Global Space-based Inter-Calibration System

GLOBAL SPACE-BASED INTERCALIBRATION SYSTEM
EXECUTIVE PANEL

SIXTEENTH SESSION
BOULDER, CO, USA, 15-16 MAY 2015

FINAL REPORT

EXECUTIVE SUMMARY

At its sixteenth meeting, the Executive Panel (EP) noted the overall progress achieved by GSICS, after exactly ten years of existence. The GSICS community is gradually encompassing all CGMS Members; GSICS proves to be a great collaboration and capacity building opportunity; GSICS products are progressing in maturity. The practical value of GSICS was demonstrated in the role played to facilitate the commissioning operations of several satellite programmes in the most recent years. GSICS thus benefits both to satellite operators, through sharing of resources and best practices, and to satellite data users, through improved calibration, assessments, and traceability to common references.

The EP confirmed the need of updated GSICS Reference Documents to ensure that the role of GSICS is well understood and is recognized as an element of the WMO Integrated Global Observing System (WIGOS). It reviewed the broad lines of such Reference Documents and the roadmap for their completion. It stressed the need to document User Requirements.

The EP acknowledged the diversity of GSICS holdings and deliverables responding to the needs of satellite data users or satellite operators, including: calibration references and tools; standards and guidelines; monitoring results and assessments; intercalibration algorithms and products; and support services. The acceptance procedures should be adapted to each product category.

The EP stressed that GSICS should bring a key contribution to the Architecture for Climate Monitoring from Space in defining a calibration infrastructure and key processes to ensure seamless continuity and consistency of climate records.

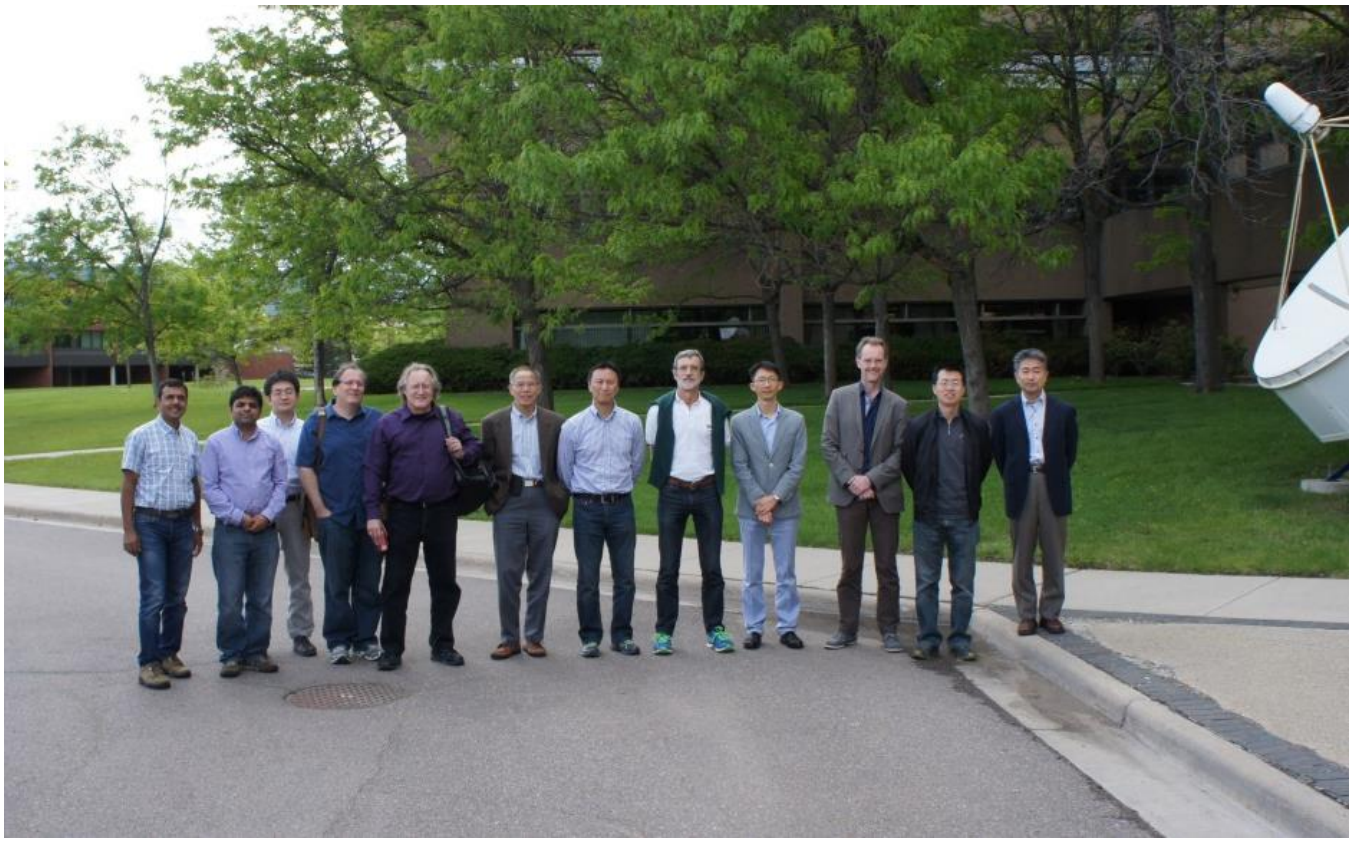
The EP welcomed the concept of “prime correction” and the proposed strategy to select and use calibration reference sensors. It highly appreciated the development of GIRO and supported the proposed approach to GIRO and GSICS Lunar Observation Dataset Usage Policy. It approved the principle of long-term preservation of “GSICS Reanalysis corrections” and collocation data. The Panel agreed that GSICS should aim to provide users with the most recently available calibration data, at the highest available update frequency, allowing users to decide to apply it at the same frequency or after filtering, depending on their own requirements.

The EP agreed updated Terms of Reference of the GSICS Research Working Group (GRWG) and the GSICS Data Management Working Group (GDWG). It designated Dohyeong Kim as new GRWG Chair, with Xiuqing (Scott) Hu and the outgoing Chair Tim Hewison as vice-chairs. Recalling the designation of Peng Zhang as EP Chair, Ken Holmlund as EP Vice-Chair, and Peter Miu and Masaya Takahashi as GDWG Co-chairs, it noted that there had been a complete turn-over of GSICS leadership since its creation, which is a sign of maturity.

In reviewing the progress made and the challenges to be faced, the Panel formulated following recommendations which were included in the GSICS report to CGMS:

- All satellite operators should participate in GSICS Working Groups, including GDWG (as a target, every member should plan a yearly contribution of at least one man-month);
- All satellite operators to evaluate their requirements for GSICS resources, products and services to serve the needs of their internal users;
- Procedures, best practices and calibration resources required to ensure the consistency of data records through accurate and homogeneous calibration should be defined by GSICS and CEOS WGCV as an input to the Architecture for Climate Monitoring from Space.
- Increased attention should be given to ground calibration sites;

- Consideration should be given to enhancing ground-based Moon observatories in order to reduce the absolute uncertainty of satellite instrument calibration by lunar observation.



*Participants in the GSICS-EP-16 meeting (from left to right)**:** Pradeep Thapliyal, Manik Bali, Masaya Takahashi, Mitch Goldberg, James Butler, Jack Xiong, Peter Miu, Jérôme Lafeuille, Dohyeong Kim, Kenneth Holmlund, Peng Zhang, Keiji Imaoka.*

MEETING REPORT

1. Opening of the meeting

The sixteenth session of the GSICS Executive Panel (EP) convened in the premises of the University Corporation of Atmospheric Research (UCAR) in Boulder, Colorado, United States of America. The meeting was held from 15 to 16 May 2015, in advance of the 43rd CGMS meeting. It was attended by representatives of CMA, EUMETSAT, ISRO, JAXA, JMA, KMA, NASA, NOAA, USGS (remotely) and WMO, as well as the GCC Director (remotely) and Deputy-Director, the GRWG Chair (remotely) and the two GDWG Co-chairs (See Annex 1).

Wendy Abshire, COMET Senior Program Manager/Meteorologist, welcomed the participants and introduced the training activities pursued by the COMET Programme.

Peng Zhang, Chair, welcomed the participants and introduced the agenda, which was approved (See Annex 2).

2. Chairman's report

P. Zhang summarized the status of GSICS, the main activities since EP-15, and introduced the main issues to be addressed and the decisions to be taken during the meeting (Doc 2).

3. Report from the GSICS Coordination Centre

Larry Flynn reported (remotely) on GCC activities (Doc. 3). The Panel noted the steady increase of GSICS registered users and the continuing success of the GSICS Quarterly. It welcomed the efforts made to strengthen the review process for the GSICS Procedure for Product Acceptance.

L. Flynn pointed out the need to clarify the ownership of GSICS results and give credit to the authors. The Panel recalled that EP-12 (EP-12 Final Report) had discussed this issue and agreed on a disclaimer and on an ownership clause: "*GSICS products are public and may be used and redistributed freely. Any publication using GSICS products should acknowledge both GSICS and the relevant data creator's organization*". This should be recalled, and reflected in the appropriate metadata entries, for all GSICS products and public deliverables.

> **Action 16.01:** GCC to recall in the GSICS Quarterly the disclaimer and the ownership clause applying to GSICS products and other deliverables.

Manik Bali asked for guidance regarding the promotion of GSICS in India, given the interest expressed by the India Institute for Science (IISc) to host a workshop.

- Recalling that GSICS activities in India are carried out by ISRO and IMD, the Panel recommended that GSICS outreach activity in India be conducted in close collaboration with ISRO or IMD, and be focused on the application of existing GSICS products. ISRO indicated its readiness to consider hosting a regional GSICS user workshop with IISc.

GCC provided an additional report as part of the NOAA agency report (item 9). It suggested that the Joint GDWG-GRWG meeting be renamed GCC-GDWG-GRWG meeting. The Panel declined this suggestion, which would be redundant since the GCC participates in GDWG and GRWG, like the GPRCs and WMO.

4. Report from GDWG

Peter Miu reported on GDWG activities (Doc. 4). He presented the comprehensive approach used by the GDWG Co-chairs to monitor the actions and to quantify the effort needed, which suggested a minimum yearly involvement of 30 man.day for each GPRC (40 man.day for the Chairs or Co-chairs). New developments are related to GSICS product generation framework, GSICS product templates, and format validation tools. Further actions will address code storage, event logging, GIRO-GLOD access (see item 13), subscription service, archiving strategy (See item12).

The Panel noted that a number of tools were designed to assist in the development of GSICS products by GSICS members. The question was raised whether these tools should also be made available to GSICS users, in addition to the GSICS products. The Panel appreciated that in some cases such tools can be useful for GSICS product users. However, making these tools available to the users could have implications on documentation, maintenance and support, which can go beyond the initial scope of the tools.

- Regarding the possible availability of GSICS software tools for external users, the Panel recommended clarifying on a case-by-case basis whether the driving requirements for these tools were internal or external, and the additional commitments that would result of making them available externally if they were initially required for internal use by GSICS developers.

5. Report from GRWG

Tim Hewison reported (remotely) on GRWG activities (Doc. 5), including the progress made through regular web meetings and at the joint working group meeting hosted by IMD in New-Delhi on 16-20 March 2015.

He highlighted that GEO-LEO IR products were now existing or in development from 6 GPRCs (EUMETSAT, NOAA, JMA, ISRO, CMA, KMA, no report being available from Roshydromet). For the first time, the infrared channels of the whole geostationary ring would thus soon be inter-calibrated against a common LEO reference. In addition, GEO-GEO comparisons, though restricted to a narrow strip and currently involving only broad-band comparisons, have the advantage of being possible at any time. A global comparison of all GEOs is being prepared. The Panel noted however that assumptions made for the evaluation of uncertainty (random component) in the GEO-LEO IR ATBD were found to be too optimistic and were being revised.

Good progress is being made on solar channel inter-calibration using both the Deep Convective Clouds (DCC) and the Moon as pseudo-invariant targets. It is planned to complete the development of lunar calibration in the first half of 2016, and then a merged calibration product involving the DCC and lunar methods. (See further discussion on lunar calibration in item 13)

The MW and UV subgroups are pursuing their activity in close collaboration with the CEOS WGCV.

The Joint Working Group had discussions on the nature of GSICS deliverables and recommended to categorize them as follows (this was further discussed under item 7):

- GSICS Tools for use by inter-calibration developers, (GIRO, SBAF, …)
- GSICS Products for users of satellite data, including calibration corrections/coefficients
- GSICS Algorithms, which describe inter-calibration processes, (described by ATBD)
- GSICS Documents, including Guidelines, Reports, …
- GSICS Recommended Standards, including e.g. reference solar spectrum.

It was not clear whether Spectral Response Functions (SRF) derived as a result of inter-calibration should be considered as GSICS products. This will be addressed at the 2015 User Workshop

Since T. Hewison had chaired GRWG for more than 5 years, the GRWG recommended a new GRWG Chair and Vice-chair, which was discussed by the Panel under agenda item 16.

T. Hewison also reported the outcome of GRWG discussions on the pros and cons of frequently updating the calibration corrections. Considering that calibration changes are partly driven by long-term instrument drift, the GRWG assumed that, for example, some users interested in long-term trends may want to apply frequent updates to the calibration corrections (which are thus expected to be small) in order to avoid large jumps in the calibration time series, while other users interested in near real-time applications may want to apply the updates less frequently (e.g. only when it exceeds a certain threshold) to avoid additional calibration noise. The Panel underlined that it is good to take into account the expectations of different user groups but it would be very confusing if GSICS delivered different calibration information for the same instrument.

- The Panel agreed that GSICS should aim to provide users with the most recently available calibration data, at the highest available update frequency, allowing users to decide to apply it at the same frequency or after filtering, depending on their own requirements.

The Panel also noted that GRWG had taken an action to review the requirements and define the specifications of a GSICS inter-calibration product supporting the generation of FCDRs. At the moment there is an internal understanding that GSICS could deliver or endorse algorithms used to generate FCDR series, but this should be formalized. The GCC recalled that the AMSU/MSU FCDR ATBD from Cheng-Zhi Zou underwent stringent review and had been recommended by reviewers, as reported at EP-15. It uses inter-comparison algorithms (as documented in the ATBD) which are similar to GSICS baseline SNO algorithms; in addition, it includes corrected radiances. This discussion was continued under item 7.

6. Documenting GSICS as an element of WIGOS

Jérôme Lafeuille presented Doc. 6.1 advocating the need for GSICS to develop a set of reference documents, in order to be visible, understood, used, and acknowledged as a building block of the WMO Integrated Global Observing System (WIGOS). He recalled the major achievements of GSICS to-date in terms of methodology, products, outreach, and the growing audience of registered users and workshop participants. Nevertheless, upon its tenth anniversary, GSICS has not yet reached a totally mature stage if we consider that no product is yet “operational”, and that GSICS is still referred to in WMO as an “initiative” rather than an established system. Besides the work needed to bring GSICS products to the “operational” stage, the status of GSICS itself must be solidified and documented.

J. Lafeuille recalled that the new “Manual on WIGOS”, in its chapter 4 on satellite observations, requests that calibration be performed along GSICS standards. This drives the need to define GSICS and its standards in the WIGOS world. A set of reference documents should be available and replace the 10-year old “GSICS Implementation Plan” which addresses the early implementation. J. Lafeuille proposed a document template and a draft Documentation Plan, which would include the following reference documents to be endorsed by the EP:

- GSICS Functions and Organization, to inform decision makers of WMO Members on the functions that GSICS is trying to accomplish, and how it is structured;
- GSICS User Requirements, listing the requirements, expressed by identified user groups, that GSICS agrees to address, and how the proposed functions and activities are articulated with these requirements;
- GSICS Vision, providing a prospective view on the scope and activity of GSICS;

- GSICS User Guide, providing the users with a general overview of the range of GSICS products and other available deliverables, and how they can be used;
- GSICS Documentation Plan listing the main categories of documents produced by GSICS, their scope, and suggested responsibilities for maintaining and for approving them.

J. Lafeuille proposed a draft GSICS Functions and Organization, an update of the existing GSICS Vision, and draft outlines of the GSICS User Guide and GSICS User Requirements. He noted that a revised template might be proposed by GCC as part of a future GSICS documentation procedure.

He further suggested replacing "*space-based* inter-calibration" by "*satellite* inter-calibration" in the name of GSICS. One could argue that in the expression "space-based inter-calibration system" the word "space-based" qualifies the system as being based in space, which is too restrictive in the case of GSICS which also includes surface-based targets. In the expression "satellite inter-calibration system", however, the noun "satellite" is the object of the calibration, which is correct: GSICS is a system performing the inter-calibration of satellites[1]. The Panel however did not support the naming change.

The Panel acknowledged the effort made to outline and draft such documents and agreed that a set of Reference Documents should be developed along these lines. There should be a clear hierarchy in these reference documents, with a high-level, primary document calling for the others.

The Panel agreed that the "GSICS Functions and Organization" is a good starting point to become the primary GSICS document, and ultimately replace the GSICS Implementation Plan, subject to revisions including: consider a more attractive title; recall the motivation for GSICS at the beginning of the document; align Sections 3 and 5 with the outcomes of EP-16 discussions of item 7 and 10; keep Section 7 (Calibration references) more general, while introducing the concept of prime reference; keep Section 8 (Production) short and high-level, since the products shall be described in the GSICS User Guide and the respective Product User Guides; insert a diagram of document hierarchy in Section 11 (GSICS Reference Documents); provide annexes 3, 4 and 5 (Terms of Reference) as a separate document.

Some editorial amendments to the GSICS Vision document were agreed.

Action 16.02: WMO (J. Lafeuille) to publish the updated version of the GSICS Vision. (Done: The Vision is published here.)

Action 16.03: WMO to revise the draft GSICS Functions and Organization document as recommended by EP-16 and submit it to the EP for approval.

Action 16.04: WMO to communicate the GSICS Function and Organization document, after finalization and approval, to the WIGOS Project Office for consideration by the Inter-Commission Coordination Group on WIGOS (ICG-WIGOS).

Action 16.05: GCC and WMO, in consultation with GRWG and GDWG, to complete a draft GSICS User Guide, for consideration by EP-17.

7. Definition of GSICS products

Larry Flynn presented an overview of the various outputs of GSICS activities (Doc. 7). He underlined the high diversity of these outputs, which include:

- Level 1 adjustments and corrections, by different methods;

[1] Note: There is no such difficulty with the expression "space-based observing system", which is correct since this observing system is indeed based in space, whereas "satellite observing system" would be ambiguous since it could mean a system observing the satellites…

- Satellite and instrument characteristics provided in databases;
- Support to production of FCDRs;
- Calibration references (spectrum, reflectance or emissivity for Solar, Lunar, cloud/ ground targets)
- Tools (SNO identifier, Display Graphics, Communication, Notification …)
- Documents (Journal articles, ATBDs, Users' manuals)
- Traceability studies (calibration uncertainty, Radiative Transfer Model error analysis, etc).

He stressed that instrument performance monitoring was encompassing various methods and addressing different components of instrument characterization, which should not be limited to a correction of calibration coefficients. He highlighted that calibration adjustments were a critical step in the creation of a Fundamental Climate Data records (FCDRs), and that the FCDR developer would benefit of a GSICS review of the algorithms and uncertainty studies underlying FCDR generation. In particular, the expertise developed within GSICS on the traceability of calibration references and the comparison of consecutive references is highly relevant for the generation of FCDR which requires long-term stability. Should the calibration adjustments and/or algorithms used for FCDR be considered as GSICS products?

He pointed out that the GSICS Procedure for Product Acceptance (GPPA) is designed for classical GSICS products (routine production of Level 1 calibration adjustments) but asked what would be the appropriate review or acceptance mechanisms for the other types of GSICS deliverables or resources shared with GSICS users, and what should be the policy for hosting, reviewing and approving documents.

The Panel agreed that the diversity of GSICS outputs was not limited to the "GSICS corrections" and that the review/acceptance mechanism should be adapted to the type of deliverable. The Panel recommended a distinction between GSICS holdings (which are not originated by GSICS but which GSICS can provide access to) and GSICS deliverables (produced by GSICS, or with significant value added by GSICS). It considered that a high-level categorization of GSICS holdings and deliverables was needed to provide visibility on what GSICS is delivering, for whom, and on the applicable review/acceptance mechanisms (for example: GPPA, GRWG/GDWG endorsement, EP approval, or simple approval by GCC or GPRC). Based on this discussion the Panel recommended a categorization (See Table 1), to be refined by GCC and the working groups.

Table 1: Proposed categorization of GSICS holdings and deliverables

	Holdings or Deliverables	Review/ acceptance	Target audience	Examples
Resources	Calibration references and databases		GSICS developers	GIRO lunar model, ground sites Solar irradiance spectrum
	Software and hardware tools			Plotting tool, THREDDS servers, product generation environment, wiki
	Standards, conventions, guidelines & procedures			Formats, metadata template, file naming convention, GPPA, doc procedure
Products	Analysis, monitoring results, assessments		GSICS users and GSICS developers	Corrected SRF; bias assessment, non-linearity, polarization sensitivity; traceability studies
	Calibration methodologies	GPPA (subset TBD)		ATBD for NRT correction, delayed correction, or re-calibration
	Routine operational corrections of L1 data	GPPA		Near Real Time or delayed corrections applying the method above on a routine basis
Service	Information on GSICS &			Science publications, GSICS Quarterly,

	calibration		GSICS users	Outreach material, websites
	Online services			User registration, product subscription,

The Panel recalled Action 15.04 from GSICS-EP-15 requesting "GCC to prepare, in consultation with GRWG and GDWG, an updated description of GSICS products, indicating how users can access and use these products, to be submitted to the EP for endorsement." This action was closed and replaced by an updated action as follows:

> **Action 16.06:** (a) GCC to finalize the high-level categorization of GSICS holdings and deliverables, ensuring that actual or planned products can be mapped to these categories, indicating a target audience, delivery or access mode;
> (b) GCC to propose appropriate review/acceptance mechanisms for each category of GSICS products (with a distinction between acceptance of the algorithms, and acceptance of the production of calibration coefficients or calibrated radiances).

8. Promotion of products to pre-operational or operational stage

The GCC reported (Doc. 8) on the overall status of GSICS correction products with reference to the GPPA. No product was proposed to the pre-operational or operational stage (See Table 2).

Table 2: Status of GSICS correction products with reference to the GPPA phases

Submission Phase	1 ISRO product *(GEO-LEO IR)* *(KMA, CMA, in preparation)*
⇩	
Demonstration Phase	4 EUMETSAT products *(GEO-LEO IR)* 17 NOAA products *(2 GEO-LEO IR, 15 LEO-LEO VIS)* 6 JMA products *(GEO-LEO IR)*
⇩	
Pre-operational phase	4 NOAA products *(GEO-LEO IR)* 4 EUMETSAT products *(GEO-LEO IR)*
⇩	
Operational Phase	None

The Panel noted that some products were left at the demonstration stage because the relevant GPRC does not have the resource to complete the application, or in the case of NOAA LEO-LEO/VIS re-calibration products, because there was no user requirement for routine dissemination of re-calibration product. This confirmed the need to review the acceptance procedure with respect to the categories of products, making a distinction between the validation of a methodology and the commitment to generate and disseminate corrections on a NRT basis.

9. Update from GSICS Members and observers

GSICS member and observer agencies provided brief reports on their overall satellite plans, their participation in GSICS working groups, the status of products submitted to the GPPA and related issues, highlights of calibration activities, and in some cases the feedback collected from GSICS users. The following reports are available on-line:

- CMA (ZHANG Peng)
- EUMETSAT (Ken Holmlund)
- ISRO (Pradeep Thapliyal)
- JAXA (Keiji Imaoka)
- JMA (Masaya Takahashi)
- KMA (Dohyeong Kim)
- NASA (Jim Butler)
- NOAA (Mitch Goldberg)
- USGS (G. Stensaas and Ron Morfitt)
- CNSA (GAO Jun, represented by Peng Zhang)

The Panel welcomed these very informative briefings, which were noted for further reference. It noted in particular:

- an issue raised by CMA about the choice of a MW calibration reference (reference imager, sounder, and/or RTM).

- several products being in development;

- the fact that GSICS methodology for instrument monitoring and comparisons have proved to be critically helpful in the commissioning phase of several satellites (Himawari-8, FY-2G, FY-3C, INSAT-3D) and in monitoring the degradation of operational sensors. It highlights the benefit of GSICS to the participating agencies;

- a lunar calibration project of CMA in 2015-2017;

- preliminary internal or external user requirements and feedback reported by agencies.

10. GSICS in the Architecture for Climate Monitoring from Space

J. Lafeuille introduced Doc. 10 as a basis for discussion on the role of GSICS in climate monitoring. He recalled that the Strategy towards an Architecture for Climate Monitoring from Space refers to four “pillars”: (i) the sensing level, which is largely inter-disciplinary; (ii) the creation of climate data record; (iii) the processing of these records for climate applications and ultimately (iv) their use in decision making. The CEOS-CGMS Working Group on climate is focusing its activity on the ECV inventory, to assess how existing data are actually used or planned to be used, which relates to “Pillar 2”. J. Lafeuille pointed out that little attention was paid to “Pillar 1” and that GSICS was in a position to provide a useful input to this aspect of the Architecture concept in defining implementation principles to ensure measurement consistency through calibration and traceability.

The Panel agreed that, in addition to the ECV inventory which provides an evaluation a posteriori, the sensing level (Pillar 1) of the Architecture should be evaluated, since it drives the future capability to generate ECV records in the following decades. The Architecture should include a high-level coordination of missions and sensors plans, at the sensing level, as well as implementation principles to ensure seamless continuity to support FCDRs, e.g.: continuous availability, comparability of new missions with heritage sensors, measurement consistency & traceability.

In this respect, the GSICS EP recommended the following elements to be included as building blocks of the Architecture:

- Calibration infrastructure to be implemented and shared among satellite operators:
  a) In-orbit references for traceability
  b) Ground-based calibration sites
  c) Databases and software tools
- Calibration processes to be implemented by each satellite operator:
  d) Best practices for pre-launch calibration
  e) Procedures for in-orbit calibration with uncertainty estimation
  f) Procedures for in-orbit comparison and inter-calibration
  g) Procedures for vicarious calibration with ground targets
  h) Algorithms/tools for re-calibration of archived data
  i) Communication and capacity building.

The Panel recommended the following way forward:

- to pursue the effort of documenting GSICS as a building block of WIGOS;

- to provide input to the WMO Vision of the space-based observing system in 2040 in order to ensure that calibration issues are included in this Vision;

- to analyse the user requirements of climate applications represented by GCOS;

- to work on a joint statement with CEOS/WGCV defining the procedures, best practices and calibration resources required to ensure consistency of data records through accurate and homogeneous calibration, along the lines of (a) to (i) above, as an input to the Architecture for Climate Monitoring from Space.

Action 16.07: The EP Chair or Vice-chair to bring the considerations on GSICS and climate monitoring to the attention of CGMS (Completed through: CGMS-43 WMO-WP-06)

Action 16.08: GRWG to review the calibration issues in the draft input to the WMO Vision of WIGOS space-based observing system in 2040 and report to the EP.

Action 16.09: The GRWG/EP Chairs to invite the CEOS WGCV to work on a joint statement on procedures, best practices and calibration resources required to ensure consistency of data records through accurate and homogeneous calibration, as an input to the Architecture for Climate Monitoring from Space

11. GSICS User Requirements

M. Bali and L. Flynn gave an overview of GSICS User Requirements (Doc. 11). They recalled that GSICS was motivated by the need to ensure consistent accuracy among space-based observations worldwide for climate monitoring, weather forecasting and environmental applications. Because of the diversity of satellites and instruments contributing to these observations, instruments must be monitored over time and compared with each other, including past and present sensors. In particular, decadal climate change detection has stringent requirements on the observation of geophysical variables, which can only be met with accurately calibrated L1 radiances.

They identified two broad categories of GSICS users: satellite operators, who strive to deliver the best possible Level 1 data, and Level 2+ product developers using these L1 radiances for particular products and applications. Some basic requirements relate to the way the service is delivered and are expected to be common to all users (clear information on how to use GSICS products, mature ATBD, scientific documentation, traceability, user manual, user support, access means, format, etc.). Other requirements relate to the definition of the products themselves and may be more application specific (corrected/uncorrected radiances, smoothing period, collocation data, sensor performance criteria, etc.).

J. Lafeuille commented that a general statement of needs and expected benefits is a good starting point to set the scene, but he suggested that GSICS user requirements should be more precise and traceable to identified requirements sources, i.e. statements or documents from representative users. Examples of such sources include: outcome of GSICS workshops, reports from GSICS beta-testers, requirements for GSICS by the GCOS-SC Chair (GSICS-EP-14), satellite instrument calibration for measuring global climate change (Ohring G. et al., BAMS, Sept 2005), GCOS Systematic observation requirements for satellite-based data products for climate (GCOS-154). For instance, GCOS-154 action C8 calls for "*Use of GSICS bias-corrected coefficients* and bias adjustment information from reanalysis".

It was clarified that the purpose should not be to record every wish list of potential users, but to provide a consolidated list of those requirements that GSICS intends to respond. This is why the GSICS User Requirements document should be developed in consultation with users, but endorsed by the Executive Panel. It is expected to be a living document.

In order to initiate this iterative process, three paths shall be pursued:

(i) an initial set of requirements could be formulated by GSICS users within the GSICS member community, including e.g. for SCOPE-CM pilot projects. The Panel recalled that the agency reports provided under agenda item 9 already contained preliminary indications of user requirements and feedback, which should be further investigated;

(ii) the GSICS User Workshop is a privileged opportunity to consult users on their requirements;

(iii) the implications of GCOS requirements should also be analyzed.

Action 16.10: All satellite operators to evaluate their requirements for GSICS resources, products and services to serve their internal users (NRT or climate applications such as SCOPE-CM projects): identify application areas, draft requirement indicating the characteristics of the product needed, quality criteria and delivery mode. Requirements shall be communicated to the GCC who will present a synthesis to the EP.

Action 16.11: GCC and GRWG Chair to organize a discussion on user requirements in the context of the 2015 GSICS User Workshop (Toulouse, 22 September 2015).

Action 16.12: GCC to analyse, in consultation with GCOS/AOPC, the implications of GCOS observation needs on GSICS products.

12. GSICS Archiving Strategy

Peter Miu introduced his proposal for GSICS Data Preservation Strategy (Doc. 12) whereby "data preservation" is understood as a way to ensure integrity, accessibility and usability of past data, but without prejudging the high-level of user services of a full archiving concept.

- The Panel agreed that an objective should be the preservation of the "GSICS Re-analysis Corrections" which are calculated everyday on a sliding temporal window, rather than the GSICS Near Real-Time Corrections, which are not used a posteriori.
- The Panel recommended that collocation data be also archived and preserved.
- To implement the preservation of GSICS re-analysis corrections, the Panel recommended the following principles:
    - Mirroring on the collaboration servers for all GSICS products.
    - Collaboration Server Administrators need to ensure high service availability and backup strategies are in place.
    - A requirement of GSICS products generation software is that they should be able to regenerate a version of the GSICS product.

Action 16.13: GDWG to define the format to be used for archiving collocation data.

13. GIRO and GSICS Lunar Observation Dataset Usage Policy

The Panel was informed on a draft policy for the usage of the GSICS Implementation of the ROLO model (GIRO) and of the GSICS Lunar Observation Database (GLOD) (Doc. 13). This policy was prepared in consultation with the participants in the lunar calibration workshop and interested members of the GRWG. The Panel thanked EUMETSAT for developing the GIRO in collaboration with USGS.

- The Panel supported the proposed approach to the use of GIRO and GLOD and invited EUMETSAT to finalize this draft policy and propose it to GSICS and CEOS WGCV members as the basis of agreements for the use of GIRO and GLOD.

The second lunar calibration workshop will be held in 2016, hosted by CMA.

14. Strategy for calibration references

Tim Hewison introduced the proposed strategy for calibration references (Doc.14). He recalled the principle of the "prime correction" whereby the monitored instrument reading is corrected by comparison with a primary reference by two ways: (i) by direct comparison with the primary reference, and (ii) by comparison with a secondary reference which is compared to the primary reference. This approach provides a way forward to ensure stability in spite of the changes of reference instruments.

He reported on-going efforts to determine criteria for the selection of the most appropriate reference sensors, which could eventually be used for a "gap analysis" of references by using OSCAR/Space.

He finally reported on lunar calibration activities, including the outcome of the lunar calibration workshop (December 2014), the implementation of GIRO and the compilation of a GLOD. It is planned to develop inter-calibration algorithms for VIS channels, using the moon as a pseudo-invariant target. Subsequently, the method would be combined with the DCC method.

The main limitation of this approach is currently the poor accuracy of ground-based measurement of the moon's reflectance, which prevents using the moon for a good absolute calibration. This is a case for recommending an extensive campaign of hyperspectral lunar observations to acquire a high-quality, representative dataset. This was explained in Doc. 14.2 provided by USGS.

- The Panel recommended giving consideration to enhancing ground-based Moon observatories, at least for a 3-year campaign, in order to reduce the absolute uncertainty of satellite instrument calibration by lunar observation.

15. Review of the Terms of Reference

The Panel reviewed the Annexes 2, 3, 4, and 5 of Doc. 6.1, containing an updated description of the role of the GCC as well as the Terms of Reference of EP, GDWG and GRWG, which had been updated as agreed in inter-sessional discussions.

These updates were agreed, with an amendment to the GDWG and GRWG ToRs which should read: “It is expected that GRWG (or GRWG) members will contribute GRWG (or GRWG) activities at the level of at least one man month per year”. Furthermore, the last paragraph of the Role of GRWG Chair should be deleted.

Action 16.14: WMO to publish the updated Terms of Reference. (Note: published here)

16. Nomination of Working Group Chair/Vice-Chairs

The Panel unanimously elected Dohyeong Kim to replace Tim Hewison as Chair of GRWG. The Panel thanked Tim for his great contribution in leading the GRWG for 6 years. As the outgoing Chair, Tim will serve as GRWG Vice-Chair in replacement of Fred Wu who had been the first GRWG Chair before serving as Vice-Chair. The Panel also nominated Xiuqing (Scott) Hu as the second Vice-Chair of GRWG.

17. GSICS operations plan: Guidance to GCC, GDWG and GRWG

The plans for GCC, GDWG and GRWG have been reviewed under item 3, 4, and 5.
No further comment was made.

18. Draft report to CGMS

The Panel agreed that the report to CGMS should recall the achievements of GSICS, its increasing maturity upon its tenth anniversary and emphasize the benefits to satellite data users – through improved data quality - as well as to the GSICS member agencies themselves, through the sharing of resources, tools, results, and best practices. The report (CGMS-43 WMO-WP-16) will also indicate current challenges and summarize the recommendations coming out of this meeting. (Note: the report is available as a presentation and document)

19. Outstanding actions from previous meetings

A summary status of actions was provided in Doc. 20. A number of actions had been completed at the meeting and were closed. A few other old outstanding actions which were no longer relevant were closed. An updated status of outstanding actions is contained in Annex 3. Progress on these outstanding actions shall be reviewed at forthcoming web meetings.

20. Other issues raised by the Working Groups or EP members

No additional point was raised.

21. Summary of actions and conclusions

The Chairman summarized the achievements of the meeting and recalled the agreed recommendations and actions. The list of new actions from this meeting is provided in Annex 4. Other key decisions and recommendations are listed in Annex 5.

ANNEX 1: LIST OF PARTICIPANTS

SIXTEENTH MEETING OF THE GSICS EXECUTIVE PANEL
Boulder, CO, USA, 15-16 May 2015

INSTITUTION	FIRST NAME	LAST NAME	Status
CMA	Peng	Zhang	Chair (Incoming)
EUMETSAT	Kenneth	Holmlund	Member
EUMETSAT	Peter	Miu	GDWG Co-Chair
ISRO	Pradeep	Thapliyal	Representing A.S.Kiran Kumar
JAXA	Keiji	Imaoka	Member
JMA	Masaya	Takahashi	Representing JMA, GDWG Co-Chair
KMA	Dohyeong	Kim	Member
NASA	James	Butler	Member
NASA	Jack	Xiong	NASA adviser
NOAA	Mitch	Goldberg	Member
NOAA	Manik	Bali	GCC Deputy Director
WMO	Jerome	Lafeuille	Member, Secretariat
REMOTE PARTICIPANTS			
NOAA	Lawrence E.	Flynn	GCC Director
EUMETSAT	Tim	Hewison	GRWG Chair
USGS	Gregory L.	Stensaas	Member
USGS	Ron	Morfitt	Advisor

ANNEX 2: PROVISIONAL AGENDA

1. Opening of the meeting
2. Chairman's report (Zhang P.)
3. Report from the GSICS Coordination Centre (L. Flynn)
4. Report from GRWG (Tim Hewison)
5. Report from GDWG (Peter Miu)
6. Documenting GSICS as an element of WIGOS (J. Lafeuille)
7. Definition of GSICS products (Larry Flynn)
8. Promotion of products to pre-operational or operational stage (L. Flynn)
9. Update from GSICS Members and observers
    - CMA (ZHANG Peng.)
    - EUMETSAT (Ken Holmlund)
    - JAXA (Keiji Imaoka)
    - JMA (Masaya Takahashi)
    - KMA (Dohyeong Kim)
    - NOAA (Mitch Goldberg)
    - NASA (Jim Butler)
    - ISRO (Pradeep Thapliyal)
    - USGS (G. Stensaas)
    - CNSA (GAO Jun, presented by Peng Zhang)
10. GSICS in the Architecture for Climate Monitoring from Space (J. Lafeuille)
11. GSICS User Requirements (L. Flynn)
12. GSICS Archiving Strategy (P. Miu)
13. GIRO and GSICS Lunar Observation Dataset Usage Policy (K.Holmlund)
14. Strategy for calibration references (T. Hewison)
15. Review of the Terms of Reference (J. Lafeuille)
16. Nomination of Working Group Chair/Vice-Chairs (Zhang P.)
17. GSICS operations plan: Guidance to GCC, GDWG and GRWG
18. Draft report to CGMS – including Resource aspects
19. Outstanding actions from previous meetings (J. Lafeuille)
20. Other issues raised by the Working Groups or EP members
21. Summary of actions and conclusions (Zhang P.)

ANNEX 3: REVIEW OF OUTSTANDING ACTIONS FROM PREVIOUS MEETINGS

Reference	Action content	Due date	Status 1 July 2015
Action EP-15.01	GCC to register the GSICS catalogue as a service in the WMO Information System (WIS), to ensure it is discoverable in the WIS.		Open
Action EP-15.02	every GPRC to nominate at least one representative on the GDWG		Open
Action EP-15.03	GCC and WMO Secretariat to coordinate with a view to send a letter of recognition from WMO to acknowledge significant personal contributions to GSICS.		Open The GCC is taking steps to identify the significant contributions
Action EP-15.04	GCC to prepare, in consultation with GRWG and GDWG, an updated description of GSICS products, indicating how users can access and use these products, to be submitted to the EP for endorsement.		Closed. Replaced by Action EP-16.06
Action EP-15W.01	WMO to finalize the updated GCC ToR		Completed (Posted here)
Action EP-15W.02	Edit the GRWG and GDWG Chair's Roles to avoid duplication with the respective ToR		Completed (Posted here)
Action EP-15W.03	Review and amend the GDWG ToR if necessary to better reflect some activities (catalogue, servers, format implementation, visualization tools) and the strong link with GCC		Completed (Posted here)
Action EP-15W.04	All EP members to seek greater support from their agency to GSICS and to consider a candidate for GRWG chairmanship.		Completed Dohyeong Kim appointed new GRWG Chair
Action EP-15W.055	GSICS Report to CGMS and Working Paper will include request for minimum engagement of members (e.g. 20 day/year)		Completed (WMO-WP-16)
Action EP-15W.06	Jerome to investigate possibility of WMO funding travel from WG chairs to attend annual meetings, and sending a letter expressing WMO's commitment for GSICS and calling for engagement of GSICS member agencies		Partly completed Mission of one GDWG co-chair was supported by WMO
EP-14.01	GCC, GDWG and GRWG to evaluate the relevance and implications of adding "calibration alert system" and "SNO and GEO-LEO collocation data" to the GSICS portfolio, and report to the Executive Panel.	EP-17	Open
EP-14.02	WMO (W. Zhang) to write to all GSICS participating agencies to communicate the importance of the data management aspects to enable GSICS to reach a fully operational maturity level.	Oct 2013	Closed Point was made at CGMS-43

EP-14.06	Roshydromet to contact the GCC (Larry Flynn, Lawrence.E.Flynn@noaa.gov) for assistance on implementing the GSICS method for Electro-L/MSU-GS GEO-to-LEO IR intercalibration.	Sept 2013	Closed Initial contact was made.
EP-14.08	NASA to present a paper about maturity levels of instrument calibration in support of re-processing, taking MODIS as an example, at a future web meeting of the Executive Panel	Oct 2015	Open Action still under consideration by NASA
EP-14.15	The Chair (Mitch Goldberg) will discuss with NIST (Eric Shirley) to review the status and need of developing a draft vocabulary, as part of a guide on uncertainty for GSICS.	Sept 2013	Closed
EP-14.16	NASA to develop a list of data that need to be produced during the pre-launch instrument characterization; this list shall be appended to the guidelines on best practice for pre-launch characterization.	Oct 2015	Open Action still under consideration by NASA
Action EP-12.03	EUMETSAT, NOAA and JMA are urged to complete the necessary steps to submit their LEO-GEO IR product to the GPPA for pre-operational status in advance of the fourth GSICS Users' Workshop and WMO CBS.	2012-09-01	Closed. Completed by NOAA, EUMETSAT. Remains an objective for all GEO operators.
Action EP-12.05	Each GPRC to consider implementing the near real time distribution of both the operational calibration information and the corrected calibration information, as part of the L1 data formats.	EP-15	Closed (To be further considered if confirmed by user requirements)
Action EP-12.22	GDWG and EUMETSAT/CDWG to define a controlled vocabulary for instruments events	2012	Closed (taken up by GDWG 2015.4l2)
Action EP-10.01	IMD (A.K. Sharma) with the assistance of GCC (Fangfang Yu) to get hold of the technical information on the GSICS Correction ATBD for GEO-LEO Infrared channels, and implement it for Kalpana.	2012	Closed
Action EP-10.13	NASA to designate an expert from the NASA/JPL AIRS team to participate in GRWG activities on traceability.		Completed. Tom Pagano was designated
Action EP-10.18	NOAA (Mitch Goldberg) and EUMETSAT (Tim Hewison) to liaise with the SCOPE-CM Pilot Projects (1), (3) and (5) respectively, in order to better understand their needs and facilitate the finalization of the Statement of Needs.	2012-08-31	Closed Will be addressed as part of the user requirement collection process Action EP-16.10.
Action EP-09.01	ISRO and the GCC to coordinate for the implementation of GEO-to-LEO algorithms by ISRO (contact Fred Wu, Fangfang Yu on NOAA side)	2012	Completed

ANNEX 4: LIST OF NEW ACTIONS

Action 16.01: GCC to recall in the GSICS Quarterly the disclaimer and the ownership clause applying to GSICS products and other deliverables.
Action 16.02: WMO (J. Lafeuille) to publish the updated version of the GSICS Vision. (Completed: The Vision is published here.)
Action 16.03: WMO to revise the draft GSICS Functions and Organization document as recommended by EP-16 and submit it to the EP for approval (30 Nov 2015)
Action 16.04: WMO to communicate the GSICS Function and Organization document, after finalization and approval, to the WIGOS Project Office for consideration by the Inter-Commission Coordination Group on WIGOS (ICG-WIGOS). (January 2016)
Action 16.05: GCC and WMO, in consultation with GRWG and GDWG, to complete a draft GSICS User Guide, for consideration by EP-17 (EP-17)
Action 16.06: (a) GCC to finalize the high-level categorization of GSICS holdings and deliverables, ensuring that actual or planned products can be mapped to these categories, indicating a target audience, delivery or access mode; (b) GCC to propose appropriate review/acceptance mechanisms for each category of GSICS products (with a distinction between acceptance of the algorithms, and acceptance of the production of calibration coefficients or calibrated radiances). (EP-17)
Action 16.07: The EP Chair or Vice-chair to bring the considerations on GSICS and climate monitoring to the attention of CGMS (Completed at CGMS-43).
Action 16.08: GRWG to review the calibration issues in the draft input to the WMO Vision of WIGOS space-based observing system in 2040 and report to the EP. (October 2015)
Action 16.09: The GRWG/EP Chairs to invite the CEOS WGCV to work on a joint statement on procedures, best practices and calibration resources required to ensure consistency of data records through accurate and homogeneous calibration, as an input to the Architecture for Climate Monitoring from Space. (September 2015)
Action 16.10: All satellite operators to evaluate their requirements for GSICS resources, products and services to serve the needs of their internal users (for NRT products or climate applications such as SCOPE-CM projects): identify application areas, draft requirement indicating the characteristics of the product needed, quality criteria and delivery mode. (January 2016)
Action 16.11: GCC and GRWG Chair to organize a discussion on user requirements in the context of the 2015 GSICS User Workshop (Toulouse, 22 September 2015)
Action 16.12: GCC to analyse, in consultation with GCOS/AOPC, the implications of GCOS observation needs on GSICS products. (January 2016)
Action 16.13: GDWG to define the format to be used for archiving collocation data.
Action 16.14: WMO to publish the updated Terms of Reference (Completed, posted here,).

ANNEX 5: OTHER KEY DECISIONS AND RECOMMENDATIONS

Recalling that GSICS activities in India are carried out by ISRO and IMD, the Panel recommended that GSICS outreach activity in India be conducted in close collaboration with ISRO or IMD, and be focused on the application of existing GSICS products. ISRO indicated its readiness to consider hosting a regional GSICS user workshop with IISc.

Regarding the possible availability of GSICS software tools for external users, the Panel recommended clarifying on a case-by-case basis whether the driving requirements for these tools were internal or external, and the additional commitments that would result of making them available externally if they were initially required for internal use by GSICS developers.

The Panel agreed that GSICS should aim to provide users with the most recently available calibration data, at the highest available update frequency, allowing users to decide to apply it at the same frequency or after filtering, depending on their own requirements.

The GSICS EP recommended including the following elements as building blocks of the Architecture for Climate Monitoring from Space:

- Calibration infrastructure to be implemented and shared among satellite operators:
  a) In-orbit references for traceability
  b) Ground-based calibration sites
  c) Databases and software tools
- Calibration processes to be implemented by each satellite operator:
  d) Best practices for pre-launch calibration
  e) Procedures for in-orbit calibration with uncertainty estimation
  f) Procedures for in-orbit comparison and inter-calibration
  g) Procedures for vicarious calibration with ground targets
  h) Algorithms/tools for re-calibration of archived data
  i) Communication and capacity building.

The Panel agreed that an objective should be the preservation of the “GSICS Re-analysis Corrections” which are calculated everyday on a sliding temporal window, rather than the GSICS Near Real-Time Corrections, which are not used a posteriori.

The Panel recommended that collocation data be also archived and preserved.

To implement the preservation of GSICS re-analysis corrections, the Panel recommended the following principles:

- Mirroring on the collaboration servers for all GSICS products.
- Collaboration Server Administrators need to ensure high service availability and backup strategies are in place.
- A requirement of GSICS products generation software is that they should be able to regenerate a version of the GSICS product.

The Panel supported the proposed approach to the use of GIRO and GLOD and invited

EUMETSAT to finalize this draft policy and propose it to GSICS and CEOS WGCV members as the basis of agreements for the use of GIRO and GLOD.
The Panel recommended giving consideration to enhancing ground-based Moon observatories, at least for a 3-year campaign, in order to reduce the absolute uncertainty of satellite instrument calibration by lunar observation.
The Panel unanimously elected Dohyeong Kim to replace Tim Hewison as Chair of GRWG. It was further decided that, as outgoing Chair, Tim Hewison will serve as Vice-Chair in replacement of Fred Wu, with Xiuqing (Scott) Hu as the second Vice-Chair.