Introduction to the Global Space-based InterCalibration System

NOAA Satellite and Information Service

Dr. Mitch Goldberg, JPSS Program Scientist and first GSICS EP Chair

2016 GSICS User Workshop
The aim of GSICS

- To organize the production of satellite inter-calibration information to enable improved and consistent accuracy among space-based observations worldwide for climate monitoring, weather forecasting, and environmental applications.

- Why? Foundation for all applications are the fundamental measurements
The Beginning: The Space Programme of WMO initiated a discussion and held several meeting in 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
- Toshi Kurino - JMA
- Tillmann Mohr – WMO
- Hank Revercomb – Univ. of Wisconsin
- Johannes Schmetz – Eumetsat
- Jörg Schulz – DWD, CM SAF
- William Smith – Hampton University
- Steve Ungar – CEOS, Chairman WG Cal/Val
Critical building blocks for accurate measurements and intercalibration

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

- Benchmark 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

[NISTIR 7637]

Best Practice Guidelines for Pre-Launch Characterization and Calibration of Instruments for Passive Optical Remote Sensing

(Report to Global Space-based Inter-Calibration System (GSICS) Executive Panel, NOAA/NESDIS, World Weather Building, Camp Springs, Maryland 20746)

R. U. Datla, J. P. Rice, K. Lykke and B. C. Johnson
NIST Optical technology Division

J.J. Butler and X. Xiong
NASA Goddard Space Flight Center

September 2009

U.S. DEPARTMENT OF COMMERCE
Gary Locke, Secretary
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
Patrick D. Gallagher, Director
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
GSICS Structure & Partnerships

- CGMS
- GSICS Coordination Center
  - GSICS Exec Panel
  - GSICS Research Working Group
  - GSICS Data Working Group
  - VIS/NIR Sub-Group
    - WGCV IVOS
    - WGCV MWSG
    - GPM X-CAL
    - WGCV ACSG
  - Microwave Sub-Group
  - UV Sub-Group
  - WGCV ACSG
  - Future Sub-Groups...
  - CEOS ACC

- WMO

- EUMETSAT
- CNES
- JMA
- NOAA
- CMA
- KMA
- ISRO
- NASA
- WMO
- USGS
- NIST
- JAXA
- ROSHYDROMET
- IMD
- ESA
GSICS Quarterly Newsletter Features

- Since Fall 2013, brand new format.
- Since Winter 2014, the Newsletter has a doi.
- Accepts articles on topics related to calibration (Pre and Post launch).
- New Landing page on the GCC website.
- Rate and Comment section: readers and authors can interact.
- Articles are reviewed by subject experts.
- Help available to non native English speaking contributors.
- Since Fall 2014, new navigation features added to the Cover Letter.
Satellite Cal/Val Programs Supports GSICS

- JPSS and GOES-R and other CGMS satellite agency requirements for on-going validation of instrument performance and stability ties into GSICS functional areas.
- These include intercalibration, instrument monitoring and campaigns, assessments, routine cause analysis, etc.
- Following are excellent examples of assessments that GSICS depends on to establish traceability and next steps
March 2015 Greenland SNPP campaign

SNPP-2 Calibration Validation

- **Mission Goals:**
  - radiometric calibration validation over cold clear scenes
  - Resolve CrIS and IASI differences
  - assess satellite T/q profile retrievals for cold scenes
- **Flights out of Keflavik from March 7-29, 2015**
  - ~4.8 hours per flight lag time over Greenland Ice Sheet
- **Primary Target – SNPP**
- **Secondary Targets – METOP A and B, Aqua, Terra**

SNPP – 2 CalVal Payload

- **S-HIS (Scanning High-resolution Interferometer Sounder)**
  - cross-track scanning interferometer sounder which measures emitted thermal radiation at high spectral resolution between 3.3 and 18 microns
  - [https://shis.ssec.wisc.edu](https://shis.ssec.wisc.edu)
- **NAST-I (NPOESS Airborne Sounding Testbed-Interferometer)**
  - high spectral resolution (0.25cm-1) and high spatial resolution (0.13 km linear resolution per km of aircraft flight altitude, at nadir) scanning
- **NAST-M (NPOESS Airborne Sounding Testbed-Microwave)**
  - passive microwave spectrometers
- **MASTER (MODIS Airborne Simulator)**
  - visible, shortwave infrared, and thermal infrared channels
Assessment of the calibration accuracy for cold Earth scenes

Mean SNO differences for 910-930 cm\(^{-1}\)

- AIRS - IASI-A
- AIRS - IASI-B
- CrIS - IASI-A
- CrIS - IASI-B

Error-bars represent statistical matchup uncertainty, not sensor uncertainty.

Decreasing Scene Temperature

0.050 K Agreement

> 0.3 K relative differences
SNAP2015, 850–900 cm\(^{-1}\)

**PRELIMINARY:** Native spectral resolutions (no DOMC)

**Error bars only represent spatial variation for footprints used in comparisons**
GSICS correction is negligible for AHI
GSICS Infrared Inter-calibration

Himawari-8/AHI IR Inter-calibration with AIRS, IASI-A/B and CrIS

AHI Infrared Bands
- Band07 (3.9 μm)
- Band08 (6.2 μm)
- Band09 (6.9 μm)
- Band10 (7.3 μm)
- Band11 (8.6 μm)
- Band12 (9.6 μm)
- Band13 (10.4 μm)
- Band14 (11.2 μm)
- Band15 (12.4 μm)
- Band16 (13.3 μm)

LEO Data
- AIRS (all)
- IASI-A (all)
- IASI-B (all)
- CrIS (all)
- AIRS (asc, 1:30pm)
- AIRS (des, 1:30pm)
- IASI-A (asc, 9:30pm)
- IASI-A (des, 9:30pm)
- IASI-B (asc, 9:30pm)
- IASI-B (des, 9:30pm)
- CrIS (asc, 1:30pm)
- CrIS (des, 1:30pm)

Time Series
- TB difference
- Regression coeff

Statistics for GSICS Correction
- Scatter plot

Month Day Year
Sep 11, 2015
Sep 12, 2015
Sep 13, 2015
Sep 14, 2015
Sep 15, 2015

Brightness Temperature Bias (HIMAWARI-8 BAND13 – CrIS)

CIRS TB at Standard Radiance (266.18 K)

Time Series
- TB difference
- Regression coeff

Statistics for GSICS Correction
- Scatter plot

Month Day Year
Sep 11, 2015
Sep 12, 2015
Sep 13, 2015
Sep 14, 2015
Sep 15, 2015

Brightness Temperature Bias (HIMAWARI-8 BAND12 – IASI)

IASI TB at Standard Radiance (266.18 K)
GSICS Himawari-8/AHI infrared inter-calibration guide

Inter-calibration between Himawari-8/AHI infrared bands and high-spectral-resolution sounders

The Meteorological Satellite Center (MSC) examines ways of improving inter-calibration between Himawari-8/AHI (referred to here as AHI) infrared bands and high-spectral-resolution sounders (hyper sounders). Data from the three hyper sounders detailed below are used for this work:

- The Atmospheric Infrared Sounder (AIRS) is a multi-aperture array grating spectrometer on board the Aqua satellite of the National Aeronautics and Space Administration (NASA, U.S.).
- The Infrared Atmospheric Sounding Interferometers (IASIs) are hosted by the Metop-A and -B satellites of the European Organization for the Exploration of Meteorological Satellites (EUMETSAT, EU).
- The Cross-track Infrared Sounder (CrIS) is a Fourier transform spectrometer hosted by NASA’s Suomi NPP satellite.

Inter-calibration is conducted once a day. The hyper-sounder data used in this work are collected via the internet. Inter-calibration completion may be canceled if network conditions are poor.

As of July 2014, AHI GSICS Corrections are under development. The products will be reviewed within GSICS to enter Demonstration-phase.

Outcome

The results of this inter-calibration work have three statistical parameters. It should be noted that the results contain a certain level of uncertainty caused due to variations in instrument accuracy, differences in observation conditions, and spectral compensation residuals.

Coefficients of correlation between the radiance of hyper sounders and AHI

Linear regression coefficients ($C_0$ and $C_1$) and their standard uncertainties are computed to allow association of Himawari Standard Data (HSD) radiance with hyper sounder radiance. The radiance is in wavenumber space, and its unit is mW cm$^{-2}$ sr$^{-1}$ cm.$^{-1}$.

Radiance (AHI) = $C_0 + C_1 \times$ Radiance (hyper sounder)

GSICS Correction

GSICS Correction is the initial core product of GSICS. It is a dataset that allows users to determine corrected satellite radiances based on the results of inter-calibration, and consists of the above linear-regression coefficients ($C_0$ and $C_1$). Corrected satellite radiances are calculated using the following equation:

$\text{Corrected radiance (AHI)} = \text{HSD radiance (AHI)} / C_1 - C_0 / C_1$
Wrap up

**Where we are:**
- GSICS has developed a cadre of calibration scientists throughout the world’s earth remote sensing satellite agencies
- Every satellite/instrument operator is now responsible for characterizing their own satellites with community consensus algorithms and tools

**Where we are going:**
- GSICS will continue to promote capacity building
- Contribute significantly to the new Climate Architecture.
Learn more about GSICS

THE GLOBAL SPACE-BASED INTER-CALIBRATION SYSTEM


An international project will use observations from operational low-earth-orbiting and geostationary environmental satellites to close the link between satellite datasets and ground-based observations. The satellite component of the Global Observing System

IMPROVED CALIBRATION IS A KEY TO SUCCESSFUL MODERN SCIENTIFIC SATISFACTION. A MAJOR CHALLENGE IN ACQUISITION OF GROUND-BASED DATA IS THE USE OF SPACE-BASED DATA TO CALIBRATE GROUND-BASED INSTRUMENTS. THE NEED FOR IMPROVED CALIBRATION OF SPACE-BASED EARTH-OBSERVING INSTRUMENTS IS A KEY TO SUCCESSFUL MODERN SCIENTIFIC SATISFACTION.

VISION OF GSICS IN THE 2020s
Shaping GSICS to meet future challenges

Global Satellite
Inter-Calibration System

Version 1.1
May 2015

BAMS April 2011
Questions?