GLOBAL SPACE-BASED INTER-CALIBRATION SYSTEM (GSICS)

Chairman’s Report
Mitch Goldberg
GSICS was formed in 2005 – let’s recall the history
(following is excerpt from the first GSICS Chair presentation)

• The GCOS Climate Monitoring Principles (GCMPs) were extended to address the problems associated with developing long-term climate data records from satellite observations
  – Stable orbits
  – Continuity and adequate overlap of satellite observations
  – Improved calibration and validation
In response to the request by WMO and CEOS on the calibration item of the GCMPs, the CGMS (Sochi, May 2004), the EUMETSAT SAF on Climate Monitoring (Hamburg, July 2004) and WMO’s CBS (St. Petersburg, Feb. 2005) had detailed discussions and tasked the WMO Space Programme to help building an international consensus and consortium for a global space-based inter-calibration system for the World Weather Watch (WWW)/Global Observing System (GOS).
The Space Programme of WMO initiated a discussion and held two meetings (June and July 2005) to develop the concept of a Global Space-based Inter-Calibration System (GSICS). The following experts participated:

- Mitch Goldberg – NOAA/NESDIS (Chair)
- Gerald Frazer – NIST
- Donald Hinsman – WMO (Space Program Director)
- John LeMarshall - JC Sat. Data Assimilation
- Paul Menzel – NOAA/NESDIS
- Tillmann Mohr – WMO
- Hank Revercomb – Univ. of Wisconsin
- Johannes Schmetz – Eumetsat
- Jörg Schulz – DWD, CM SAF
- William Smith – Hampton University
- Steve Ungar – NASA/CEOS, Chairman WG Cal/Val
- George Ohring (NOAA),
- Jerome Lafeuille (Meteo-France)
To integrate observations and products from different satellite systems, the measurements must be inter-calibrated. Without inter-calibration of the space-based component of the WWW’s GOS and of GEOSS, the full benefit of the observations will not be realized.

The purpose of inter-calibration is to quantitatively relate the radiances from different sensors viewing the same target to allow consistent measurements to be taken over the globe by all elements of the space-based observing system.
Objectives

• The objectives for the operational Global Space-based Inter-calibration Systems (GSICS) are:

  – Primary goal: To improve the use of space-based global observations for weather, climate and environmental applications through operational inter-calibration of satellite sensors.

  – Secondary goal: To provide for the ability to retrospectively re-calibrate archive satellite data using the operational inter-calibration system in order to make satellite data archives worthy for climate studies.
Enabler

• An operational global space-based inter-calibration system to better characterize space-based observations by measuring, documenting, understanding and accounting for differences between different sensors viewing the same target - analyses of the differences will provide for recommended actions to meet the following benefits.
Benefits

• **High-level**
  – Enhanced usefulness of satellite **products** to observe **climate variability**
  – Improved utility (ease of use) of satellite radiances in NWP
  – Improved cost-benefit ratio from an optimized global system of satellites.

• **Technical**
  – Consistent calibration of space-based radiometers
  – Allows adjustments to sensors with less stringent stability
  – Significantly improved characterization of space-based radiometers
  – Move towards absolute calibration; this would also necessitate a reference measurement network
  – Improve understanding of physical processes in atmospheric models (requires absolute calibration)
Prerequisites

- Extensive pre-launch characterization of all instruments traceable to SI standards

- Some instruments in space with appropriate accuracy, spectral coverage and resolution to act as a standard for inter-calibration

- Independent observations (calibration/validation sites – ground based, aircraft)
Space-based Instrument Characterization Elements

- Fully characterized sensor components
  - Traceability standard
    - Full instrument cycle test to ensure every component is traceable to SI standard
  - Pre-launch tests
  - Sustained post-launch characterization
    - Satellite to Satellite comparisons
    - Collocated in-situ observations
    - Radiative transfer models
    - Data assimilation models
Building Blocks for Satellite Intercalibration

- **Collocation**
  - Determination and distribution of locations for simultaneous observations by different sensors (space-based and in-situ)
  - Collocation with benchmark measurements

- **Data collection**
  - Archive, metadata - easily accessible

- **Coordinated operational data analyses**
  - Processing centers for assembling collocated data
  - Expert teams

- **Assessments**
  - Communication including recommendations
  - Vicarious coefficient updates for “drifting” sensors
Global Space-based Inter-Calibration System

• What is GSICS?
  – Global Space-based Inter-Calibration System
  – Initiative of CGMS and WMO
  – Effort to produce consistent, well-calibrated data from the international constellation of Earth Observing satellites

• What are the basic strategies of GSICS?
  – Improve on-orbit calibration by developing an integrated inter-comparison system
    • Initially for GEO-LEO Inter-satellite calibration
    • Being extended to LEO-LEO
    • Using external references as necessary
  – Best practices for calibration & characterisation

• This will allow us to:
  – Improve consistency between instruments
  – Reduce bias in Level 1 and 2 products
  – Provide traceability of measurements
  – Retrospectively re-calibrate archive data
  – Better specify future instruments
GSICS Principles

• Systematic generation of inter-calibration products
  • for Level 1 data from satellite sensors
  • to compare, monitor and correct the calibration of monitored instruments to community references
  • by generating calibration corrections on a routine operational basis with specified uncertainties
  • through well-documented, peer-reviewed procedures
  • based on various techniques to ensure consistent and robust results

• Delivery to users
  • Free and open access
  • Adopting community standards

• To promote
  • Greater understanding of instruments’ absolute calibration, by analysing the root causes of biases
  • More accurate and more globally consistent retrieved L2 products
  • Inter-operability for more accurate environmental, climate and weather forecasting products
Global Space-based Inter-calibration System - GSICS

GSICS Products

- GSICS Bias Monitoring
  - Routine comparisons of satellite radiances against reference
- GSICS Correction
  - Function to correct issued radiances
  - For consistent calibration with reference
- GSICS Reports & Guidelines
  - Recommendations to modify practices
  - Design and Operation of future satellite instruments
- For Operational Environmental Satellites
  - Infra-red recalibration (GEO and LEO) (current operational satellites)
  - Visible and near-infrared recalibration (GEO and LEO)
  - Microwave – Conical & Cross-track Scanners (LEO)
  - Historical Instruments

Research satellites often used as reference Instrument (MODIS, AIRS)

- Pre-Operational & Demo status
- Near real-time and re-analysis
- In development within GSICS
- In development with GPM XCAL
- In development at NOAA, EUMETSAT...
GSICS User Community

• Satellite Application Community
  – CDR generation for climate monitoring
    “SCOPE-CM” framework, national/international programs
    WCRP/GEWEX/ISCCP - (Planned beta-testing of GEO GSICS Corrections)
  – Reanalysis community for climate modelling (ECMWF reanalysis – 2012/15)
  – Operational NWP: direct radiance assimilation
  – Other users interested in accurate/consistent calibration
to generate stable (composite) L2 quantitative products or imagery

• Satellite Operators
  – Prelaunch instrument characterization guidelines
  – Cal/Val Plans
  – Best practices for instrument monitoring and improved calibration
GSICS Procedure for Product Acceptance

- Based on QA4EO
- Products progress from
  - Demonstration Mode
- Through
  - Pre-Operational Mode
- To
  - Operational Mode
- By a series of reviews
- Over period of ~1.5yr
- Subject to meeting acceptance criteria

Figure 1: From top to bottom, the GSICS Procedure for Product Acceptance is described by four phases - Product Submission Phase, Demonstration Phase (DP), Pre-operational Phase (PP), and Operational Phase (OP) - and their review and revision cycles. The time markers at the far right, and their defined limits, are: date of submission (D_s); and the number of days from D_s to fulfill requirements to enter DP (D_{DP} ≤ D_s + 90 days), PP (D_{PP} ≤ D_{DP} + 365 days), and OP (D_{OP} ≤ D_{PP} + 180 days).
<table>
<thead>
<tr>
<th>Algorithm Type</th>
<th>GPRC</th>
<th>Monitored Instrument</th>
<th>Reference Instrument</th>
<th>GSICS NRT Correction</th>
<th>GSICS Re-Analysis Correction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GEO-LEO IR</strong></td>
<td>EUMETSAT</td>
<td>Meteosat</td>
<td>IASI</td>
<td>Pre-Operation</td>
<td>Pre-Operation</td>
</tr>
<tr>
<td></td>
<td>JMA</td>
<td>MTSAT</td>
<td>IASI (+ AIRS)</td>
<td>Demo (close to Pre-Op)</td>
<td>Demo (close to Pre-Op)</td>
</tr>
<tr>
<td></td>
<td>NOAA</td>
<td>GOES Imager</td>
<td>IASI (+ AIRS)</td>
<td>Pre-Operation</td>
<td>Pre-Operation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GOES Sounder</td>
<td>IASI (+ AIRS)</td>
<td>In development</td>
<td>In development</td>
</tr>
<tr>
<td><strong>GEO-LEO Vis/NIR DCC</strong></td>
<td>EUMETSAT</td>
<td>Meteosat</td>
<td></td>
<td>In development</td>
<td>In development</td>
</tr>
<tr>
<td></td>
<td>JMA</td>
<td>MTSAT</td>
<td></td>
<td>In development</td>
<td>In development</td>
</tr>
<tr>
<td></td>
<td>NOAA</td>
<td>GOES Imager</td>
<td>Aqua MODIS</td>
<td>In development</td>
<td>In development</td>
</tr>
<tr>
<td></td>
<td>CMA</td>
<td>FY-2X</td>
<td></td>
<td>In development</td>
<td>In development</td>
</tr>
<tr>
<td></td>
<td>KMA</td>
<td>COMS</td>
<td></td>
<td>In development</td>
<td>In development</td>
</tr>
<tr>
<td><strong>LEO-LEO Visible/NIR</strong></td>
<td>NOAA</td>
<td>AVHRR</td>
<td>MODIS</td>
<td>Demonstration</td>
<td>Demonstration</td>
</tr>
<tr>
<td><strong>LEO-LEO Microwave</strong></td>
<td>NOAA</td>
<td>MSU(AMSU)</td>
<td>(A)MSU</td>
<td>Pre-Operational</td>
<td>Demonstration</td>
</tr>
</tbody>
</table>
Outreach

• Quarterly newsletter (revamped)
• Certificates of Appreciation
• User Workshops (Spring 2013 – NOAA)
  – Upcoming – China (AOMSU) – Fall 2014
• GRWG – promoting scientific partnerships
Issues

• GDWG - need better representation.
• GDWG interim chair is Manik Bali (NOAA) following the departure of Aleksandar Jelenak
• Need a self assessment on support needed for GDWG which can be coordinated by GCC and presented to EP.
• Need more active participation by Roshydromet
• Good news - last year we noted the need for more participation by IMD and ISRO
  – Both IMD and ISRO participated in GRWG/GDWG at EUMETSAT March 2014
  – IMD is hosting next year’s GRWG/GDWG meeting
  – ISRO developing GEO to LEO Intercalibration.
Priorities for GEO to LEO

• Establish CrIS as a reference instrument in addition to IASI and AIRS
• Studying removing spectral gaps in CrIS for JPSS2.
• Need more than one reference polar orbiting reference instrument (e.g. hyperspectral IR) to capture diurnal bias in geostationary due to solar intrusion on current 3-axis stabilized geo imagers
  – Ideally three orbits
• Eventually need to establish additional satellite reference for visible/near infrared because MODIS is way beyond its design life. Is VIIRS or Sentinel 3 imagers the new reference?
Vision for GSICS

- **The scope of GSICS** is to provide a collaborative framework among satellite operators and science teams to develop, implement and share community-agreed best practices and standards, procedures and tools in order to monitor, improve and harmonize the calibration of GOS environmental satellites. The focus is on the systematic generation of in-orbit inter-calibration information to correct the individual calibration of Level 1 satellite data.

- **Expected benefits** to satellite operators are to assess uncertainties, to assess calibration methods, to deliver state-of-the-art NRT calibration through correcting the operational calibration, to understand and mitigate the calibration differences, and to share knowledge, development effort, test data sets, calibration references.

- **Expected benefits** to users are to provide time-consistent data series for climate monitoring, consistent multi-satellite data for composite products, and error characterization for NWP. It thus enables integration of observation systems (along the lines of WIGOS) and should ensure the traceability and comparability required for the Architecture for Climate Monitoring from Space, in support of climate monitoring activities including GCOS.
GSICS Vision (continued)

• **The core principles** guiding the GSICS strategy are therefore reaffirmed:
  – Calibration of satellite instruments is monitored and assessed by comparing with community references, using common methodologies, international standards, best practices, & ultimately SI-traceable standards;
  – This should be achieved through a continuous chain of comparisons with stated uncertainties, to ensure metrological traceability;
  – Calibration corrections are generated for both Near-Real-Time use and retrospective analyses, with specified uncertainties, through documented, peer-reviewed procedures to ensure consistent and robust results;
  – Inter-calibration assessments, comparisons and corrections are delivered through free and open access, adopting community data standards.

• **The core expertise** of GSICS lies in operational monitoring of passive radiometric sensors and comparison of L1 data, from UV to VIS/NIR to IR to MW.

• It is imperative to maintain at least one calibration reference standard. GSICS should advocate for the availability of in-orbit SI-traceable reference missions. The involvement in active sensor calibration is not decided, but should be evaluated taking into account CEOS/WGCV activities.

GSICS-EP-15, May 2014, Guangzhou, China
GSICS Vision (continued)

- *In terms of partnerships*, GSICS should be part of the international calibration community with BIPM, WMO/CIMO, CEOS/WGCV. It should strengthen its interaction with CEOS/WGCV/IVOS. Some activities of these groups are clearly complementing each other (e.g. operational inter-satellite calibration by GSICS, cal/val sites and campaigns by IVOS), other activities should preferably be conducted jointly e.g. on methodology (ATBD, traceability), terminology, or outreach (IEEE TGRS publication). Some cross-participation in both groups is helpful. As concerns the GSICS-GRUAN collaboration it is expected to be mutually beneficial: GSICS could provide travelling reference standards for GRUAN stations, while GRUAN with Radiative Transfer Models (RTM) could provide references for MW calibration. Interaction with the RTM community (e.g. through ITWG, or other group of the International Radiation Commission) is also desirable to improve use of ground targets.
Regarding membership and organization, the Panel envisions that all CGMS Members should be encouraged to participate in, and benefit from GSICS. It is assumed that GSICS member organizations, like CGMS members, are governmental agencies. All members are expected to be actively involved in technical activities as well as in the leadership, through encouraged rotation of chairmanship. GSICS processes should be documented and may evolve ultimately into WMO Guides. GSICS should raise user awareness and provide guidance/training on the use of GSICS products.

The Panel agreed that GSICS should play a role in the Architecture for Climate Monitoring from Space. GCOS stressed the need for uniform calibration of individual satellites; it encouraged GSICS to analyze root causes of discontinuity or drifts in data series, to allow modeling the inter-satellite differences rather than adjusting the series to reduce bias. GCOS also suggested taking advantage of the GCOS Reference Upper Air Network (GRUAN) to improve traceability of GSICS calibration.
Summary

• GSICS is still heading in the right direction
• Science collaboration has never been better!!
• Need to improve participation in data working group.
• GSIC Procedure for Product Acceptance (GPPA) is very robust and provides the rigor needed to provide the provenance needed for our GSICS products
• GSICS is an integral part of the climate architecture
• First GEO to LEO IR will become operational next year

• Congratulations to Dr. Peng Zhang, our new GSICS EP chair!!