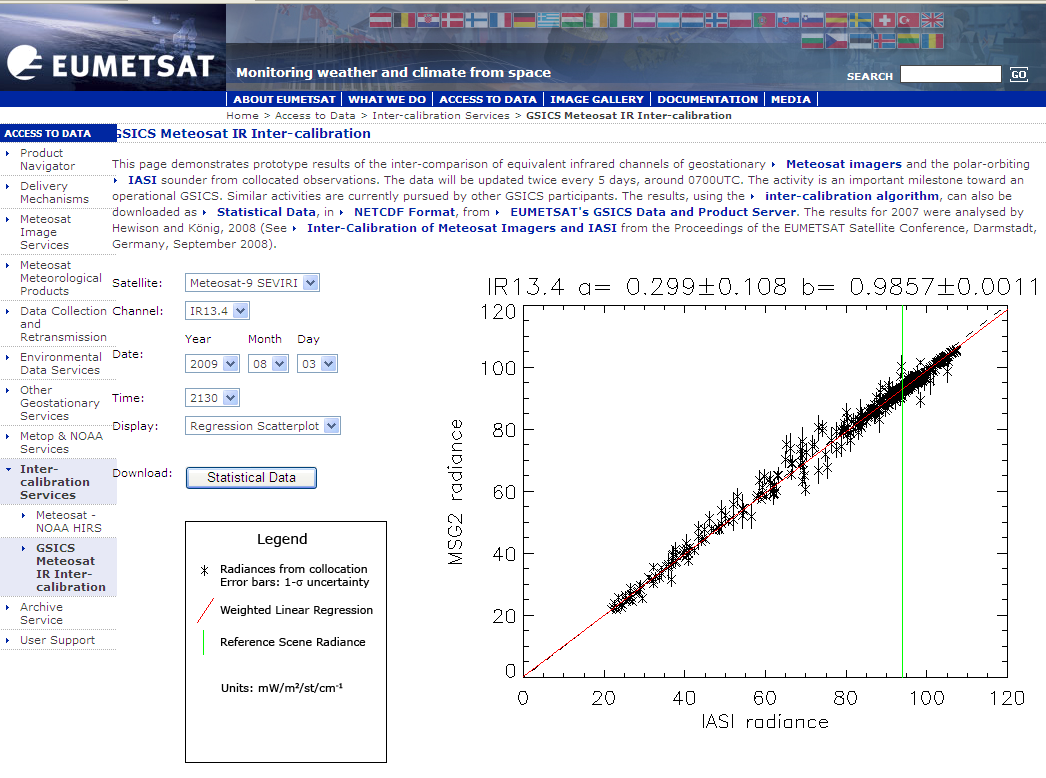
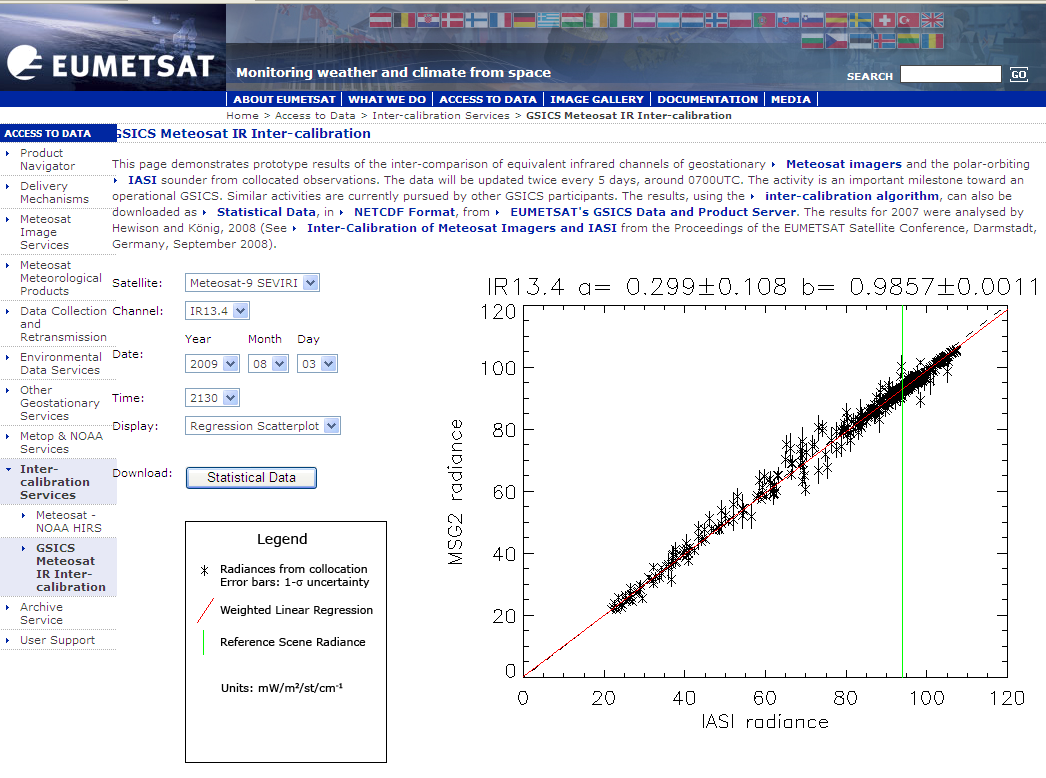
Figure 1: Illustration of spatial transformation.

Small circles represent the GEO FoVs and the two large circles represent the LEO FoV for the extreme cases of FY2-IASI, where *n*x*m*=3x3 and SEVIRI-IASI, where *n*x*m*=5x5.

* ***Transformation:*** collocated data are transformed to allow their direct comparison. This includes modifying the spectral, temporal and spatial characteristics of the observations, which requires knowledge of the instruments’ characteristics. The corresponding channels of the two instruments must contain common information to allow meaningful inter-calibration. These are then transformed into comparable pseudo channels, accounting for the deficiencies in spectral matches. The observations from each instrument are transformed to comparable spatial scales, and the pixels identified as being within the *target* and *environment* areas are averaged. The uncertainty due to spatial variability is estimated. The possible small timing difference between instruments’ observations is established and the uncertainty of the comparison is estimated based on (expected or observed) variability over this timescale. The outputs of this step are the best estimates of the channel radiances, together with estimates of their uncertainty.

Figure 2: Example radiance spectra measured by IASI (black) and modeled by LBLRTM (grey), convolved with the Spectral Response Functions of SEVIRI channels 3-11 from right to left (colored shaded areas).   
N.B.: The IASI observations (645 – 2760 cm-1) do not quite cover the full spectrum observed by SEVIRI.

* **Filtering**: if relevant, the data can be filtered to remove certain data that should not be analyzed (quality control), and to add auxiliary data that will improve further analysis. For example to reduce uncertainty due to spatial/temporal mismatches in the comparison, the collocation dataset may be filtered to only compare observations in homogenous scenes. “Outliers” may be rejected on a statistical basis. It may be useful to incorporate for example land/sea/ice masks and/or cloud flags to better classify the results.
* ***Monitoring:*** This step includes the actual comparison of the collocated radiances produced in Steps 1-4, the production of statistics summarizing the results to be used in the Correcting step, and reporting any differences in a meaningful way. The monitoring step provides standard reference scene radiances at which instruments’ inter-calibration bias can be directly compared and conveniently expressed in units understandable by the users. Regression coefficients for the compared radiances (or counts, or brightness temperatures) are calculated. These regressions allow visualization of scatterplots, as well as investigation of possible dependences on various geophysical variables. Inter-instrument biases are evaluated at standard radiances, and compared to previous values in order to establish the trend and to alert on any sudden change in calibration.
* ***Correction:*** This final step of the algorithm is to calculate the GSICS Correction, allowing the calibration of one instrument’s observed data to be modified to become consistent with that of the reference instrument. The exact form of the GSICS Correction is instrument specific.



*x*REF

*x*MON

GSICS Correction function

Some illustration needed

Masks, flags, …

SRFs, PSFs, …

**2. Collocating**

**3. Transforming**

**4. Filtering**

**6. Correcting**

**GSICS Correction**

Archive ~1 month

Archive ~1 month

Archive ~ 1 year

Archive ~ 1 year

Correction Coeffs

Analysis Data

Comparison Data

Collocated Data

Subset MON Data

Subset REF Data

MON Lvl 1 Data

Re-Cal Data

Plots and Tables

**1. Subsetting**

Orbital Prediction

Colloc. Criteria

MON Level 1 Data

REF Level 1 Data

Reports

**5. Monitoring**

**7. Diagnosing**

**Collocation**

**Transformation**

**Analysis**

**Products**

Figure XX1: Diagram of generic data flow for inter-calibration of monitored (MON) instrument with respect to reference (REF) instrument

### Specific considerations applicable to Solar channel calibration (if any)

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Some text ?

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….

### Specific considerations for Microwave channel calibration (if relevant)

….….

…..

Some text ?

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….

### Anything about double-differences with GEO or with NWP (if relevant?)

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Some text ?

### Anything about bias removal by matching overlapping series (?)

…

Some text ?

…

## GSICS product overview

### Product categories

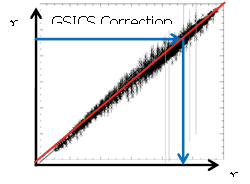
GSICS products are referenced in the on-line [Product Catalogue](http://www.star.nesdis.noaa.gov/smcd/GCC/ProductCatalog.php) maintained by the GSICS Coordination Center (GCC). The products fall into the broad categories listed in Table 1 depending on the spectral domain (Solar channels, Infrared, Microwave), the orbit type (GEO, LEO) and the temporal approach (near real-time, retrospective, or recalibration).

TABLE 1: GSICS Product Categories (to be updated !)

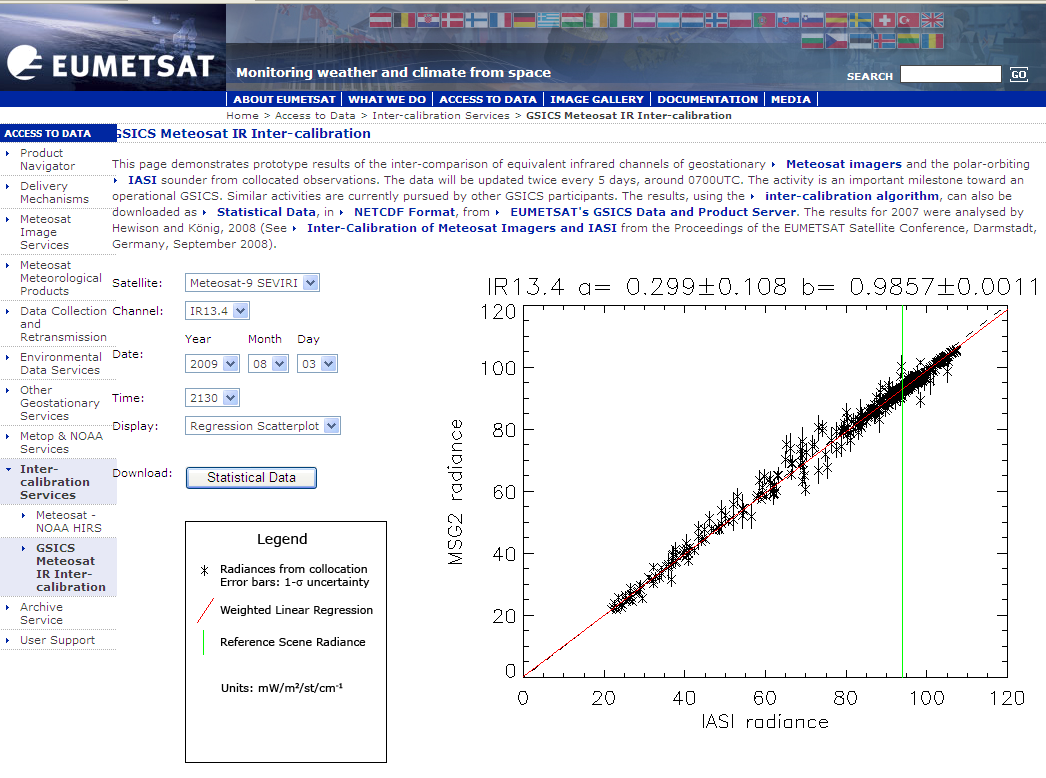
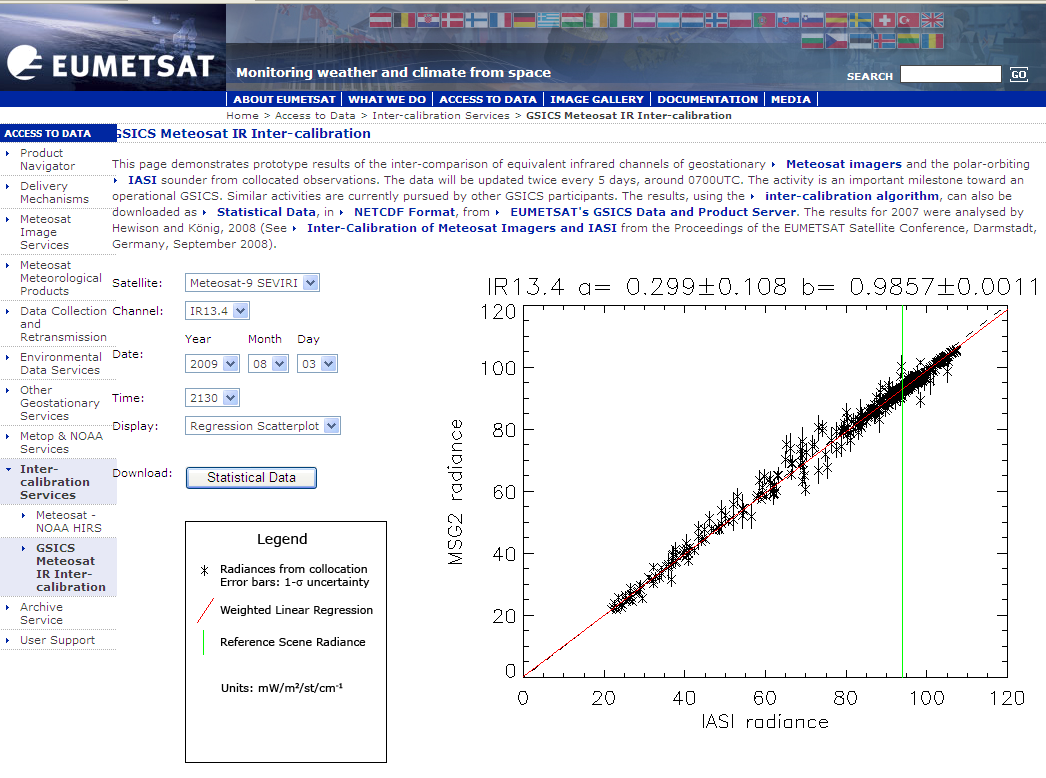
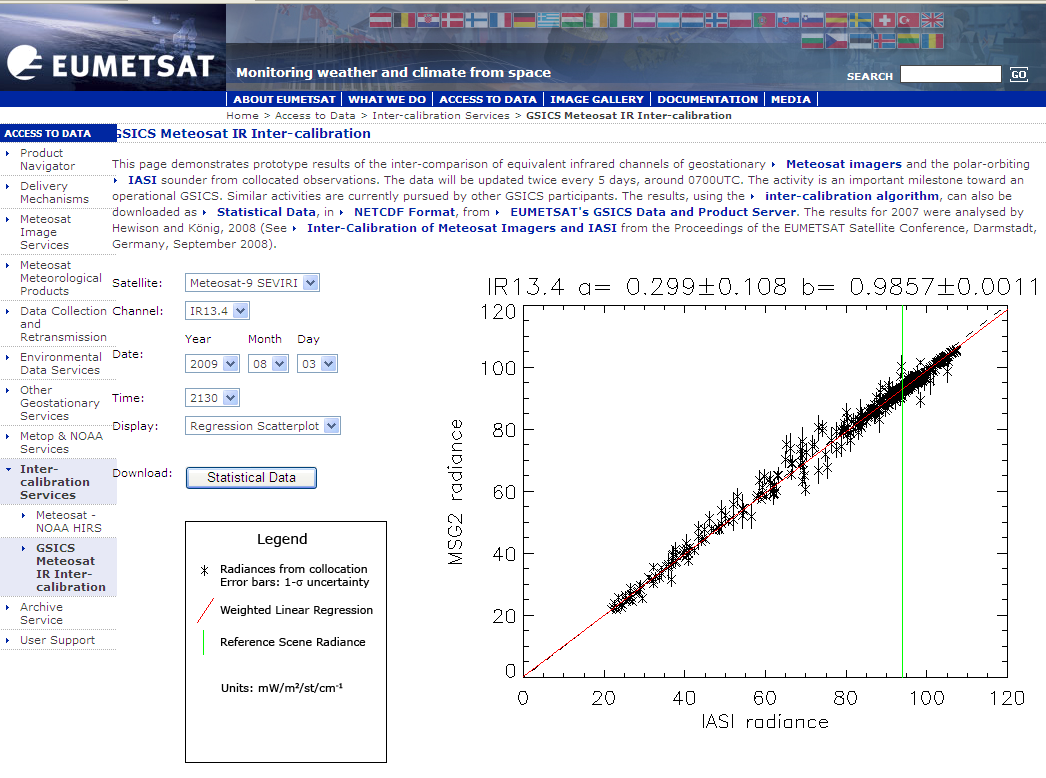
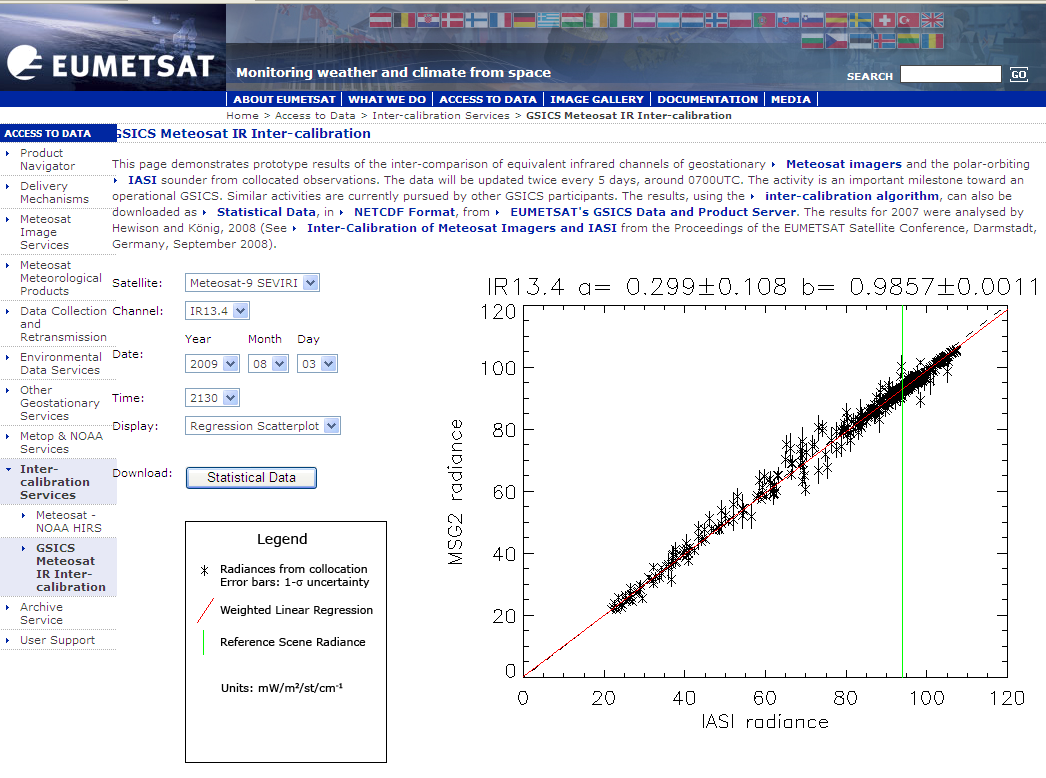
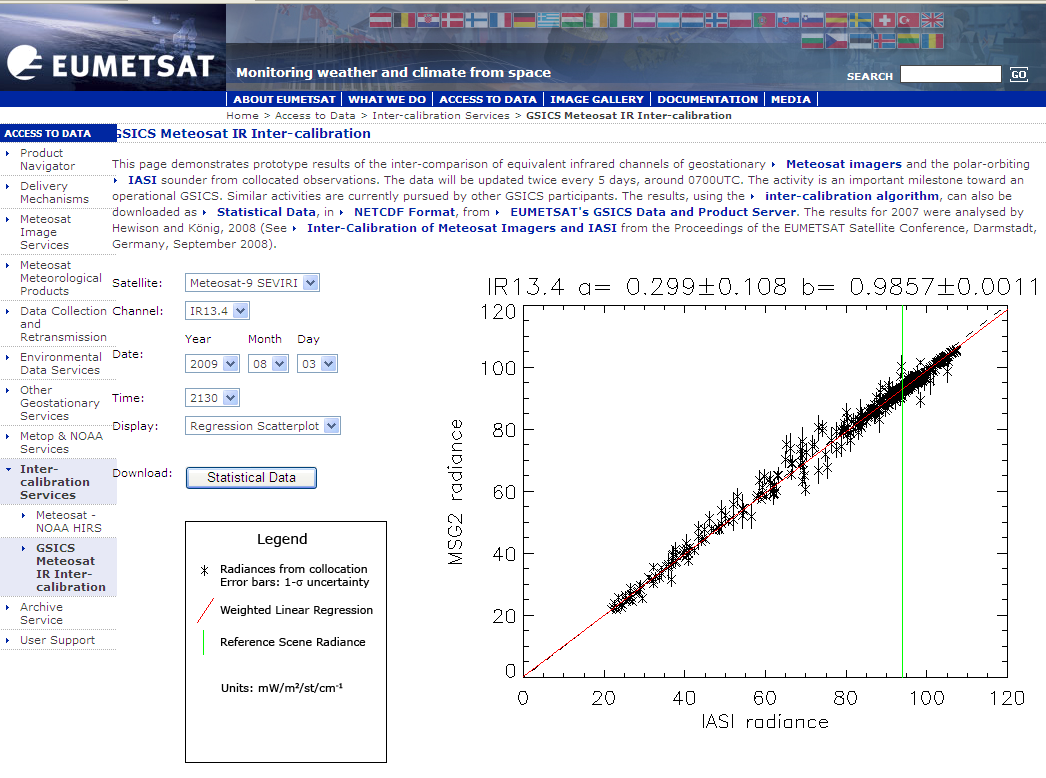
|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | |  |  | NRT correction | Retrospective correction | Recalibration algorithm |
| Orbit type of the monitored instrument | | Orbit type of the reference instrument | | Spectral Domain |
| GEO - LEO | | | | IR |  |  |  |
| GEO - LEO | | | | VIS |  |  |  |
| GEO – LEO | | | | UV |  |  |  |
| GEO - GEO | | | | IR |  |  |  |
| GEO - LEO | | | | IR |  |  |  |
| GEO - LEO | | | | VIS |  |  |  |
| LEO - LEO | | | | MW |  |  |  |
| LEO – LEO | | | | UV |  |  |  |

### Difference between Near Real-Time and retrospective products

* Near real-time products are calculated over a time window including the latest measurements.
* Retrospective analyses are calculated for measurements performed several days in the past, over a time window centered at the measurement.



We need some illustrations !



**Users**

*x*REF

*x*MON

### Algorithms for archive recalibration

The recalibration of historical datasets for the re-processing of climate data records requires a special approach. Because of the lack of fully compliant measurement reference, a selection must generally be made on the most acceptable instruments to be used as references taking into account their accuracy, stability, length of data record and time overlap with other sensors.

Special attention has to be paid to changes of instrument operating mode, changes of satellite status, and transition between recurrent instruments in a series.

Recalibration algorithms are validated by GSICS on a test period of a given duration [TBD] and tested furthermore on an instrument transition to get confidence in their robustness. It is then made available to climate users for the generation of Fundamental Climate Data Records or and /or Thematic Climate Data Records

….



Example of historical measurement reference standard (!)

### Summary characteristics of GSICS products

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Product type | Principle /Typical features | Averaging period | Product frequency | Product form | Access |
| LEO-GEO IR | Calibration adjustment of a GEO sensor based on comparison with a hyperspectral LEO sensor taken as reference, calculated daily by linear regression on all the occurrences of Simultaneous Nadir Observation over a period of 10 last days. The product is recalculated and refreshed at every orbit pass, | 10 days | 1 orbit pass | netCDF | ?? |
| GEO-LEO Visible | Calibration adjustment of a GEO sensor based on a comparison with a reference LEO spectrometer. The end result is a blend of methods optimized for each transfer target type (Moon, deep convective clouds, oceans, deserts, etc.). The use of pseudo invariant targets may not require the use of Simultaneous Nadir Observations. |  | Daily for NRT applications / TBD for retrospective analysis | NetCDF | ?? |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

## GSICS Services and Tools

### Access to GSICS products

Need here a full description of how to access GSICS products

### Data access and utilization tools

Collaborative tools and services have been developed and implemented in order to support data exchange, development and usage of GSICS deliverables:

* Collaboration Servers for the exchange of calibration dataset and GSICS product download;
* Bias plotting tool for the visualization of GSICS products hosted on the GSICS collaboration servers;
* GSICS product subscription service for the automated downloading of new products as they become available (*to be available in 2016*);

### Examples of utilization

…

…

…

### User information tools

GSICS User Services include:

* GSICS portal maintained by WMO ([http://gsics.wmo.int](http://gsics.wmo.int/) ) with high-level information on GSICS and links to the GCC website maintained by the GCC, and related websites maintained by each GPRC;
* GSICS User Messaging Service managed by the GCC;
* GSICS Quarterly newsletter distributed electronically to all registered users;
* GSICS User Workshop organized in conjunction with major satellite user conferences;
* GSICS wiki providing access to technical documentation such as the Algorithm Theoretical Baseline Documents (ATBD) of each product.

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# ANNEXES

## Annex 1: GSICS structure

WMO Members participate in GSICS through their satellite operating agencies and associated scientific and technical institutes. Participation in GSICS implies acceptance of the GSICS principles, practices and procedures. Details on accession to GSICS are provided in Annex 1.

GSICS Production and Research Centres (GPRC) are performing operational calibration, comparison and calibration adjustment of the instruments they are operating. They also contribute to GSICS research and development activities. The GSICS Calibration Support Segments (CSS) provide tools, calibration references, and contribute to development activities.

The GSICS Coordination Centre (GCC) coordinates the definition of GSICS products and services, it maintains a repository of GSICS practices, procedures and tools, it coordinates the acceptance procedure of new products and coordinates the exchange of information with the user community.

GSICS operates under the guidance of the GSICS Executive Panel composed of representatives designated by each participating organization. The WMO Secretariat serves as Secretary of the Panel. Representatives of partner organizations or potential future GSICS members can be invited to participate in the GSICS Executive Panel as Observers. The Executive Panel is advised by a Data Management Working Group (GDWG) and a Research Working Group (GRWG).

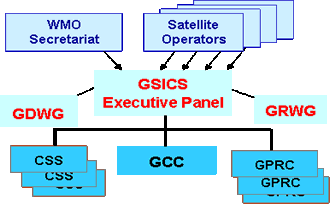


Figure 3: Structure of GSICS.

GSICS works in partnership with organizations pursuing complementary activities, such as the Committee on Earth Observation Satellites (CEOS) Working Group on Calibration Validation (WGCV), and organizations involved in the applications of calibrated data.

## Annex 2: Contacts

The GSICS Portal maintained by WMO: <http://gsics.wmo.int> contains links to the GCC, the GSICS Product Catalogue, the GSICS wiki and the GSICS websites of all the GSICS product and Research Centres (GPRC).

## Annex 3: Glossary

ATBD

BIPM

CEOS

CGMS

GCC

GDWG

GEO

GIRO

GLOD

GPPA

GPRC

GRWG

GSICS

GUMS

LBLRTM

LEO

PSF

RTM

SRF

WGCV

## Annex 4: References

Chander G., et al., Overview of Intercalibration of Satellite Instruments, IEEE TGRS

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1. Calibration: operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication (International vocabulary of metrology, BIPM, 2008) [↑](#footnote-ref-1)
2. Ohring G., Wielecki B., Spencer R., Emery B., Datla R., [Satellite instrument calibration for measuring global climate change](http://map.nasa.gov/documents/CLARREO/BAMSOhringetalSept2005SatelliteClimateCalib%5B3%5D.pdf), Bulletin of the American Meteorological Society, September 2005, p.1303-1313 [↑](#footnote-ref-2)