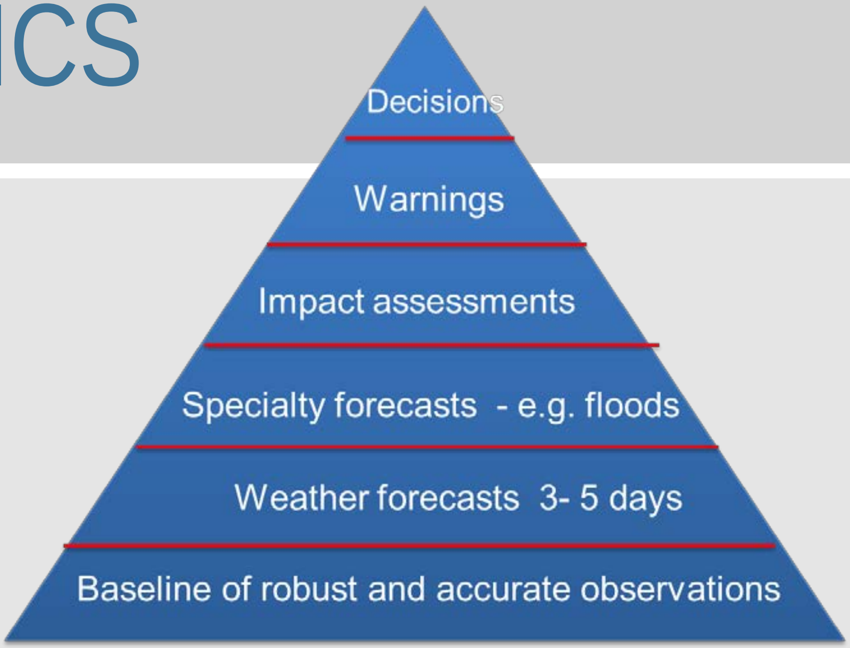
Introduction to the Global Space-based InterCalibration System

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:

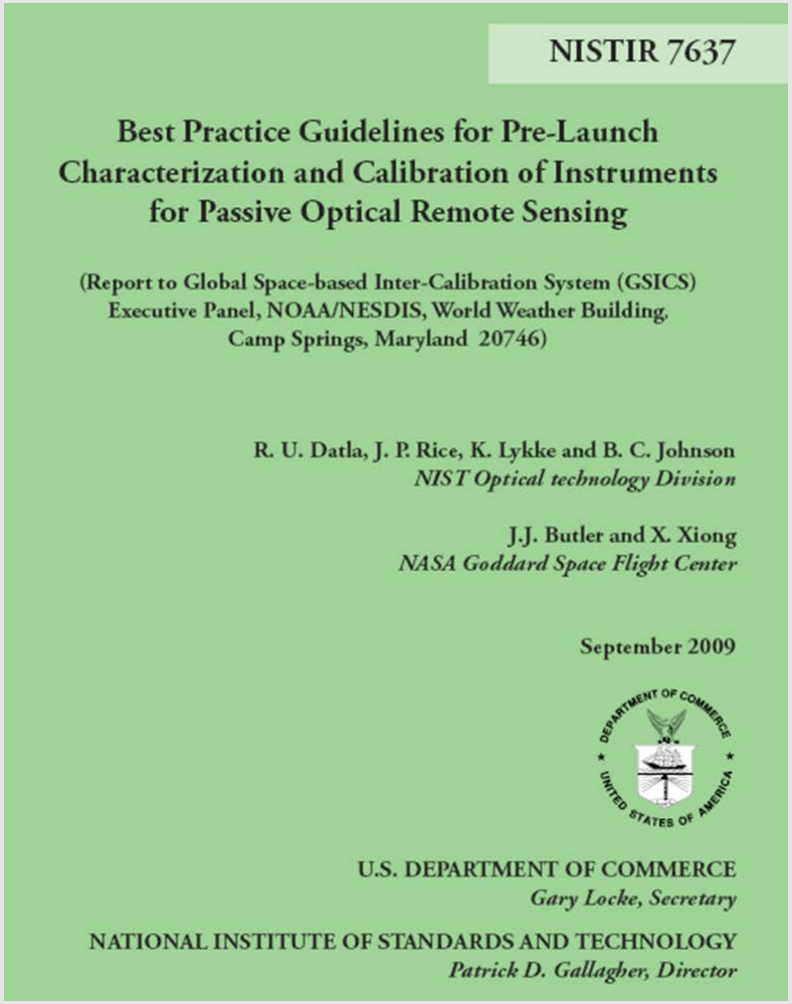
- Mitch Goldberg – NOAA/NESDIS (Chair)
- Gerald Frazer – NIST
- Donald Hinsman – WMO (Space Program Director)
- John LeMarshall - JC Sat. Data Assimilation
- Paul Menzel –NOAA/NESDIS
- Toshi Kurino - JMA
- Tillmann Mohr – WMO
- Hank Revercomb – Univ. of Wisconsin
- Johannes Schmetz – Eumetsat
- Jörg 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

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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

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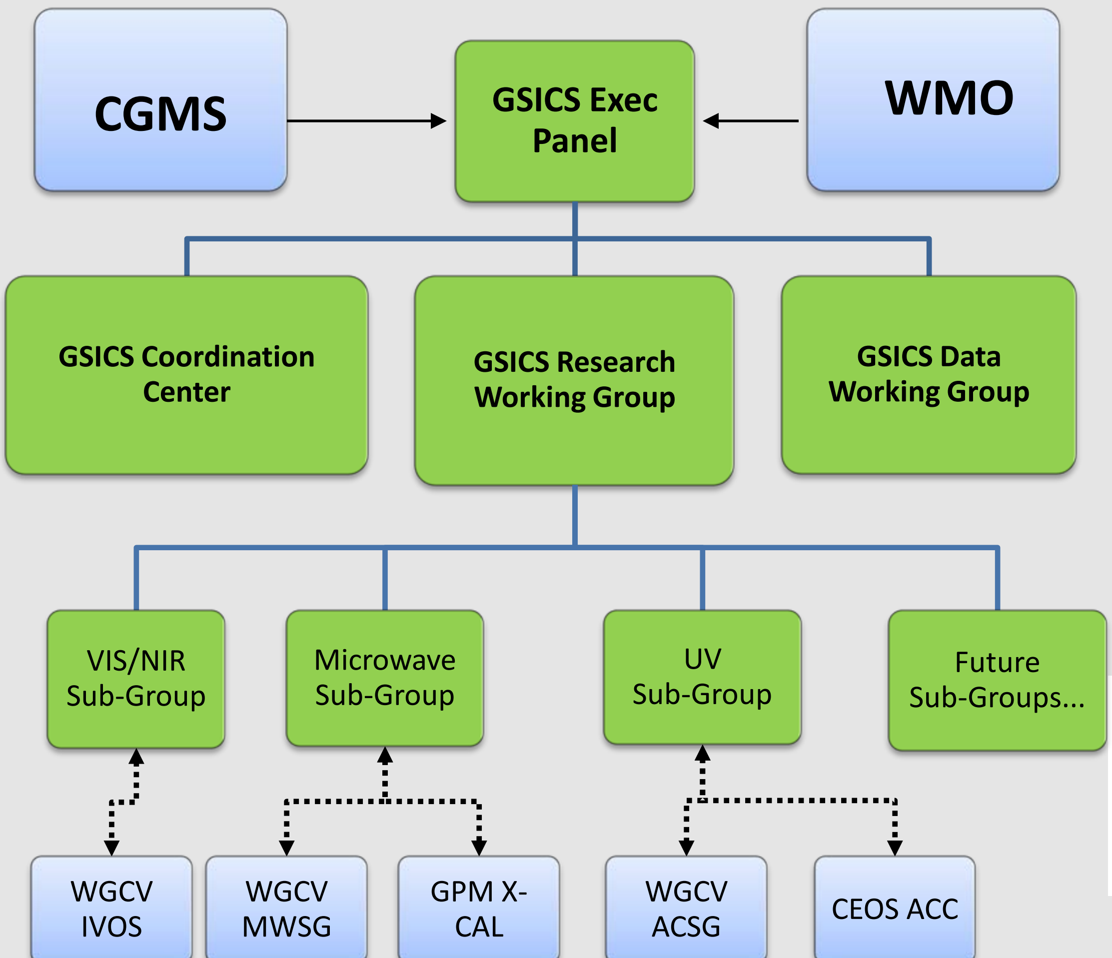
Building Blocks for Satellite Intercalibration

- 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

GSICS
Global Space-based Inter-Calibration System



EUMETSAT CNES JMA

NOAA CMA KMA

ISRO NASA WMO

USGS NIST JAXA

ROSHYDROMET IMD ESA

GCC – GSICS Quarterly Newsletter

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**

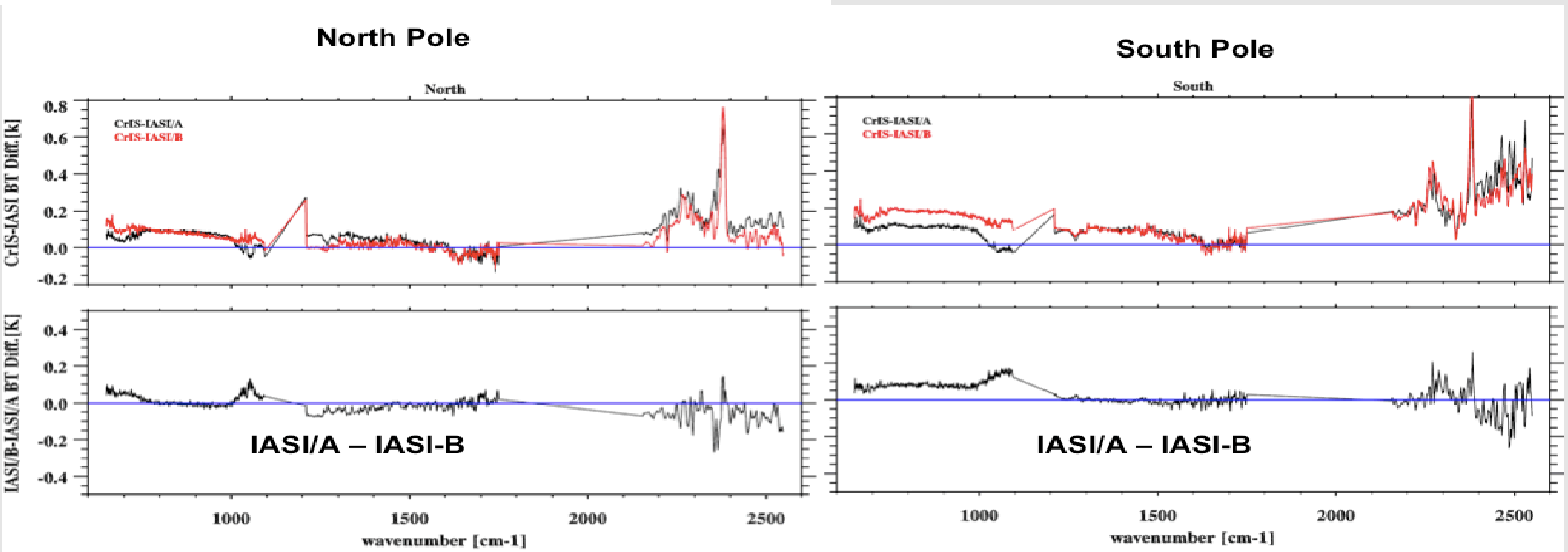
March 2015 Greenland SNPP campaign

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

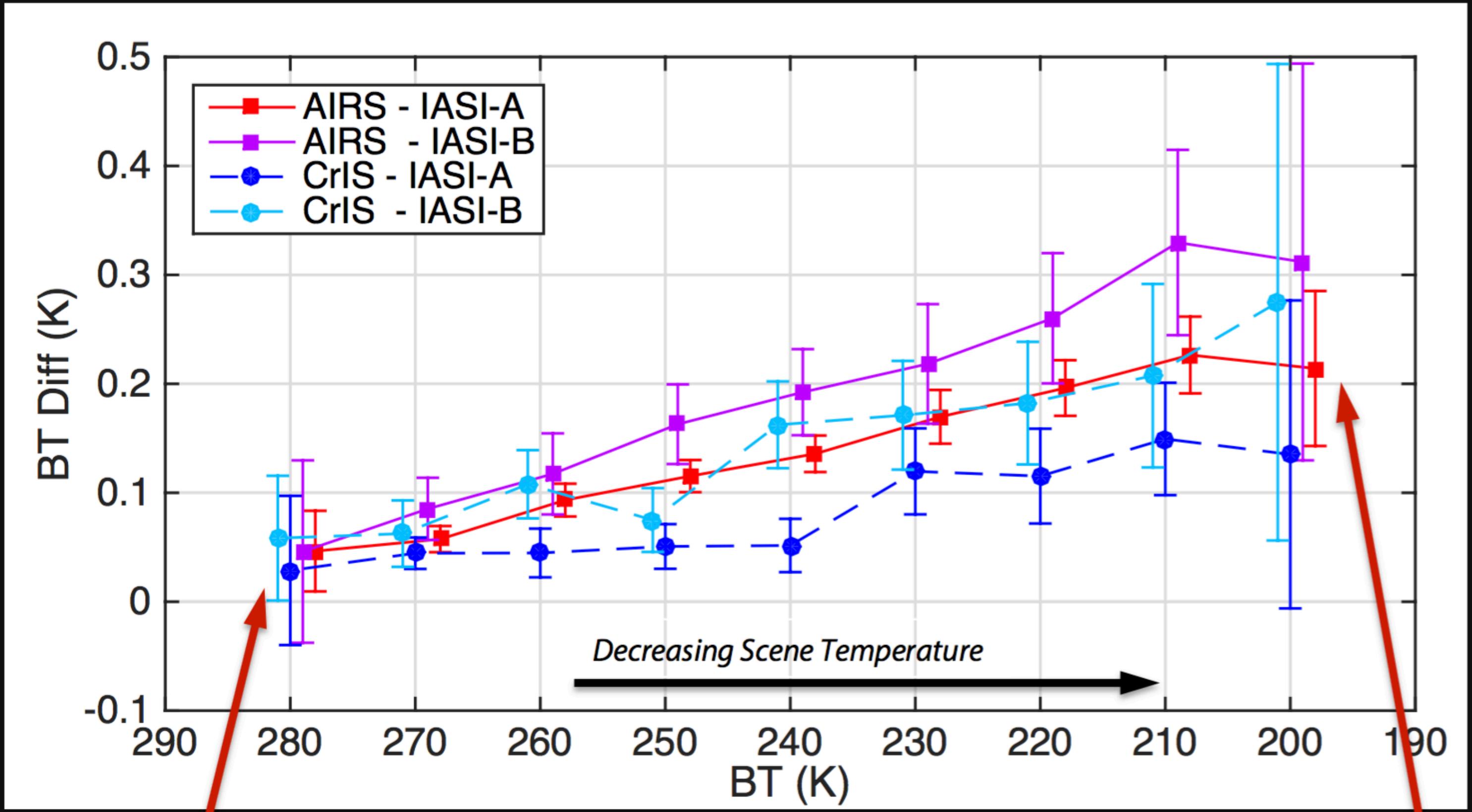
SNPP – 2 CalVal Payload

- 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
- 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
  - http://masterweb.jpl.nasa.gov



Assessment of the calibration accuracy for cold Earth scenes

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



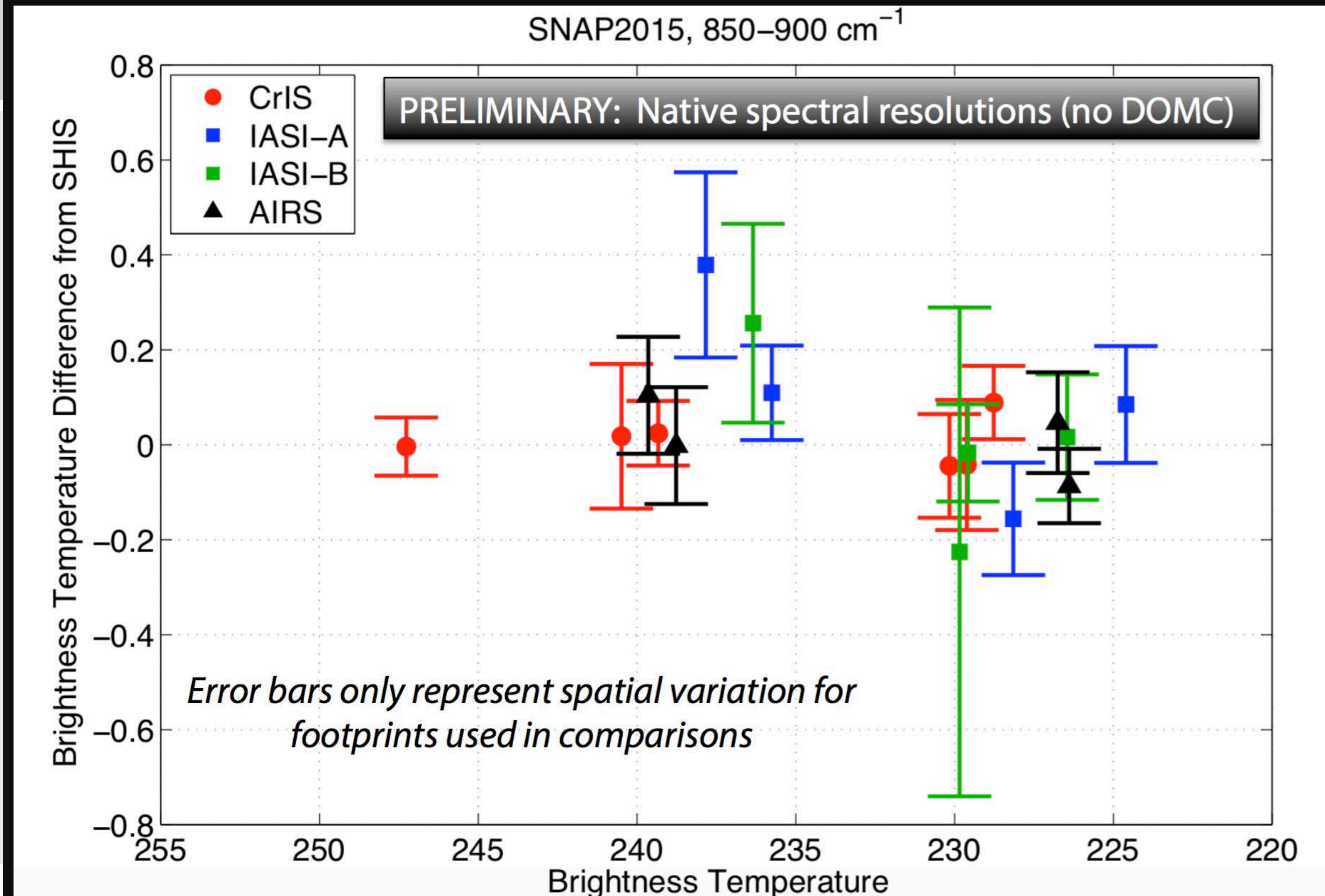
Error-bars represent statistical matchup uncertainty, not sensor uncertainty

0.050 K Agreement

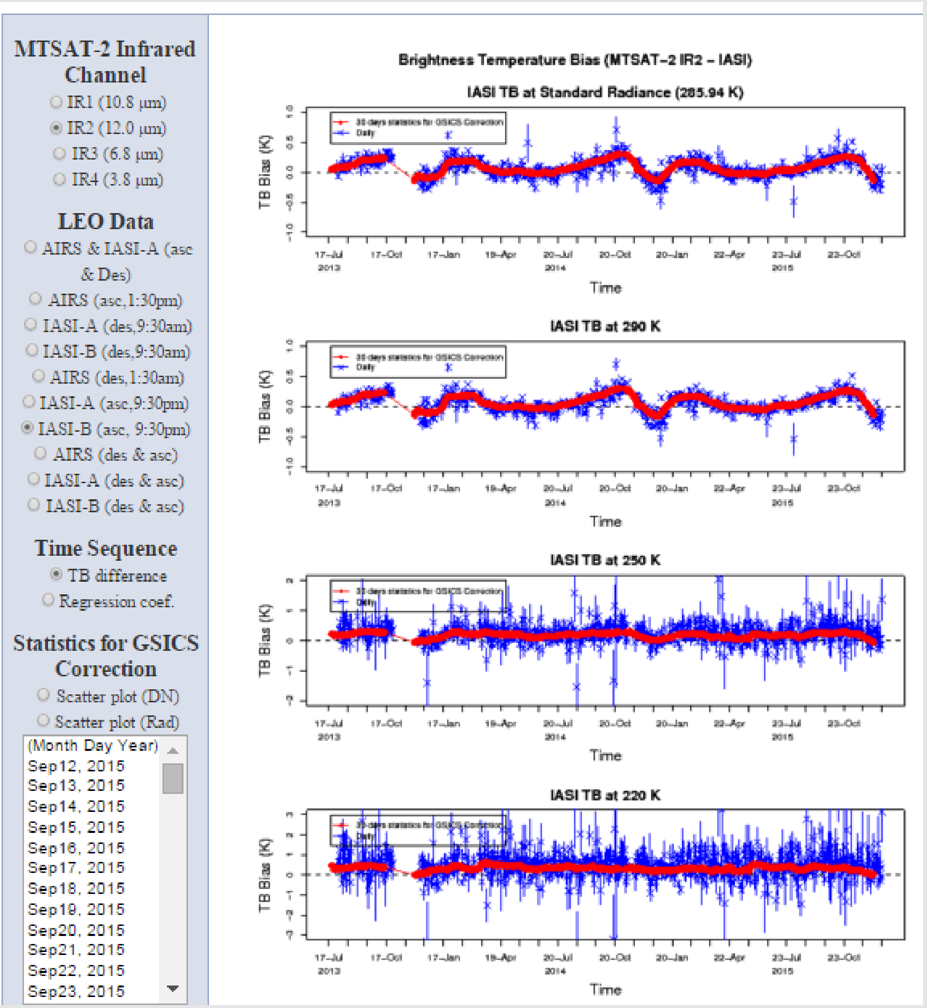
> 0.3 K relative differences

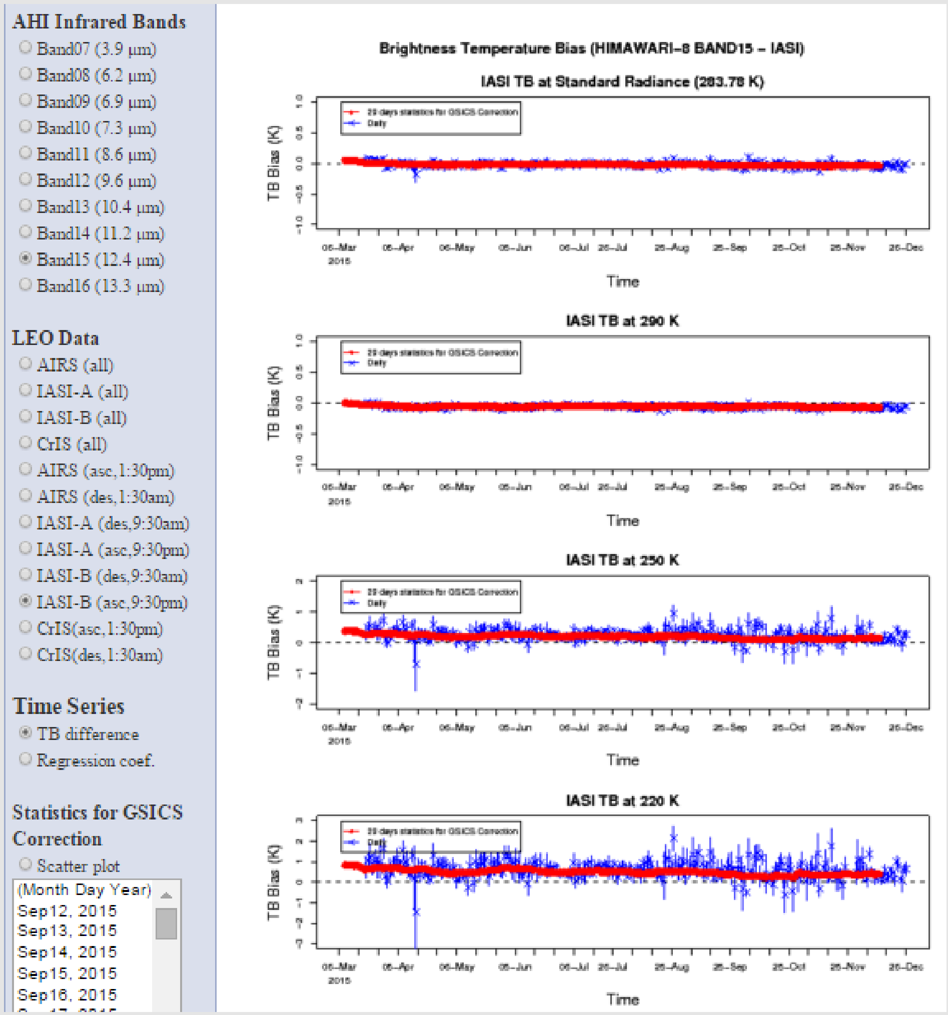
Preliminary Analysis and Results: SNPP Calibration Validation Campaign 2015

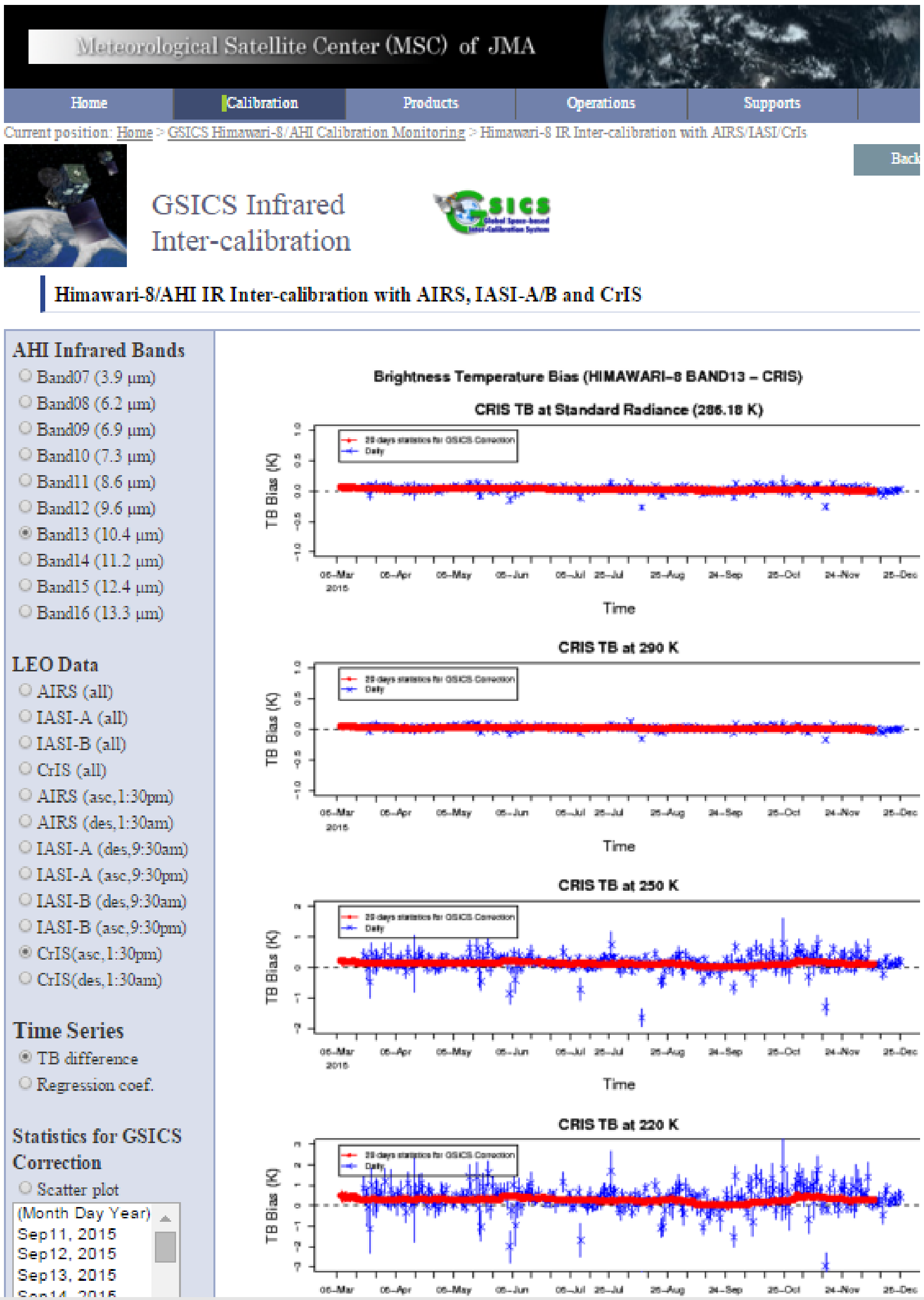
Credit: Tobin



GSICS correction is negligible for AHI



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GSICS Infrared Inter-calibration
GSICS
Himawari-8/AHI IR Inter-calibration with AIRS, IASI-A/B and CrIS
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Band08 (6.2 μm)
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LEO Data
AIRS (all)
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CrIS (all)
AIRS (asc,1:30pm)
AIRS (des,1:30am)
IASI-A (des,9:30am)
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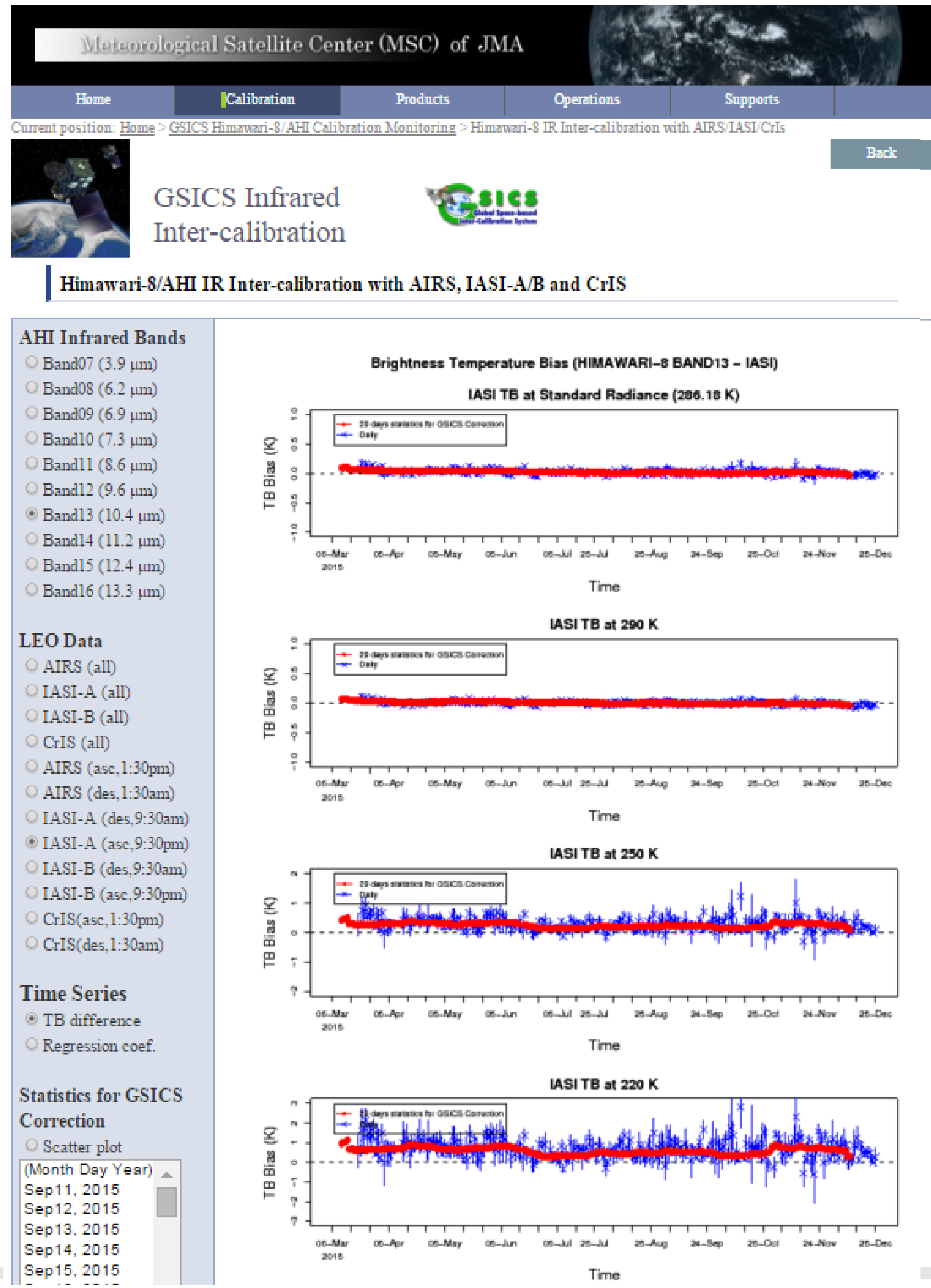
IASI-B (des,9:30am)
IASI-B (asc,9:30pm)
CrIS(asc,1:30pm)
CrIS(des,1:30am)
Time Series
TB difference
Regression coef.
Statistics for GSICS Correction
Scatter plot
(Month Day Year)
Sep11, 2015
Sep12, 2015
Sep13, 2015
Brightness Temperature Bias (HIMAWARI-8 BAND13 – CRIS)
CRIS TB at Standard Radiance (286.18 K)
CRIS TB at 290 K
CRIS TB at 250 K
CRIS TB at 220 K
TB Bias (K)
Time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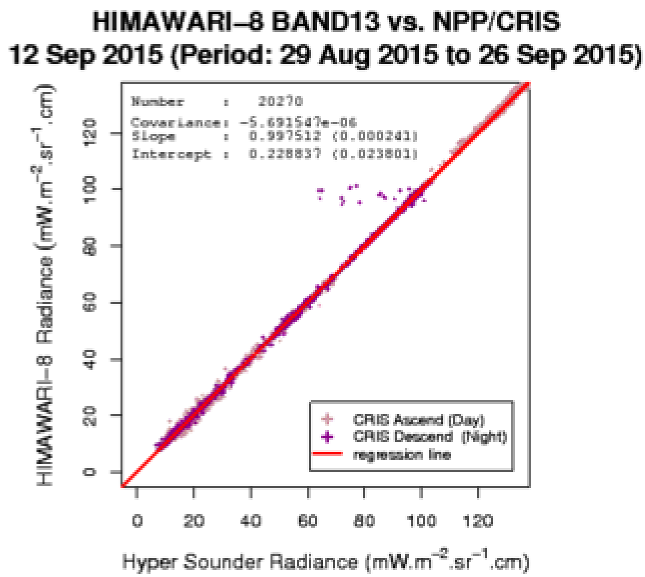
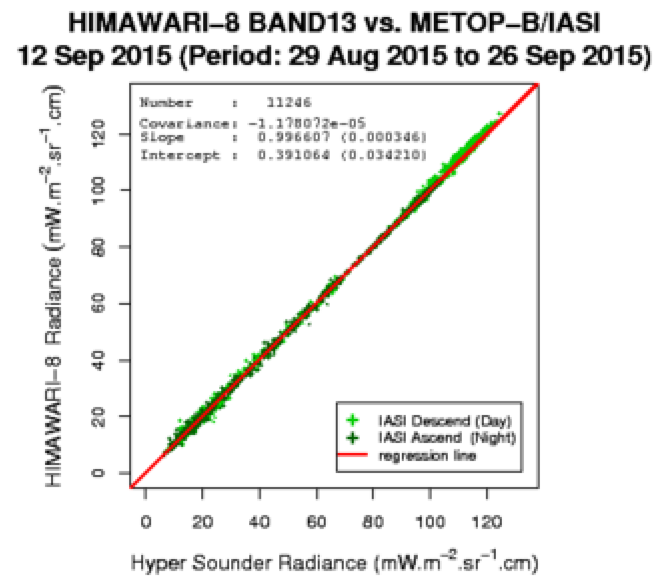
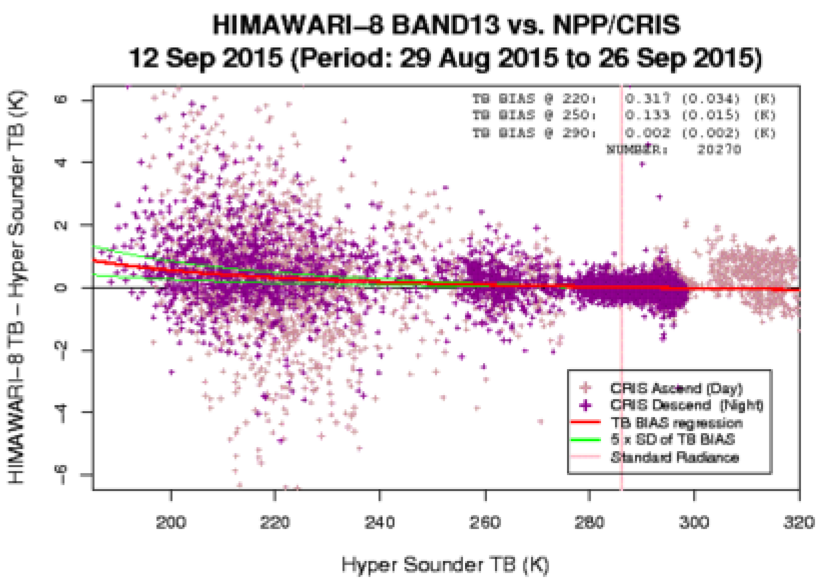
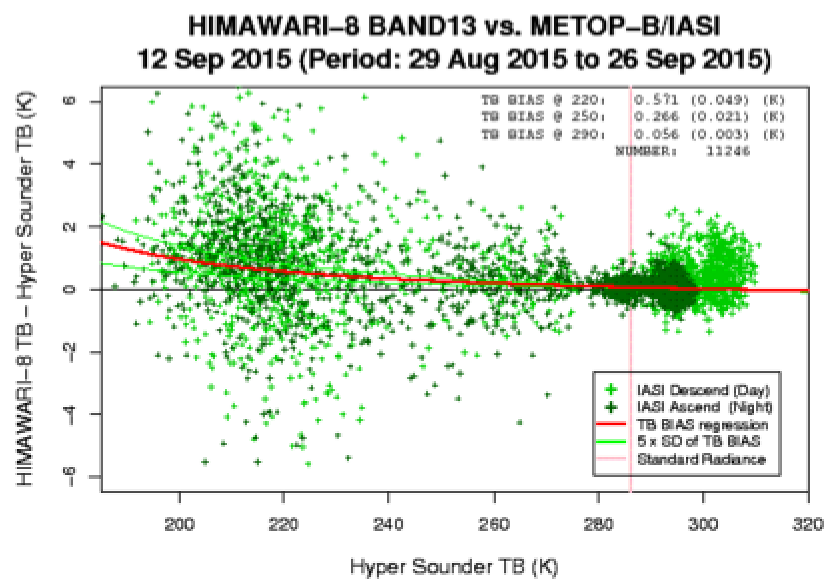
TB Bias (K)
Time


HIMAWARI–8 BAND13 vs. NPP/CRIS
12 Sep 2015 (Period: 29 Aug 2015 to 26 Sep 2015)
Number : 20270
Covariance: -5.691547e-06
Slope : 0.997512 (0.000241)
Intercept : 0.228837 (0.023801)
CRIS Ascend (Day)
CRIS Descend (Night)
regression line
HIMAWARI–8 Radiance (mW.m^{-2}.sr^{-1}.cm)
Hyper Sounder Radiance (mW.m^{-2}.sr^{-1}.cm)


HIMAWARI–8 BAND13 vs. METOP–B/IASI
12 Sep 2015 (Period: 29 Aug 2015 to 26 Sep 2015)
Number : 11246
Covariance: -1.178072e-05
Slope : 0.996607 (0.000346)
Intercept : 0.391064 (0.034210)
IASI Descend (Day)
IASI Ascend (Night)
regression line
HIMAWARI–8 Radiance (mW.m^{-2}.sr^{-1}.cm)
Hyper Sounder Radiance (mW.m^{-2}.sr^{-1}.cm)


HIMAWARI–8 BAND13 vs. NPP/CRIS
12 Sep 2015 (Period: 29 Aug 2015 to 26 Sep 2015)
TB BIAS @ 220: 0.317 (0.034) (K)
TB BIAS @ 250: 0.133 (0.015) (K)
TB BIAS @ 290: 0.002 (0.002) (K)
NUMBER: 20270
CRIS Ascend (Day)
CRIS Descend (Night)
TB BIAS regression
5 x SD of TB BIAS
Standard Radiance
HIMAWARI–8 TB – Hyper Sounder TB (K)
Hyper Sounder TB (K)


HIMAWARI–8 BAND13 vs. METOP–B/IASI
12 Sep 2015 (Period: 29 Aug 2015 to 26 Sep 2015)
TB BIAS @ 220: 0.571 (0.049) (K)
TB BIAS @ 250: 0.266 (0.021) (K)
TB BIAS @ 290: 0.056 (0.003) (K)
NUMBER: 11246
IASI Descend (Day)
IASI Ascend (Night)
TB BIAS regression
5 x SD of TB BIAS
Standard Radiance
HIMAWARI–8 TB – Hyper Sounder TB (K)
Hyper Sounder TB (K)

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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 way 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 Exploitation 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 computation may be canceled if network conditions are poor.

As of July 2015, 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 regression 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 $mW.m^{-2}.sr^{-1}.cm$.

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

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:

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

GSICS Correction is computed for every day. To reduce the random component of uncertainty, correction is derived from data over 29- and 15-day time periods for Re-Analysis Correction (RAC) and Near Real Time Correction (NRTC), respectively. The smoothing period for RAC is t - 14 days to t + 14 days, and that for NRTC is t - 14 days to t + 0 days (where t is the date of validity).

TB difference between hyper sounders and AHI

The brightness temperature (TB) difference (AHI value minus hyper sounder value) and its standard uncertainties associated with AHI and hyper sounder radiance are computed at reference temperatures of standard radiance, 290 K, 250 K and 220 K. A standard radiance from GSICS is defined to allow comparison and convenient expression of instrument inter-calibration bias in units that are understandable to users.

The standard radiance of AHI was calculated for each channel by RTTOV-11.2 in a 1976 US Standard Atmosphere at nadir, at night, in clear sky, and over the sea with an SST of 288.15K and a wind speed of 7m/s.

$$d\,Tb = Tb\,(\text{AHI}) - Tb\,(\text{hyper sounder})$$

AHI band (µm)	Band7 (3.9)	Band8 (6.2)	Band9 (6.9)	Band10 (7.3)	Band11 (8.6)	Band12 (9.6)	Band13 (10.4)	Band14 (11.2)	Band15 (12.4)	Band16 (13.3)
Standard radiance [K]	285.95	234.65	243.85	254.59	283.82	259.45	286.18	286.10	283.78	269.73

Conversion between brightness temperature and radiance

The Planck function and sensor spectral response functions are used to compute brightness temperature [K] from radiance [$mW.m^{-2}.sr^{-1}.cm$] and vice-versa. In general, approximation equations called *sensor Planck functions*, which are generated for AHI infrared bands, are used to facilitate computation.

Brightness temperature to radiance

$$B_i(T_b) = \frac{2\,h\,c^2\,\nu_i^3}{\exp\{h\,c\,\nu_i\,/\,k\,(a_{1i} + a_{2i}\,T_b) - 1\}}$$

where B_i: sensor Planck function of band i
T_b: brightness temperature
ν_i: central wavenumber of band i
a_{1i}, a_{2i}: band correction coefficients of band i
h: Planck constant
k: Boltzmann constant
c: speed of light

Radiance to brightness temperature

$$T_b = b_{1i} + b_{2i}\,T_e + b_{3i}\,T_e^2,$$

$$T_e(B_i) = \frac{\frac{hc}{k}\nu_i}{ln(\frac{2\,h\,c^2\,\nu_i^3}{B_i} + 1)}.$$

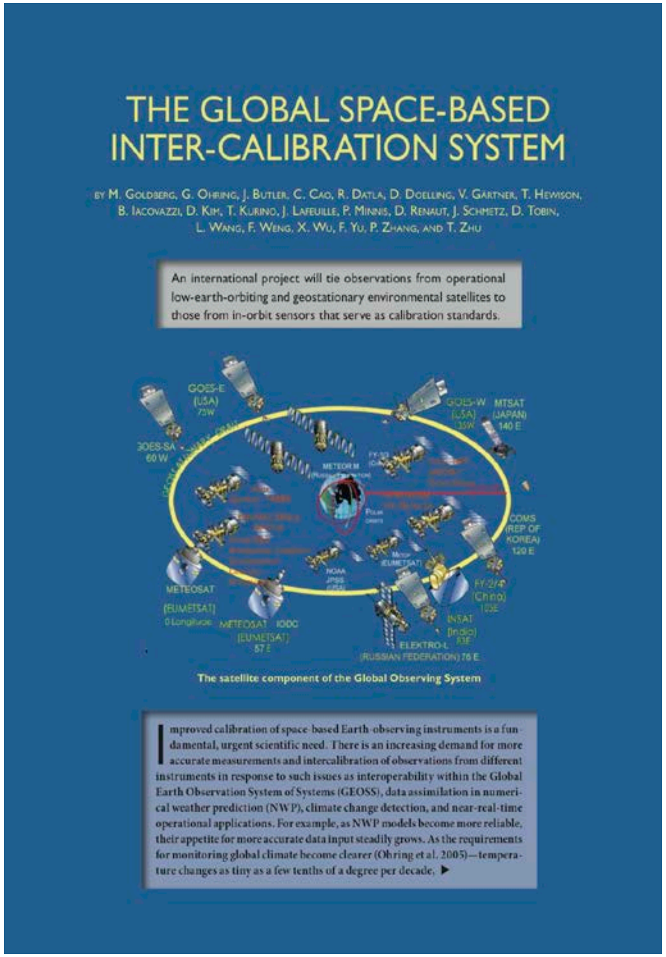
where T_b: the Planck temperature of band i
T_e: effective temperature
B_i: spectral radiance
b_{1i}, b_{2i}, b_{3i}: band correction coefficients of band i

AHI band	Wavenumber	Band correction coefficients				
	v (cm^{-1})	a1	a2	b1	b2	b3
Band 7 (3.9 µm)	2575.767	0.464673802	0.999341618	-0.479757	1.000766	-1.860569e-07
Band 8 (6.2 µm)	1609.241	1.646844799	0.996401237	-1.662616	1.003694	-1.732716e-07
Band 9 (6.9 µm)	1442.079	0.30813537	0.999259063	-0.3357036	1.000974	-4.847962e-07
Band 10 (7.3 µm)	1361.387	0.057369468	0.999854346	-0.06306013	1.000195	-1.069833e-07
Band 11 (8.6 µm)	1164.443	0.135127541	0.999615566	-0.1605105	1.000589	-4.019762e-07
Band 12						

Wrap up

- Where we are:
  - GSICS has developed a cadre of calibration scientists through out 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 promote capacity building
  - Contribute significant to the new Climate Architecture.

Learn more about GSICS



THE GLOBAL SPACE-BASED INTER-CALIBRATION SYSTEM

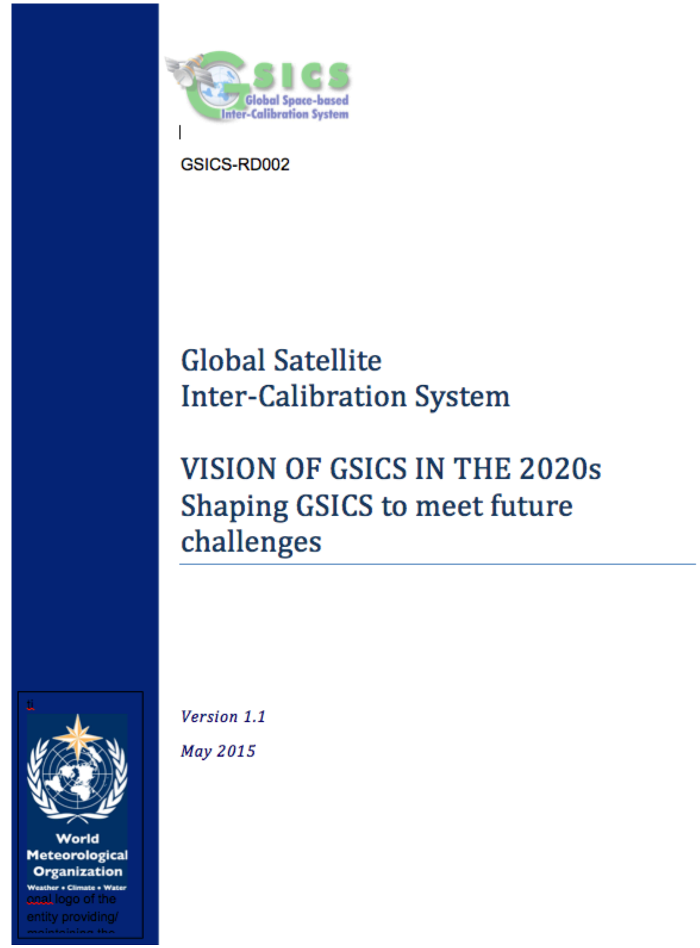
BY M. GOLDBERG, G. OHRING, J. BUTLER, C. CAO, R. DATLA, D. DOELLING, V. GÄRTNER, T. HEWISON, B. IACOVAZZI, D. KIM, T. KURINO, J. LAFEUILLE, P. MINNIS, D. RENAUT, J. SCHMETZ, D. TOBIN, L. WANG, F. WENG, X. WU, F. YU, P. ZHANG, AND T. ZHU

An international project will tie observations from operational low-earth-orbiting and geostationary environmental satellites to those from in-orbit sensors that serve as calibration standards.

The satellite component of the Global Observing System

Improved calibration of space-based Earth-observing instruments is a fundamental, urgent scientific need. There is an increasing demand for more accurate measurements and intercalibration of observations from different instruments in response to such issues as interoperability within the Global Earth Observation System of Systems (GEOSS), data assimilation in numerical weather prediction (NWP), climate change detection, and near-real-time operational applications. For example, as NWP models become more reliable, their appetite for more accurate data input steadily grows. As the requirements for monitoring global climate become clearer (Ohring et al. 2005)—temperature changes as tiny as a few tenths of a degree per decade. ▶

BAMS April 2011



GSICS-RD002

Global Satellite Inter-Calibration System

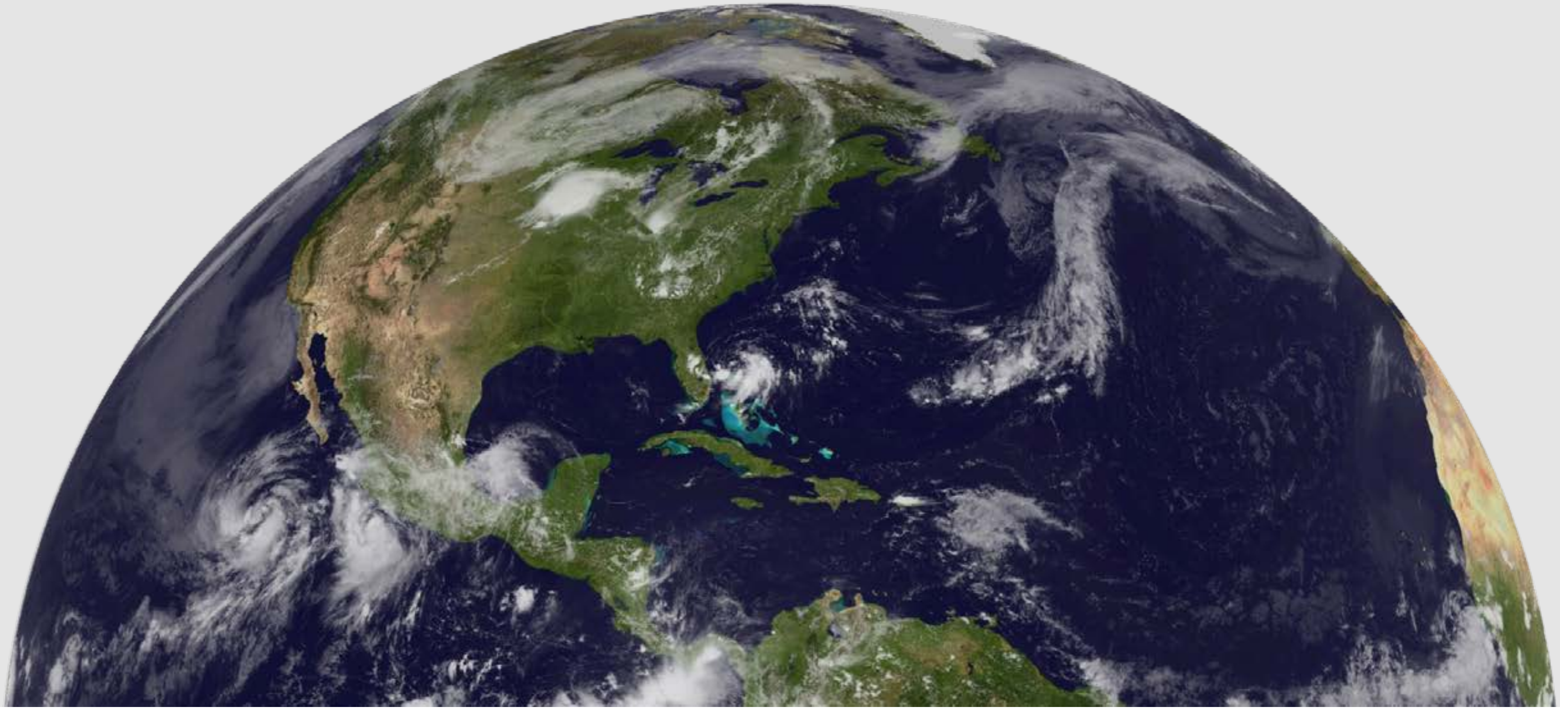
VISION OF GSICS IN THE 2020s
Shaping GSICS to meet future challenges

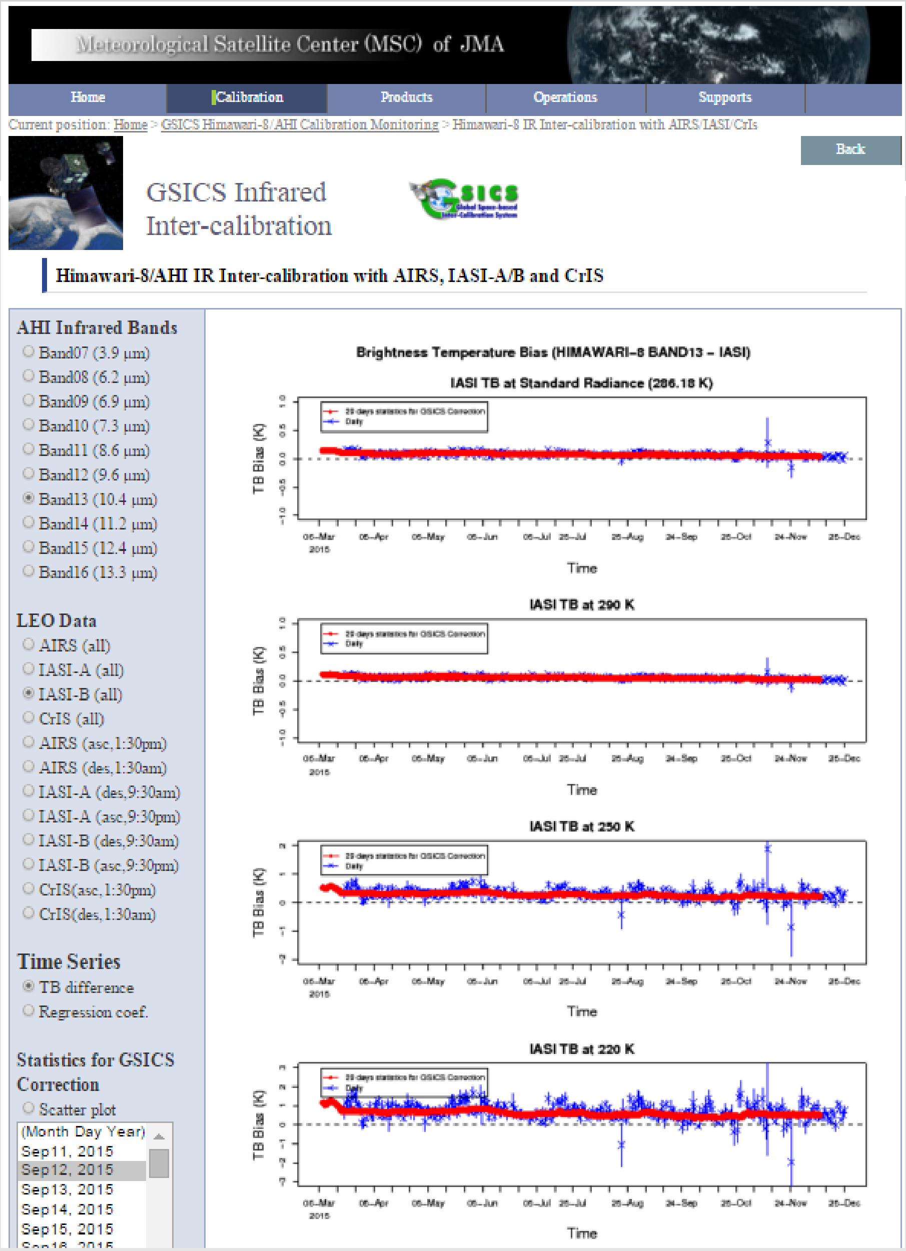
Version 1.1

May 2015

World Meteorological Organization
Weather • Climate • Water

Questions?





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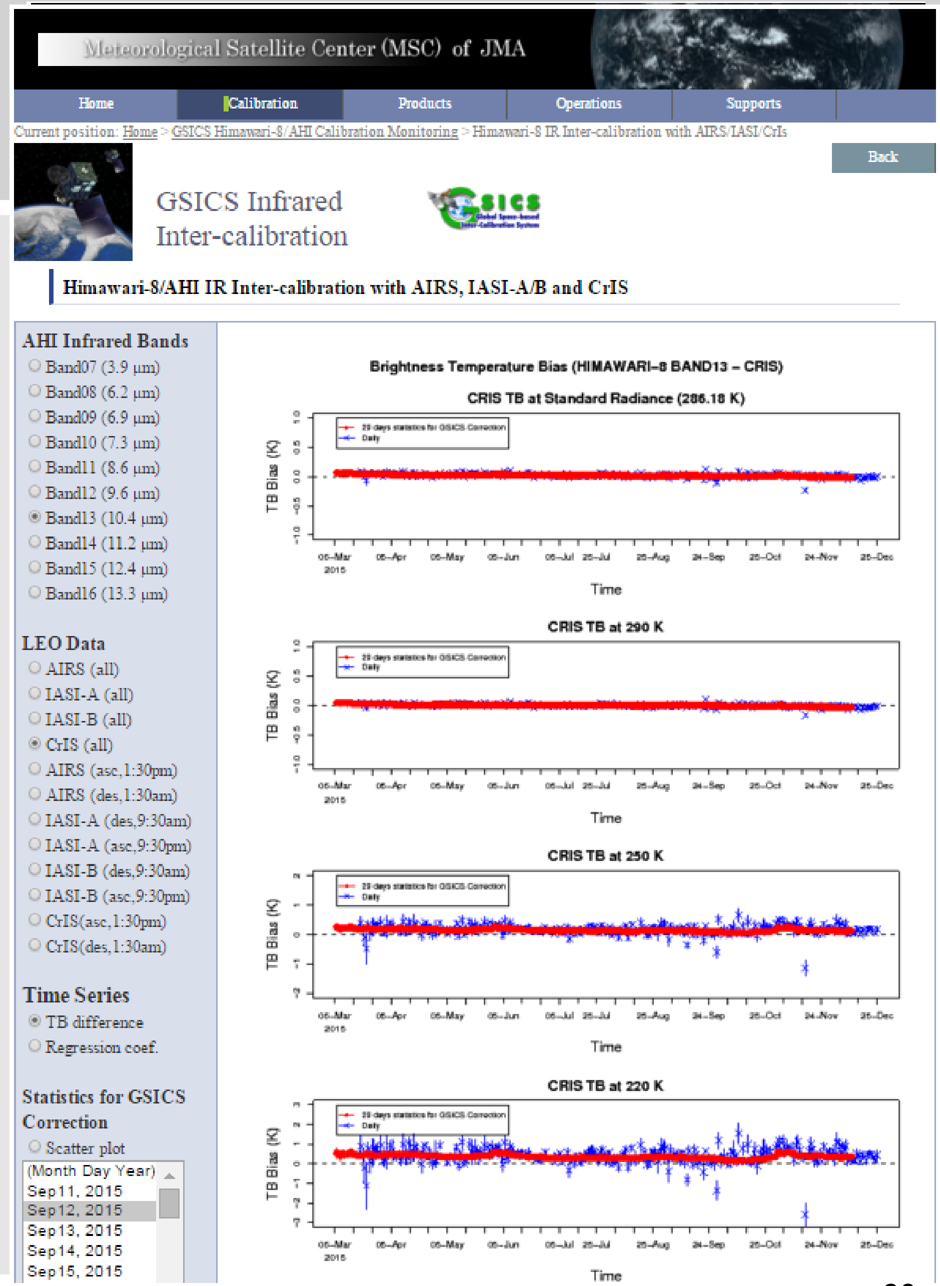

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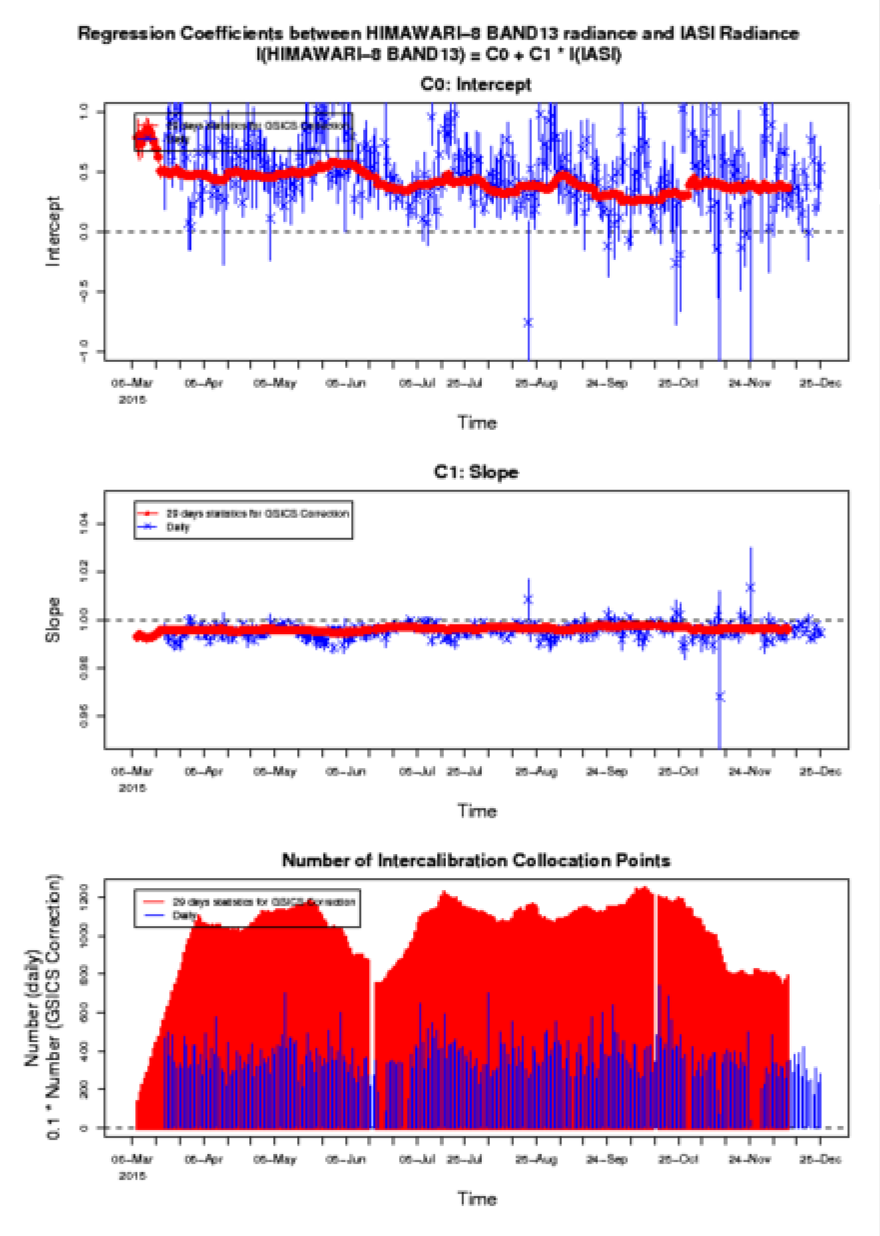
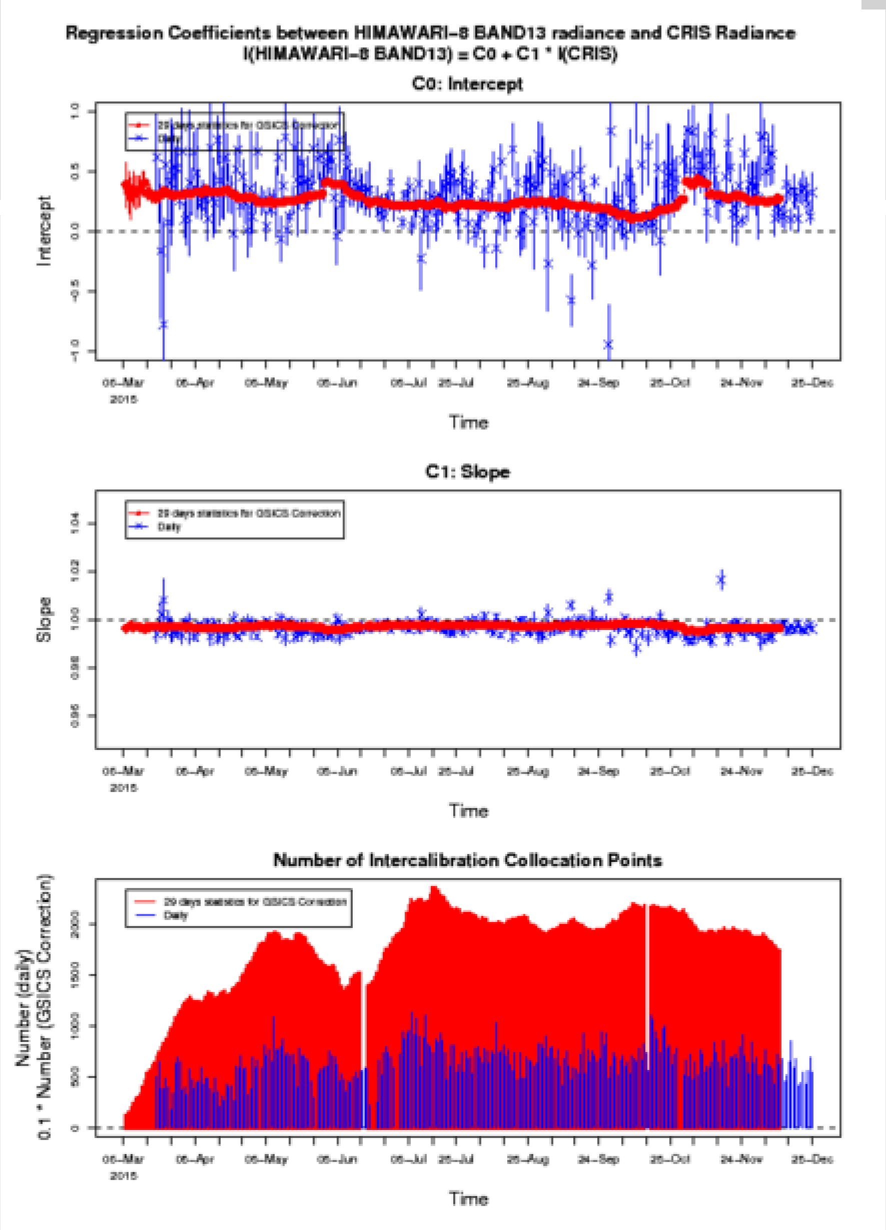
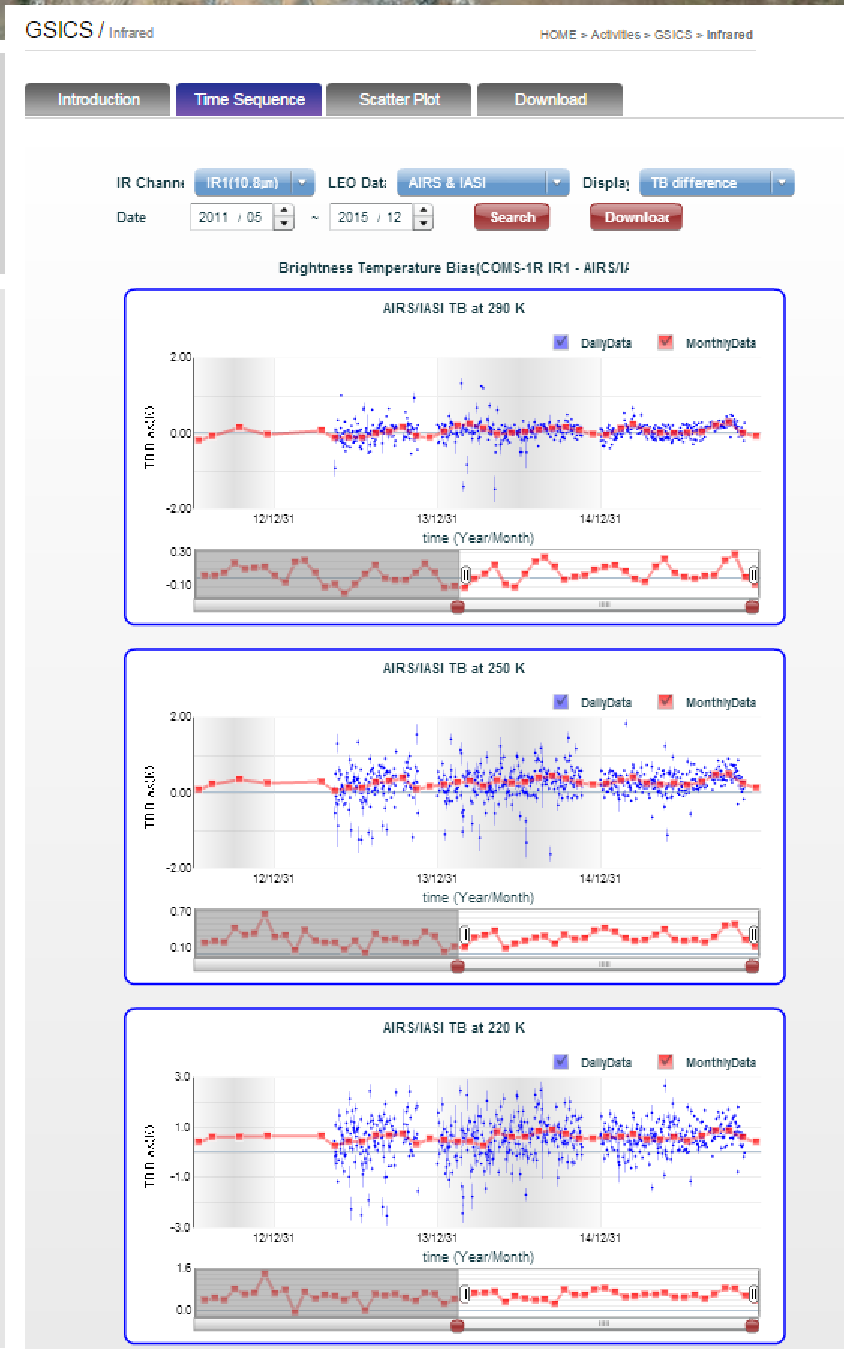
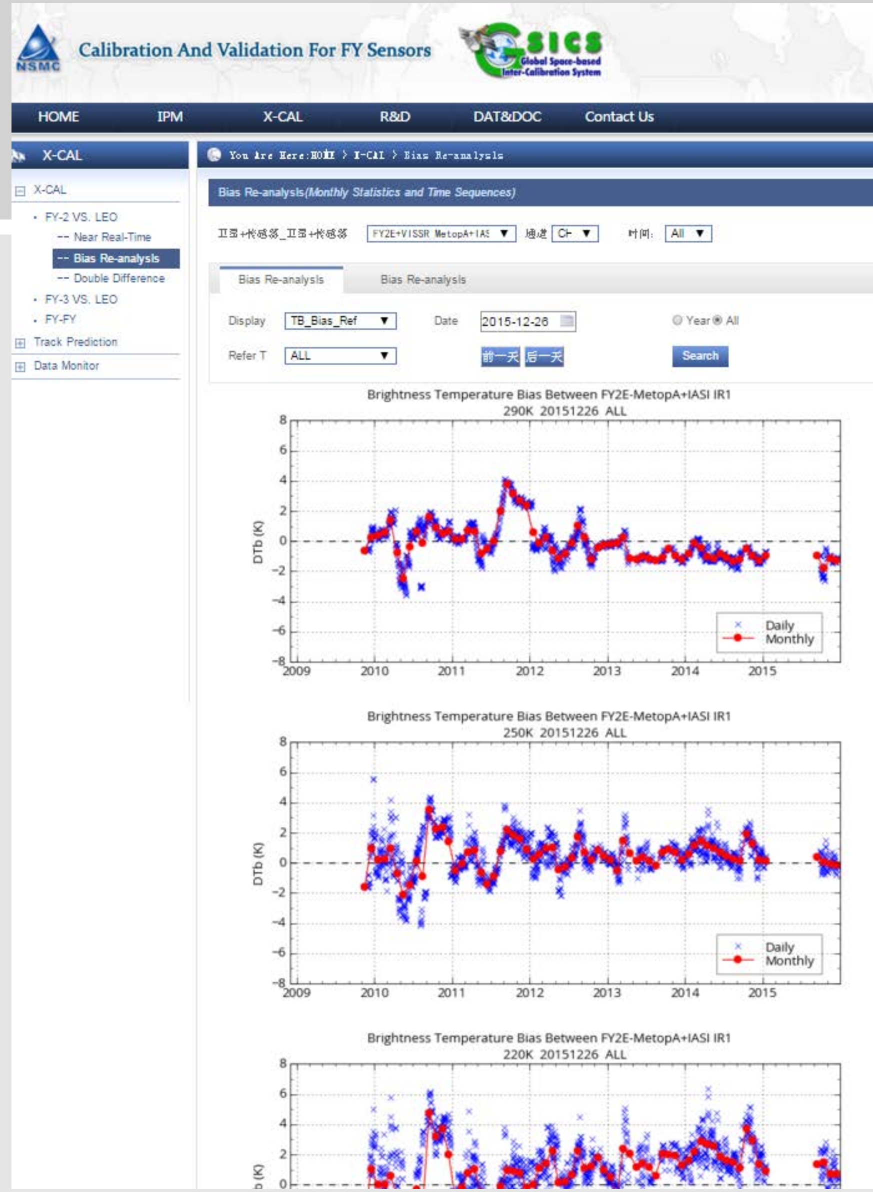
IASI-A (des,9:30am)
IASI-A (asc,9:30pm)
IASI-B (des,9:30am)
IASI-B (asc,9:30pm)
CrIS(asc,1:30pm)
CrIS(des,1:30am)
Time Series
TB difference
Regression coef.
Statistics for GSICS Correction
Scatter plot
(Month Day Year)
Sep11, 2015
Sep12, 2015
Sep13, 2015
Sep14, 2015
Sep15, 2015
Brightness Temperature Bias (HIMAWARI-8 BAND13 – CRIS)
CRIS TB at Standard Radiance (286.18 K)
CRIS TB at 290 K
CRIS TB at 250 K
CRIS TB at 220 K
TB Bias (K)
Time


Regression Coefficients between HIMAWARI-8 BAND13 radiance and IASI Radiance
I(HIMAWARI-8 BAND13) = C0 + C1 * I(IASI)
C0: Intercept
Intercept
Time
C1: Slope
Slope
Time
Number of Intercalibration Collocation Points
Number (daily)
0.1 * Number (GSICS Correction)
Time


Regression Coefficients between HIMAWARI-8 BAND13 radiance and CRIS Radiance
I(HIMAWARI-8 BAND13) = C0 + C1 * I(CRIS)
C0: Intercept
Intercept
Time
C1: Slope
Slope
Time
Number of Intercalibration Collocation Points
Number (daily)
0.1 * Number (GSICS Correction)
Time


GSICS / Infrared
HOME > Activities > GSICS > Infrared
Introduction
Time Sequence
Scatter Plot
Download
IR Channel IR1(10.8μm)
LEO Data AIRS & IASI
Display TB difference
Date 2011 / 05 ~ 2015 / 12
Search
Download
Brightness Temperature Bias(COMS-1R IR1 - AIRS/IA
AIRS/IASI TB at 290 K
DailyData
MonthlyData
12/12/31
13/12/31
14/12/31
time (Year/Month)
AIRS/IASI TB at 250 K
AIRS/IASI TB at 220 K


Calibration And Validation For FY Sensors
GSICS
Global Space-based Inter-Calibration System
HOME
IPM
X-CAL
R&D
DAT&DOC
Contact Us
X-CAL
FY-2 VS. LEO
Near Real-Time
Bias Re-analysis
Double Difference
FY-3 VS. LEO
FY-FY
Track Prediction
Data Monitor
Bias Re-analysis(Monthly Statistics and Time Sequences)
Display TB_Bias_Ref
Date 2015-12-26
Refer T ALL
Search
Brightness Temperature Bias Between FY2E-MetopA+IASI IR1
290K 20151226 ALL
250K 20151226 ALL
220K 20151226 ALL
DTb (K)
Daily
Monthly