GSICS Products and Projects for UV/Vis

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CEOS AC-VC

3 May 2018

Compiled from presentations by GSICS participants including the GRWG Chair, Dohyeong Kim, and Vice Chairs, Tim Hewison and Scott Hu, GDWG Chair, Masaya Takahashi, GRWG Visible SG Chair, Dave Doelling, GRWG MW SG Chair, Ralph Ferraro, and GCC Deputy Director Manik Bali

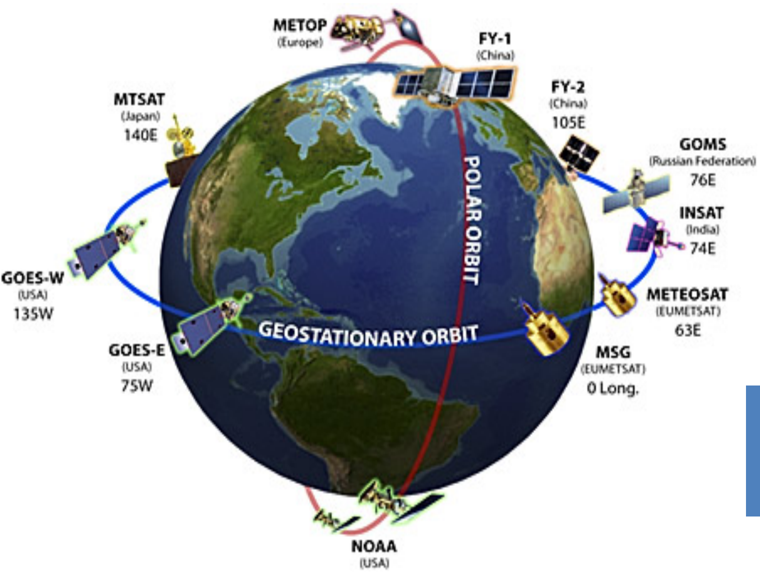
Outline

- Introduction to GSICS Principles, Methods and Resources
- Visible Subgroup activities
- Ultraviolet Subgroup activities

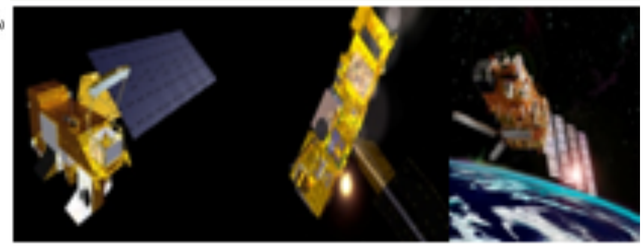
GSICS Introduction

http://gsics.wmo.int/

The Global Space Based Inter-calibration System (GSICS) is an international collaborative effort initiated in 2005 by WMO and the CGMS to monitor, improve and harmonize the quality of observations from operational weather and environmental satellites of the Global Observing System.



GSICS Reference Instruments



AIRS/IASI/CrIS   MODIS/VIIRS

GSICS Component of WIGOS space component through the CGMS

NIST

GSICS Global Space-based Inter-Calibration System

GSICS Research Working Sub-Groups

http://gsics.atmos.umd.edu/bin/view/Development/MeetingsAndConferences

Infrared Sub-Group

Standardized LEO/LEO and GEO/GEO monitoring algorithms.

Developed GEO-LEO monitoring products (SEVIRI, MTSAT, INSAT, Himawari, GOES)

Developed Prime Reference Product.

Multiple products available online via product catalog.

VIS/NIR Sub-Group

Developed techniques to monitor VIS GEO (SEVIRI) instruments.

Developed Techniques that uses the Moon and DCC as calibration targets.

Two products that use DCC as transfer have been accepted in GSICS.

Microwave Sub-Group

Intrusions of the Moon in the Deep Space View.

In-orbit Microwave Reference Records help in re-calibrating MW instruments.

GPM-X GMI inter-calibration.

Ultraviolet Sub-Group

Reference Solar Spectrum
Aim: Evaluate the available reference solar spectra.

Characterization of UV/Vis/NIR/SWIR spectrometers. Aim: Prepare a white paper documenting best-practices for the on-ground calibration of UV/Vis/NIR/SWIR spectrometers based on in-orbit experience from relevant missions

Match-ups and Target Sites. Aim: to produce over-pass comparisons of UV sensors for specific target sites in use by the community.

Cross-calibration below 300nm. Aim: To devise and apply methods for comparison of wavelength pairs for different viewing geometries taking into account contribution function equivalence to allow radiometric performance comparisons for ozone profiles.

GSICS Global Space-based Inter-Calibration System

GSICS Monitoring Products

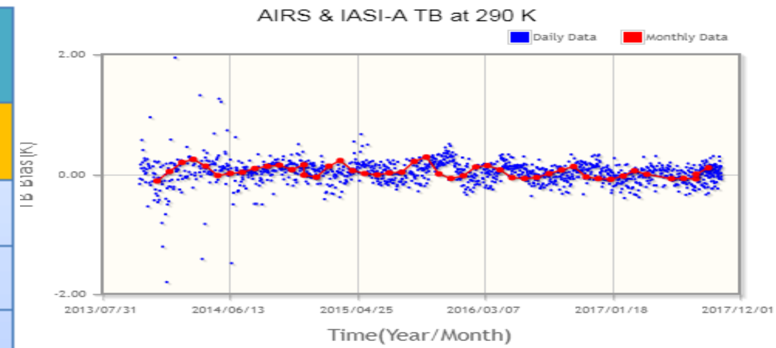
https://www.star.nesdis.noaa.gov/smcd/GCC/ProductCatalog.php

GSICS GEO Products 2017-08

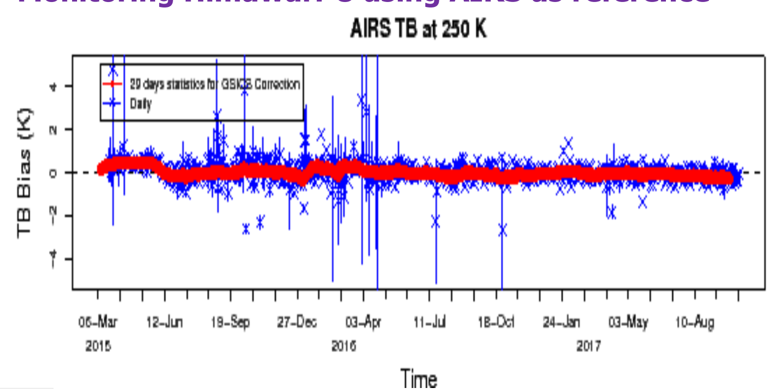
GPRC	Monitored Instrument	IR Method, Reference	IR Product Status	VIS/NIR Method, Reference	VIS/NIR Product Status
EUMETSAT	Meteosat-8-11/SEVIRI	GEO-LEO SNO Metop-A/IASI	Operational	DCC, Lunar Aqua/MODIS	Demo, In Dev
JMA	MTSAT-2 Imager	GEO-LEO SNO IASI (+ AIRS)	Demo		
NOAA	GOES-13 & -15 Imager GOES-11 & -12 Imager	GEO-LEO SNO IASI (+ AIRS)	Pre-op	Pre-op Demo	Prototype
	GOES Sounder	GEO-LEO SNO IASI (+ AIRS)	Development	Development	In development
CMA	FY2C – E	GEO-LEO SNO IASI (+ AIRS)	Development	Development	Prototype
KMA	COMS	GEO-LEO SNO IASI (+AIRS)	Demo		
ISRO	INSAT-3D Imager INSAT-3D Sounder	GEO-LEO SNO IASI	Demo		

Product Summary
Operational 4 products [4 EUMETSAT]
Preoperational 4 products [4 NOAA]
Demonstration 38 products [10 EUMETSAT, 13 NOAA, 12 JMA, 2 ISRO, 1 KMA]

Monitoring COMS using IASI-A as reference



Monitoring Himawari-8 using AIRS as reference



Product Plotting Tool:
http://gsics.tools.eumetsat.int/plotter/

GSICS Global Space-based Inter-Calibration System

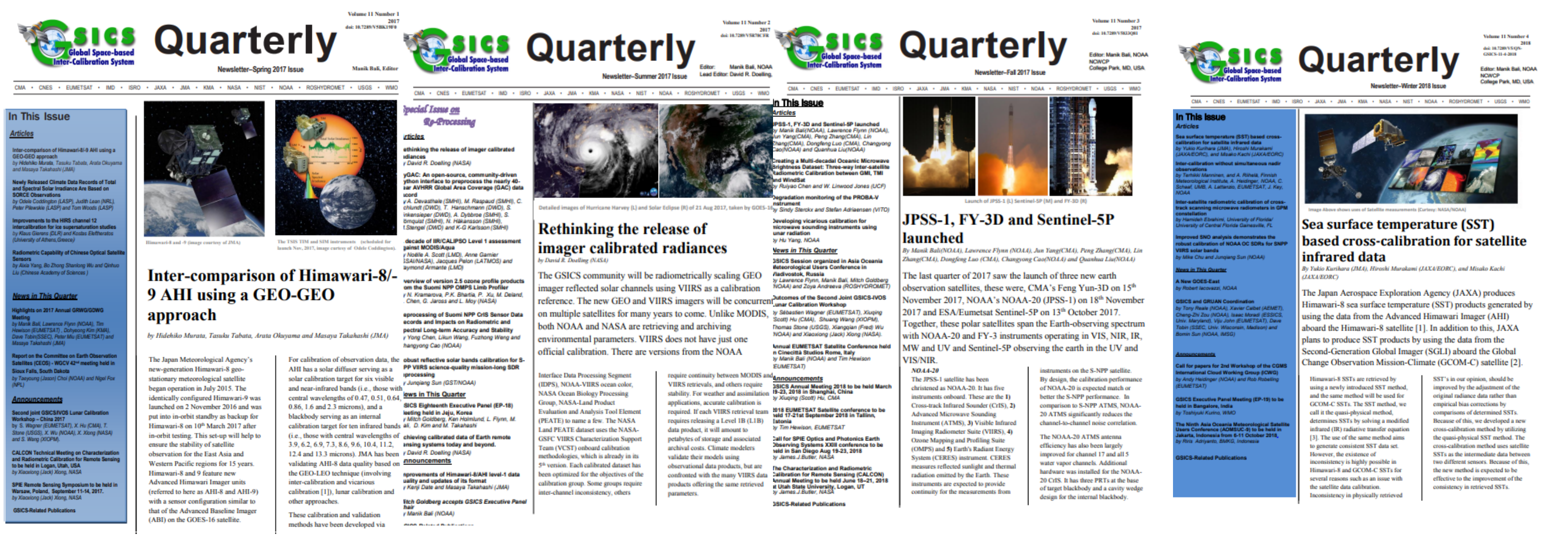
GSICS Activities-GSICS Newsletter

https://www.star.nesdis.noaa.gov/smcd/GCC/newsletters.php

https://www.star.nesdis.noaa.gov/smcd/GCC/index.php

Over the last year, we published four New Issues of the GSICS Newsletter

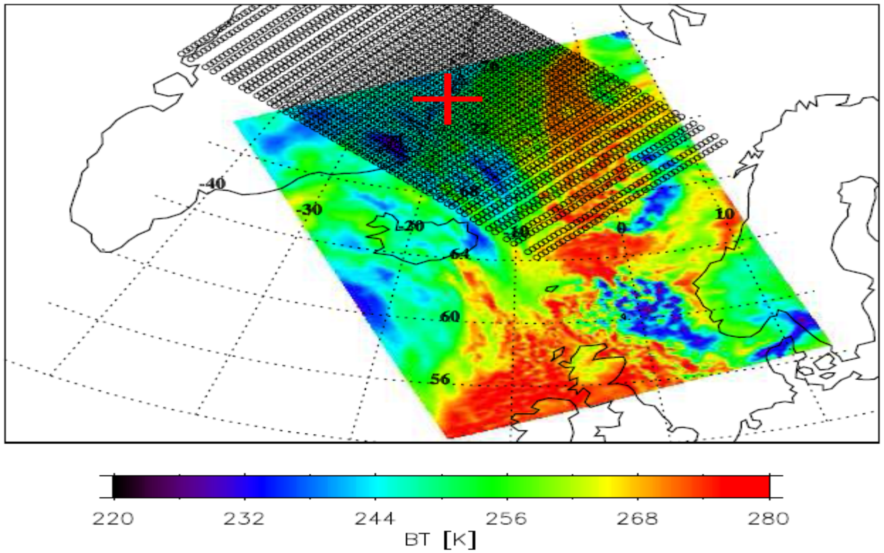
- Over 22 Research Articles, 15 Topics of News to which
- Nearly 70 Scientists contributed as Authors & Co-Authors.
- Reviewed contemporary journal policy on content sharing.
- Contributions from non-GSICS members have increased.
- Next issue (Spring 2018) of the Newsletter is a special Issue on Russian Cal/Val.



GSICS Comparison Method: Example

Simultaneous Nadir Overpass

Step 1. Identification of Collocated Pixels that satisfy GSICS selection criterion.



Step 2. Selection of pixels for inter- comparison

……………………………………Selection Criterion…………………………………………………

GSICS collocated pixel selection criterion

Time difference of observations < 5 Min

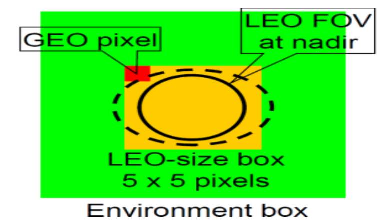
Atmospheric path difference Δsec(sat. zenith angle) < 0.01

Uniformity Constraint

STD (GEO pixels within LEO FOV) < 0.01 K (yellow in figure below).

STD (GEO pixels around the LEO pixel) < 1 K (Green in figure below).

One reference (e.g., IASI) instrument footprint is compare with the averaged value of the GOES pixels falling into that IASI footprint.

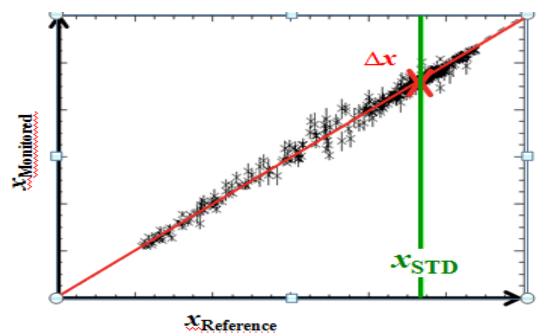


Step 3. Convolution and Comparison

$$L_i = \frac{\int_{\nu_1}^{\nu_2} R(\nu) S_i(\nu) d\nu}{\int_{\nu_1}^{\nu_2} S_i(\nu) d\nu}$$

R is the Hyperspectral Radiance
S is the spectral response function
L is the IASI convolved radiance
V is the wavenumber

Step 4. GSICS Product Regression Coefficients.



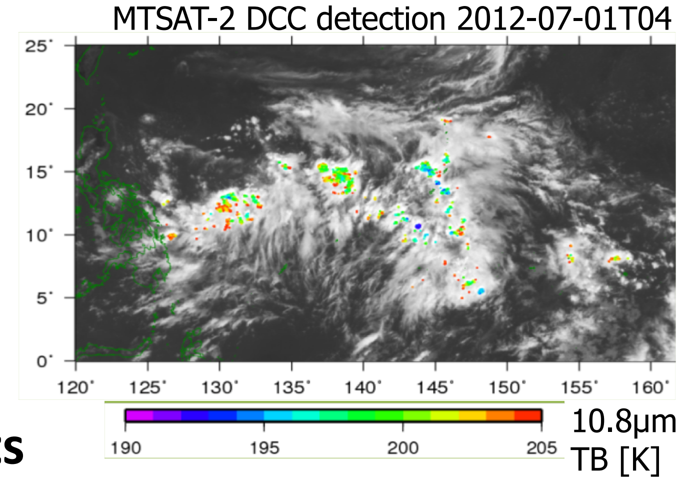
Step 5. Final Result

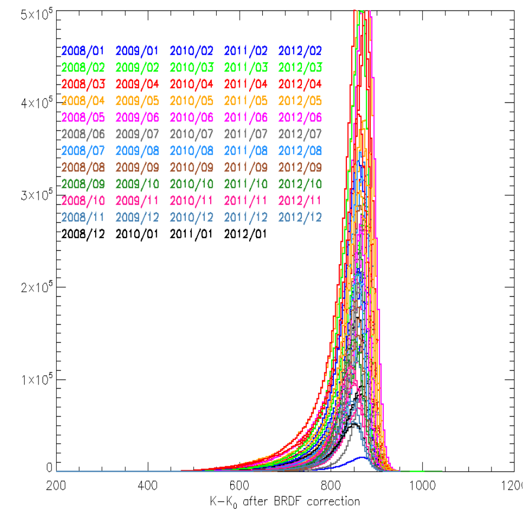
Correction Formula To be applied to a Monitored Instrument

GSICS Global Space-based Inter-Calibration System

GEO-LEO VIS - Deep Convective Clouds (DCCs)

- **Bright, natural solar diffusers**
- **Near Top Of Atmosphere**
  - Little water vapour, aerosol
- **Globally available**
  - In Equatorial Band
- **Use as Pseudo Invariant Targets**
  - to transfer calibration MODIS->GEO
- **Select coldest, brightest pixels**
  - Identify using T_{IR} threshold
  - Homogeneity Tests
  - Limit viewing and solar geometry & Normalis
- **Build up monthly PDF statistics**
- **Compare mode/mean with ref obs**
- **Derive Calibration Coefficients**
  - Seasonal and Land/Sea Variations



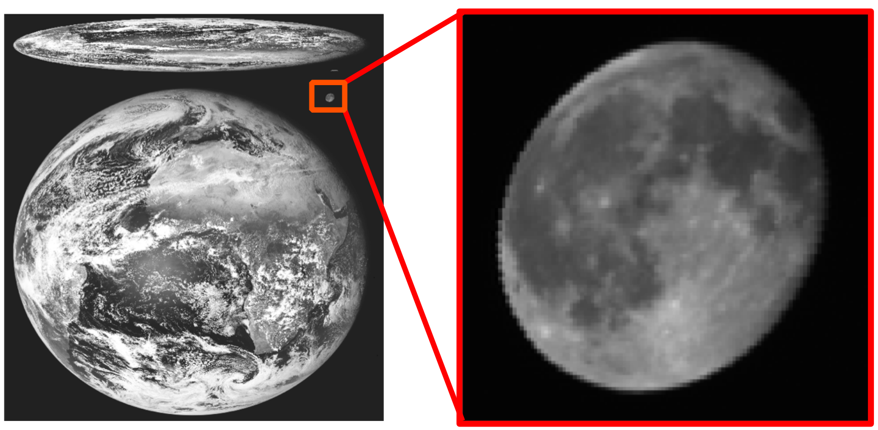


Gains for Meteosat-7/VIS using Aqua/MODIS Reference via DCCs

Lunar Calibration Status

- Preparation of the EUMETSAT License Agreement for distributing the GSICS Implementation of the ROLO (GIRO) model and the GSICS Lunar Observation Dataset (GLOD). First two agreements sent out in February 2017 to USGS and JMA. Once signed by all parties, the license will be provided to the Lunar Calibration Community members. This open the distribution of the GIRO and GLOD.
- Second Joint GSICS/IVOS Lunar Calibration workshop, hosted by CMA November 13~16, 2017 in Xi'an China. Agenda and talks available at http://gsics.atmos.umd.edu/bin/view/Development/20171106

SEVIRI L1.0 image



- Dark, natural solar diffuser
- Extremely stable with no atmosphere
- Globally available

White Paper on Ground-based Characterisation

White Paper still in drafting stage – contributions and/or offers to author sub-sections welcome!

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<u>Proposed table of contents</u>

I. Accuracy, sensitivity and repeatability
II. Sources / commissioning
III. Thermal and pressure environment / stability and characterization
IV. Instrument components
V. Detector level
   a) Noise
   b) PRNU/PPG
   c) SMEAR
   d) Etaloning
VI. Stray-light
VII. Grating and alignment (ISRF)
   a) Spectral assignment
   b) Spectral stability
VIII. Pointing and Spatial stability (ISRF/PSF)
   a) Spatial and spectral aliasing
   b) Radiometric and spectral scene in-homogeneity errors.
   c) Detector co-registration (overlap)
IX. Polarisation sensitivity
X. Radiometric response
   a) Sources
   b) Geometry
XI. Diffuser characterisation
XII. Degradation and contamination

The IEEE Geoscience and Remote Sensing Society/Standards Committee (GRSS/SC) is sponsoring a new standard: P4001 - Standards for Characterization and Calibration of UV-SWIR Hyperspectral Imaging Devices.
http://www.spie.org/SI/special-events/Technical-Event?SSO=1
David Allen of NIST is an organizer.

GSICS Action: A.GRWG.2018.10g.1: Tim Hewison (EUMETSAT) to setup a planning web meeting for the workshop on CLARREO-like reference instruments by September 2018.

GSICS UV Solar Spectra Project (UV)

- The purpose of this project is to compare solar measurements from BUV (Backscatter Ultraviolet) instruments.
- The first step is to catalog high spectral resolution solar reference spectra and agree on a common one to use for the project
- For each instrument, participants should provide the following datasets:
  - Solar measurement for some date (wavelength scale, irradiance) adjusted to 1 AU
  - Wavelength scale and bandpass ($\Delta\lambda$, # of points, bandpass centers, normalized bandpass weights)
  - Synthetic spectrum from common reference (wavelength scale, irradiance)
  - Synthetic for wavelength scale perturbations ($\pm$0.01 nm) from common reference (wavelength scale, irradiance)
  - Synthetic from alternative reference spectra (wavelength scale, irradiance)
  - Solar activity pattern (wavelength, relative change)
  - Mg II index (if 280 nm is covered) Mg II 279.6 Mg I 285.2 (date, index)
  - Ca H/K index (if 391 nm to 399 nm is covered) CA II 393.4 and 396.8.
- Goals:
  - Agreement at 1% on solar spectra relative to bandpass-convolved high resolution spectra as a transfer after identifying wavelength shifts and accounting for solar activity
  - Long-term solar spectral measurement drift and instrument degradation by using OMI solar activity pattern (with internal confirmation from Mg II Indices and scale factors)

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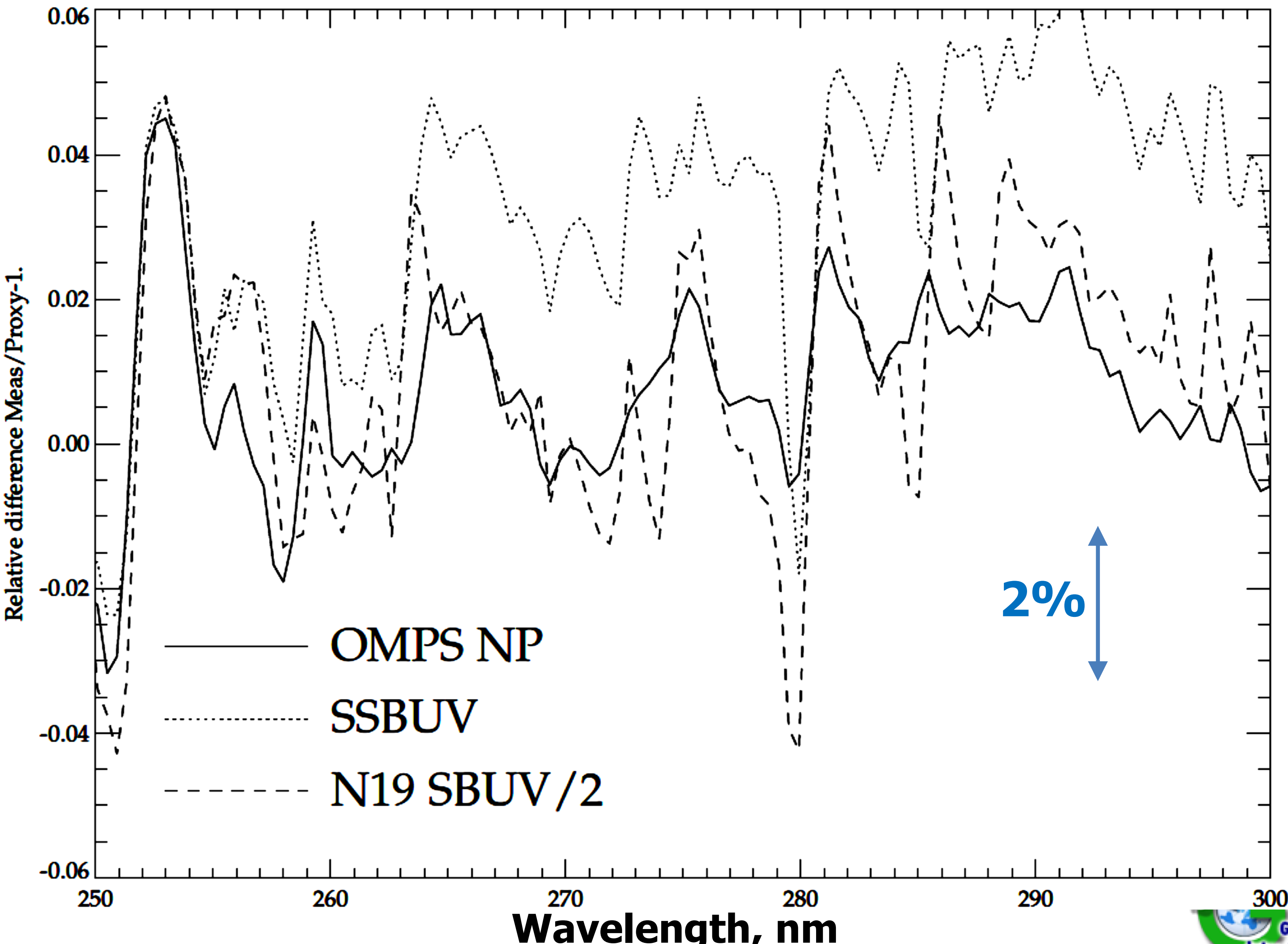
Solar Measurement Comparisons to KNMI Proxy

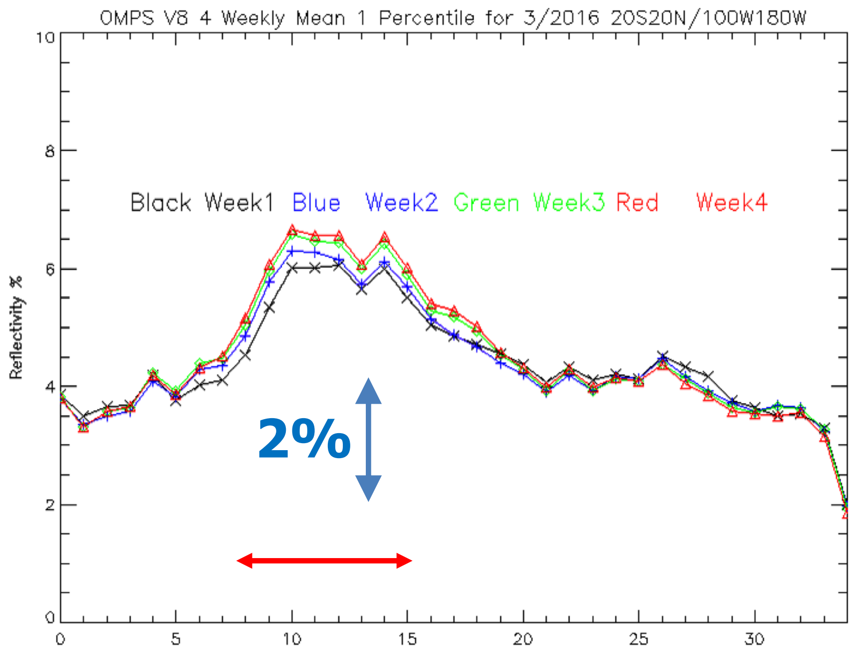


Background: Effective Reflectivity Project

The aim is to produce over-pass comparisons of UV/Vis sensors for specific target sites or regions in use by the community. As a first step, summaries of methods and results for target sites currently in use will be collected. We will compare measurements at reflectivity channels from 330 nm to 500 nm.

- Ice sheets, deserts, vegetative land and open ocean targets.
- Absolute Radiance/Irradiance check; Track variations over time.
- Reflectivity range/distribution, 1-percentile, Deep Convective Clouds (DCC)
- Wavelength Dependence – Aerosol Indices, Clean atmospheres
- Complications
  - Viewing and Solar angle considerations
  - Sun Glint
  - Surface pressure
  - Partially cloudy scenes
  - Polarisation
  - Inelastic Scattering
  - Turbidity, chlorophyll
- Compare Global monthly surface reflectivity data bases
- Goals
  - Agreement at 1% on cloud free scene reflectivity for 340 nm. Desert, Equatorial Pacific, Polar Ice.
  - Agreement at 1% on aerosol index – wavelength dependence of reflectivity.
  - Long-term reflectivity channels at 0.5% stability

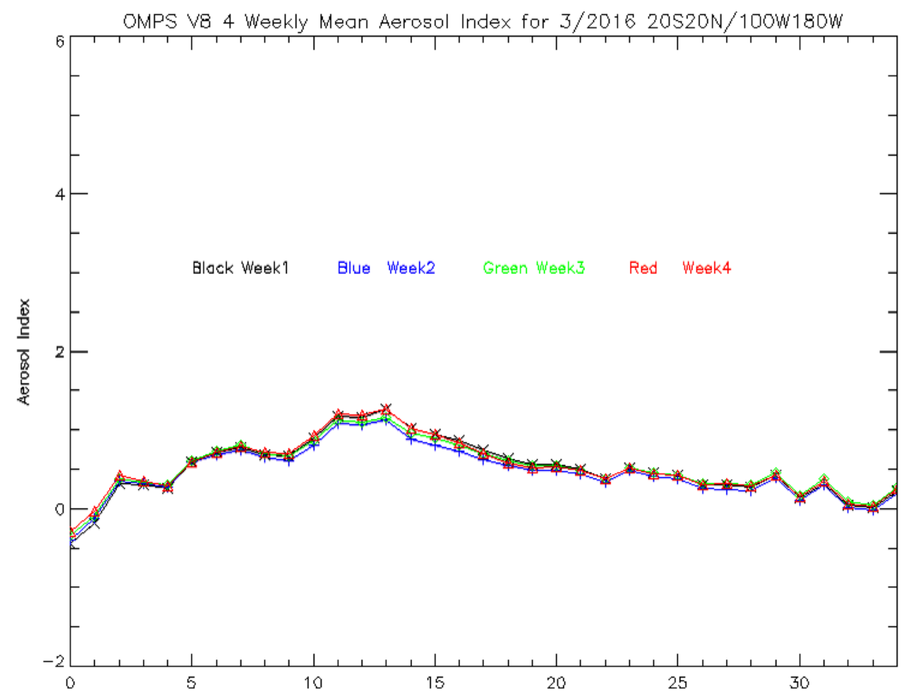
Cross-Track Internal Consistency for OMPS



Cross-Track, Pixel #

← Weekly Effective Reflectivity values for the V8 algorithm for March 2016 for all the data in a latitude/ longitude box in the Equatorial Pacific versus cross-track view position, 17 is nadir. We expect the 1-percentile values to be approximately 5% for this region of the globe. The cross-track variations for positions 8 to 15 are related to sun glint effects.

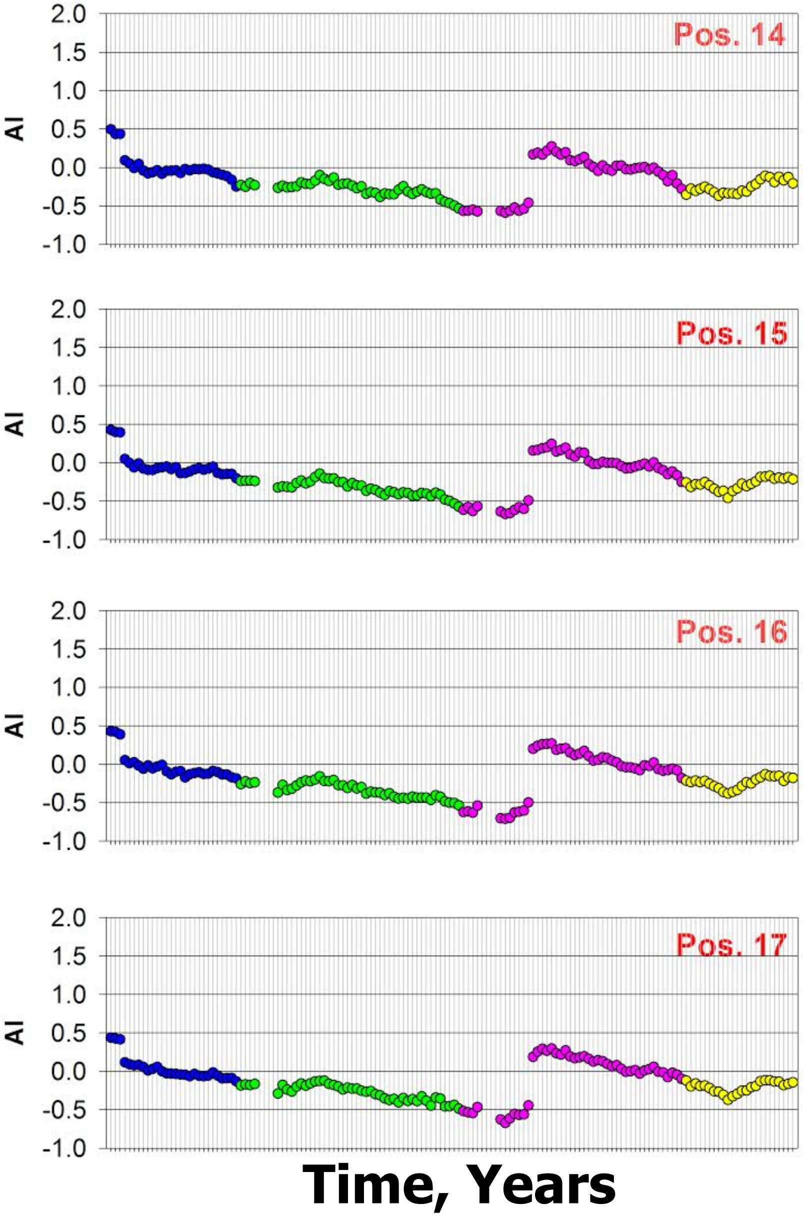
Weekly Aerosol Index values for the V8 → algorithm for March 2016 for all the data in a latitude/ longitude box in the Equatorial Pacific versus cross-track view position, 17 is nadir. We expect the aerosol index values to be approximately zero N-values for this region of the globe. The cross-track variations for positions 8 to 15 are related to sun glint effects.



Cross-Track, Pixel #

Global Space-based Inter-Calibration System

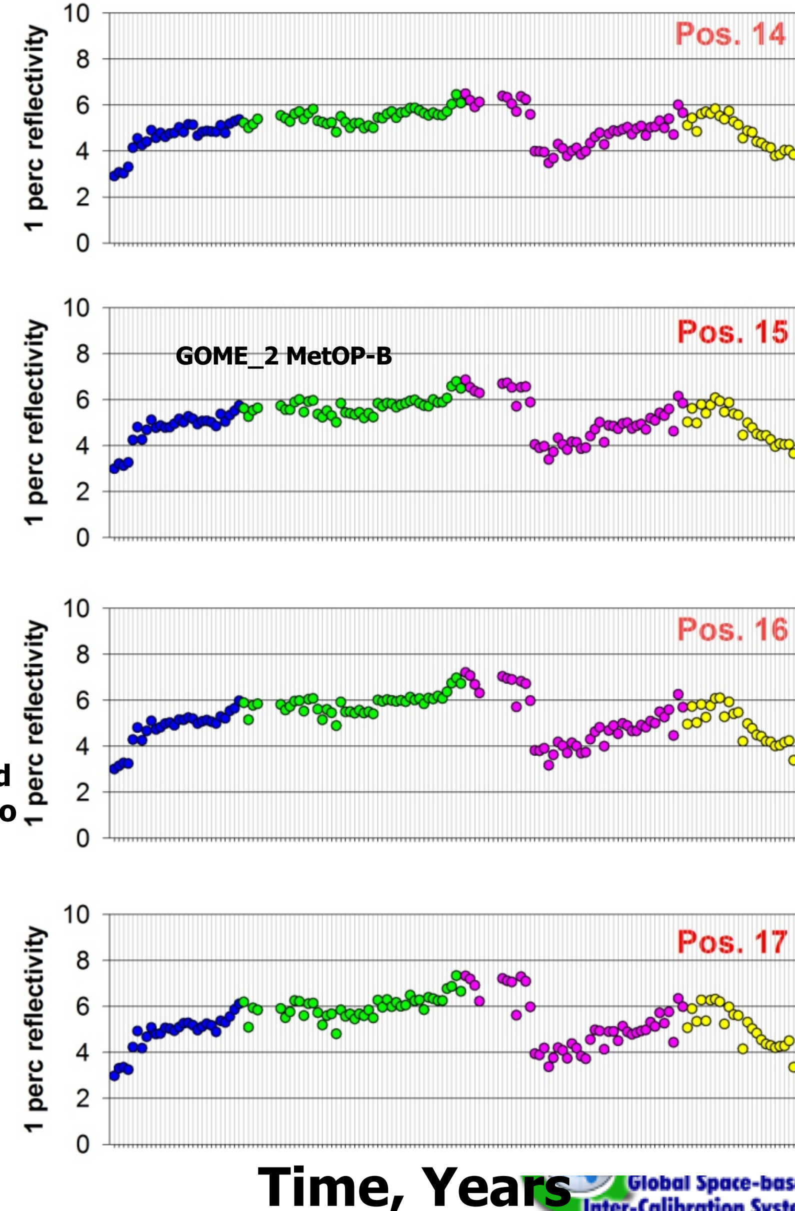
We are examining the V8 TOMS algorithm reflectivity and Aerosol Index Values for an Equatorial Pacific Region for OMPS, OMI and GOME-2



← Time Series of GOME-2 Aerosol Index (360 nm versus 331 nm) Equatorial Pacific

Time Series of GOME-2 → 1-percentile Reflectivity Equatorial Pacific

Jumps are from NOAA-applied soft calibration adjustments to the operational products.



Global Space-based Inter-Calibration System

Initial Measurement Residual Project

The purpose of this project is to use initial measurement residuals from the Version 8 ozone profile retrieval algorithm to compare channels from 240 nm to 290 nm. (Note, this will require modification of the first guess creation to use consistent total ozone starting values as inputs.)

- Ascending/descending equivalent channel ideas will be used with hyperspectral measurements.
- Zonal mean and other matchup criteria will be used both to establish offsets and track relative drifts.
- Expand SBUV(/2) results to other sensors (OMPS, SBUS, OMI, GOME-2)
- Monitor time dependence for multiple instruments.

http://www.star.nesdis.noaa.gov/smcd/spb/OMPSDemo/proSBUV2released-2.php

http://www.star.nesdis.noaa.gov/smcd/spb/OMPSDemo/proOMPSbeta.O3PRO_V8.php

- Goals
  - Agreement at 2% for Profile channels by using the Version 8 *A Priori* Profiles with TOMRad Tables and single scattering.

GSICS Global Space-based Inter-Calibration System

Outline of an Approach for Comparisons of radiance/irradiance ratios from 240 nm to 300 nm

Double Difference using Climatology:

Compute the measurement residuals using a forward model with the effective scene reflectivity of the clouds and surface determined from longer channel measurements, and the ozone profile prescribed by the Version 8 *a priori* climatology. Use viewing geometries and bandpasses are as reported for each instrument.

Compare residuals for channels $\lambda 1$ and $\lambda 2$ where $S1*\alpha 1 = S2*\alpha 2$, where S values give the path lengths and α values give the ozone absorption cross sections. That is, works with pairs of wavelengths where the measurement contribution functions are similar.

Perform comparisons (statistical trade off in quantity of matchups vs. quality)

- Simultaneous nadir overpass matchups
- Zonal means (and No-local-time-difference zonal means)
- Opportunistic formation flying / Chasing orbits
- Benign geographic regions (e.g., Equatorial Pacific Box)
- Ascending/descending zonal means (In the Summer hemisphere, the same latitude is observed twice so one can obtain a set of internal comparisons.)

Forward model and measurements

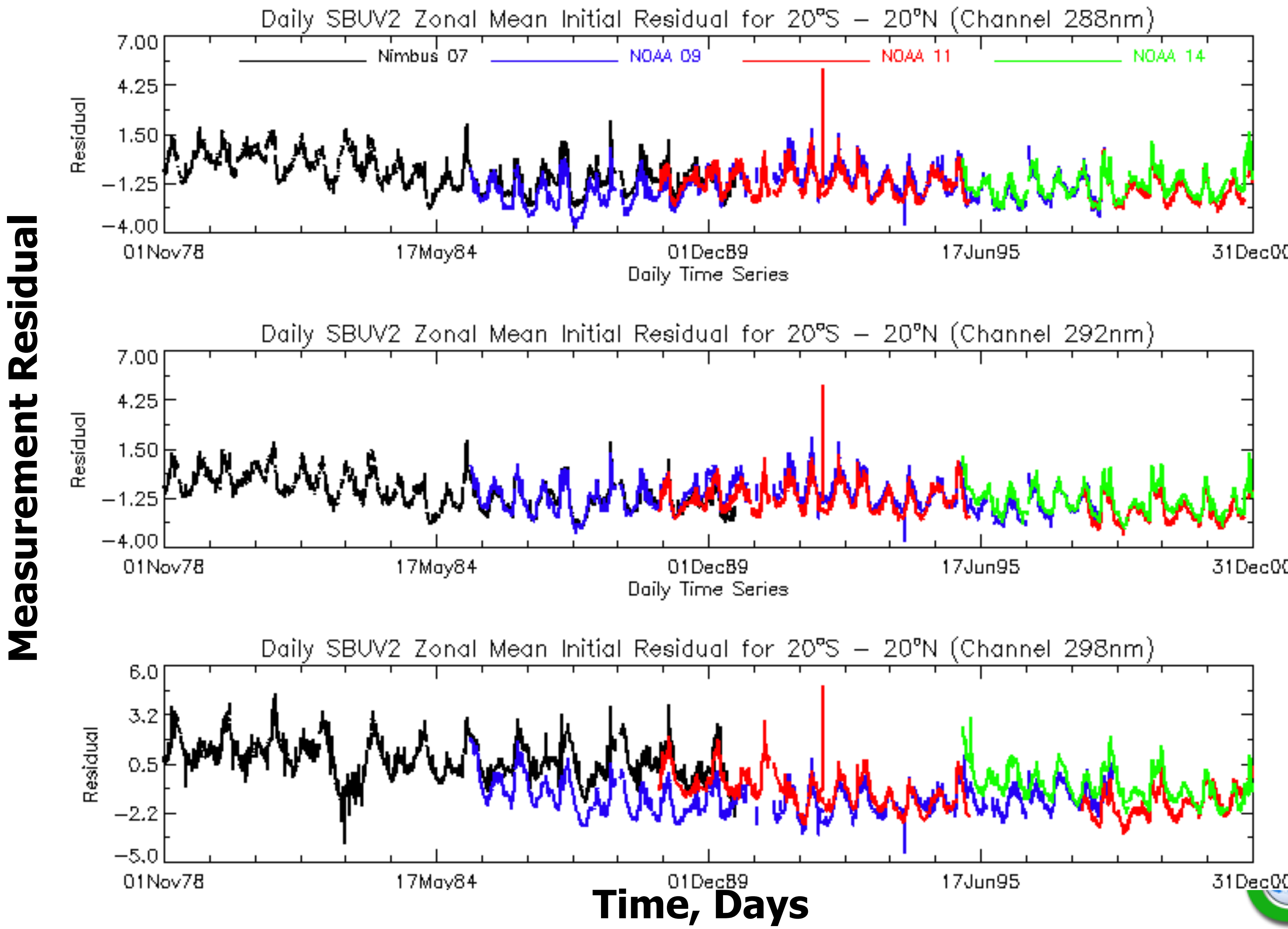
- V8 SBUV/2 forward model and *A Priori* as transfer for Viewing conditions

Complications from real diurnal variations in the ozone profiles

Complications if best ozone product values differ and initial residuals are used

Measurement residuals' correlation with scene reflectivity for longer wavelengths can disclose stray light contamination.

Long-term Inter-calibrated Initial Measurement Residuals for SBUV/2



GSICS Global Space-based Inter-Calibration System

Summary and Invitation

- GSICS has developed well-defined methods and processes to monitor on-orbit instrument calibration.
- You can register with the GSICS Users' Messaging Service at
  https://www.star.nesdis.noaa.gov/smcd/GCC/index.php
- You can access GSICS products through the catalog at
  https://www.star.nesdis.noaa.gov/smcd/GCC/ProductCatalog.php
- You can find information on the meetings of the research subgroups at http://gsics.atmos.umd.edu/bin/view/Development/MeetingsAndConferences
- There are also links there to the agendas and presentations for past meetings.

GSICS Global Space-based Inter-Calibration System

Backup slides and older presentations

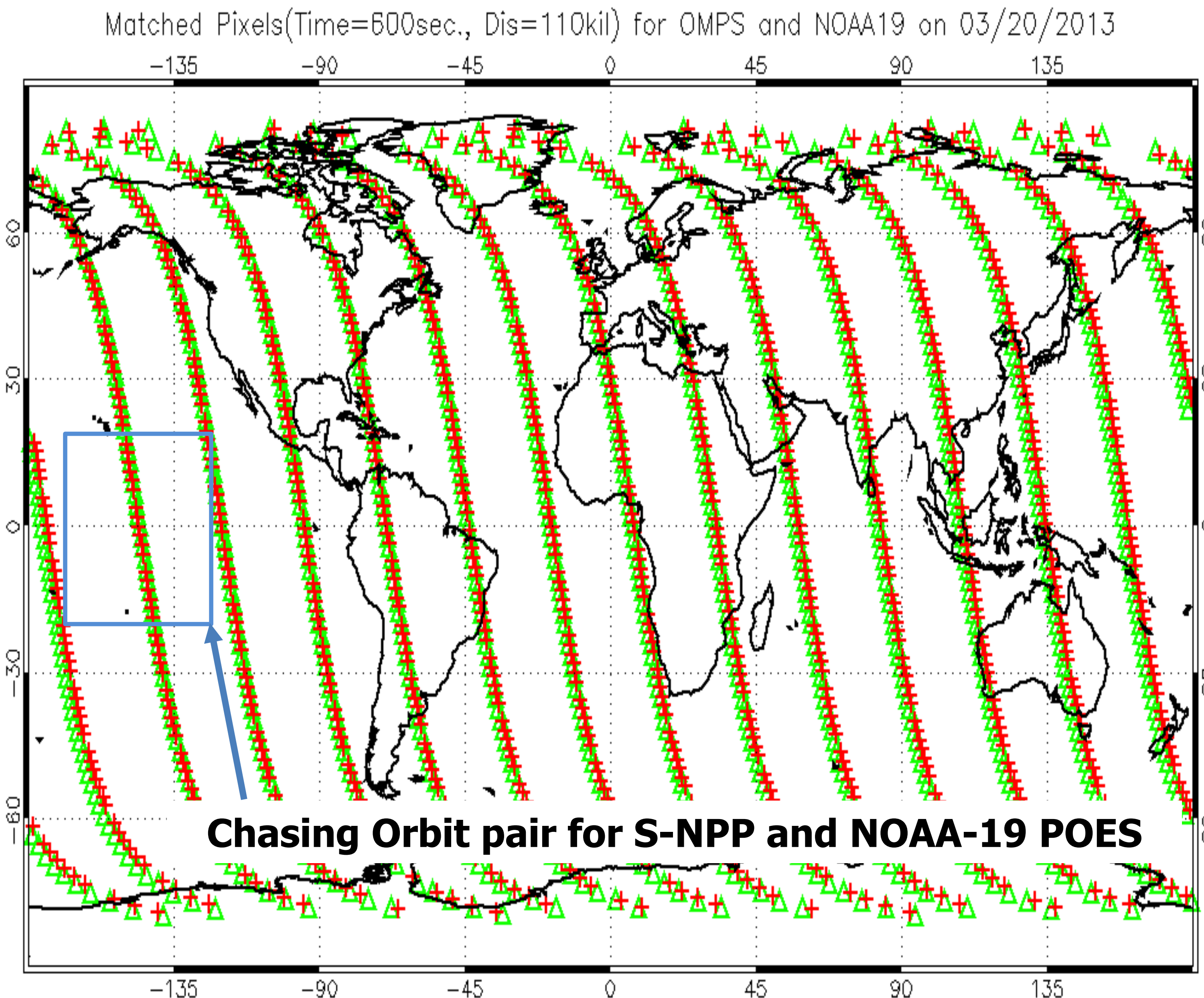
GSICS Research Methods

- Opportunistic Formation Flying
- No-Local Time Difference Latitudes
- Simultaneous Nadir Overpass (SNO)
- Nadir Underpass and Ray Tracing
- GEO Ring
- Spatial and Spectral Resolution
- Deep Convective Clouds as Invariant Targets
- Lunar models
- Rayleigh Scattering
- Measurement Residuals

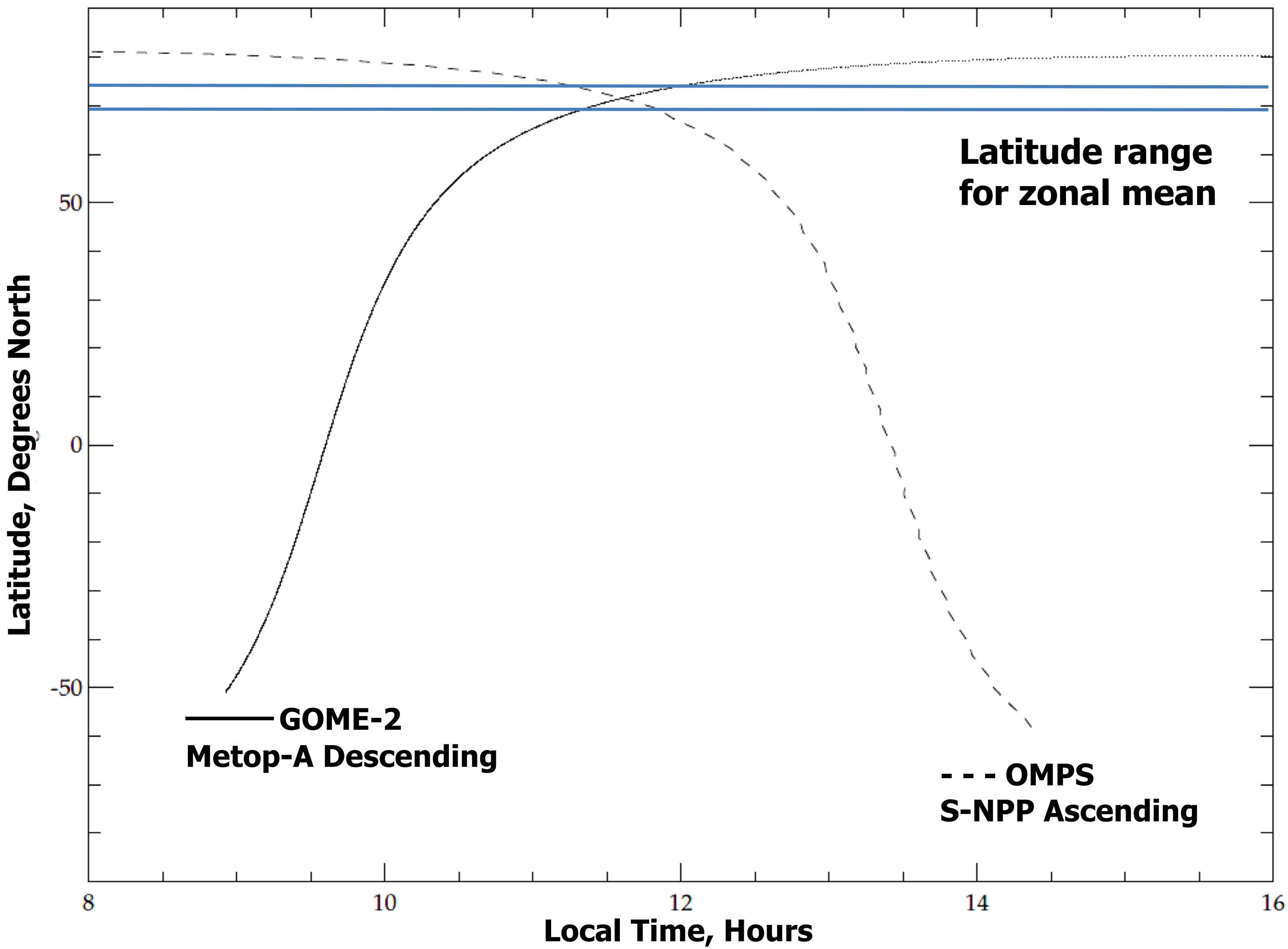
Match-Up Comparisons

Approaches include:

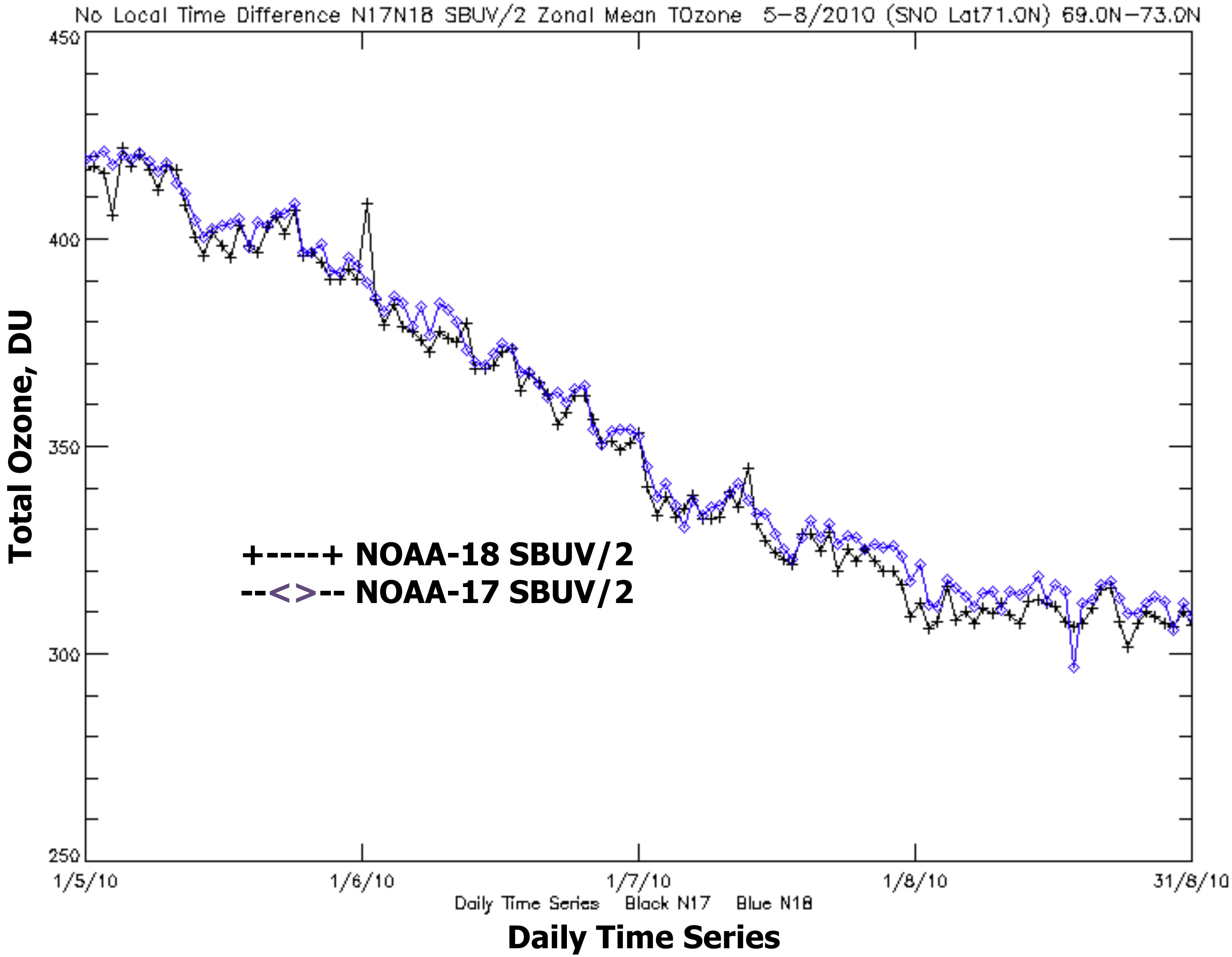
- **Chasing Orbits (Opportunistic Formation Flying)**
  - For example S-NPP and EOS-Aura have 16-day repeat cycles but one makes 227 orbits and the other 233 so once every 16 days they are flying with orbital tracks within (360/14)*110/(14*16*2) ~ 6 km of each other, 15 minutes apart.
- **LEO vs LEO Simultaneous Nadir Overpass (and its non-simultaneous No-Local-Time-Difference zonal means)**
- **LEO underflights of GEO and L-1 instruments – Coincident Line-of-Sight Observations.**
- **Target areas (Desert, Ice Fields, Open Oceans and Zonal Means)**

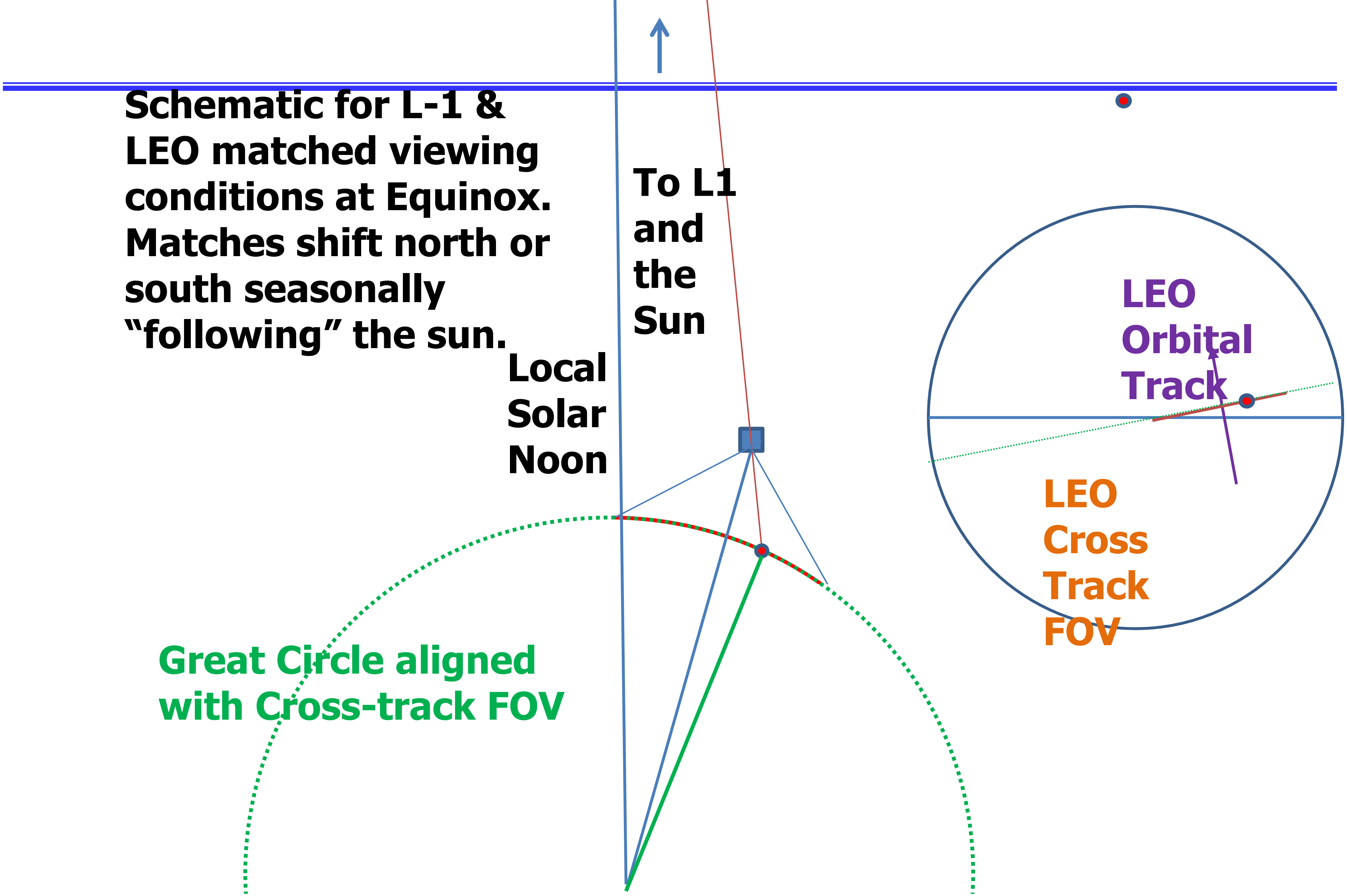

Matched Pixels(Time=600sec., Dis=110kil) for OMPS and NOAA19 on 03/20/2013
Chasing Orbit pair for S-NPP and NOAA-19 POES

Simultaneous Nadir Overpass and No Local Time Difference Comparisons



No Local Time Difference Comparisons, NOAA-17 SBUV/2 & NOAA-18 SBUV/2
May-August 2010, 69 N to 73 N, Daily Zonal Mean

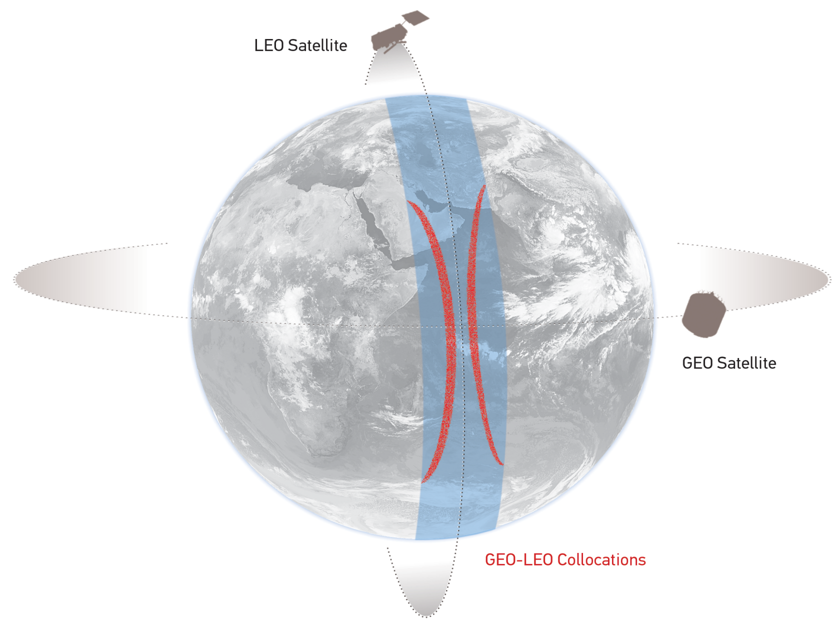




Simultaneous View Path (SVP) match up between DSCOVR EPIC at 0º offset with the Earth/Sun line and S-NPP OMPS. Matches will be present for any BUV instrument on a GEO platform with one in a LEO orbit as the LEO orbital tracks pass near the GEO sub-satellite point.

GEO-LEO IR - Hyperspectral SNO

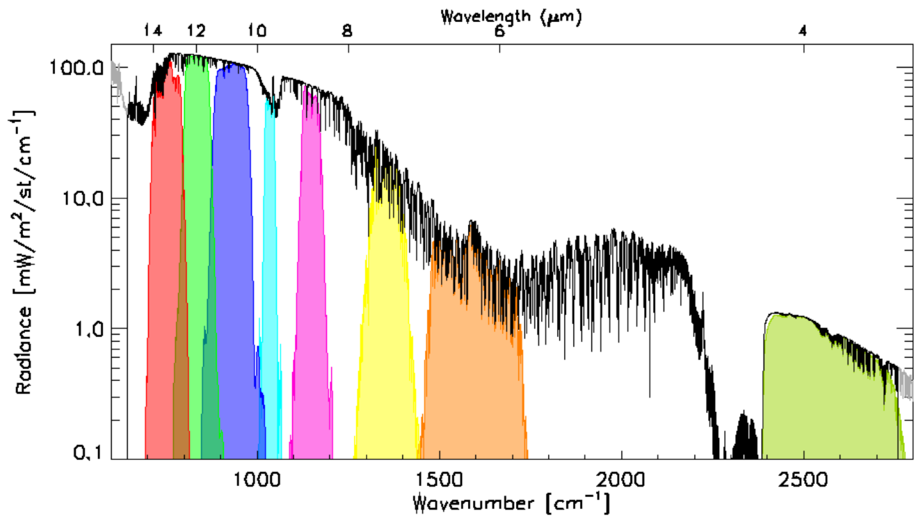
- Simultaneous near-Nadir Overpasses
  - of GEO imager and LEO sounder
- Select Collocations
  - Spatial, temporal and geometric thresholds



Schematic illustration of the geostationary orbit (GEO) and polar low Earth orbit (LEO) satellites and distribution of their collocated observations.

GEO-LEO IR - Hyperspectral SNO

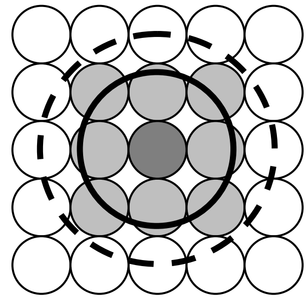
- Simultaneous near-Nadir Overpasses
  - of GEO imager and LEO sounder
- Select Collocations
  - Spatial, temporal and geometric thresholds
- Spectral Convolution:
  - Convolve LEO Radiance Spectra
    with GEO Spectral Response Functions
  - to synthesise radiance in GEO channels



Example radiance spectra measured by IASI (black), convolved with the Spectral Response Functions of SEVIRI channels 3-11 from right to left (colored shaded areas).

GEO-LEO IR - Hyperspectral SNO

- Simultaneous near-Nadir Overpasses
  - of GEO imager and LEO sounder
- Select Collocations
  - Spatial, temporal and geometric thresholds
- Spectral Convolution:
  - Convolve LEO Radiance Spectra with GEO Spectral Response Functions
  - to synthesise radiance in GEO channels
- Spatial Averaging
  - Average GEO pixels in each LEO FoV
  - Standard Deviation of GEO pixels as weight



LEO FoV~10km

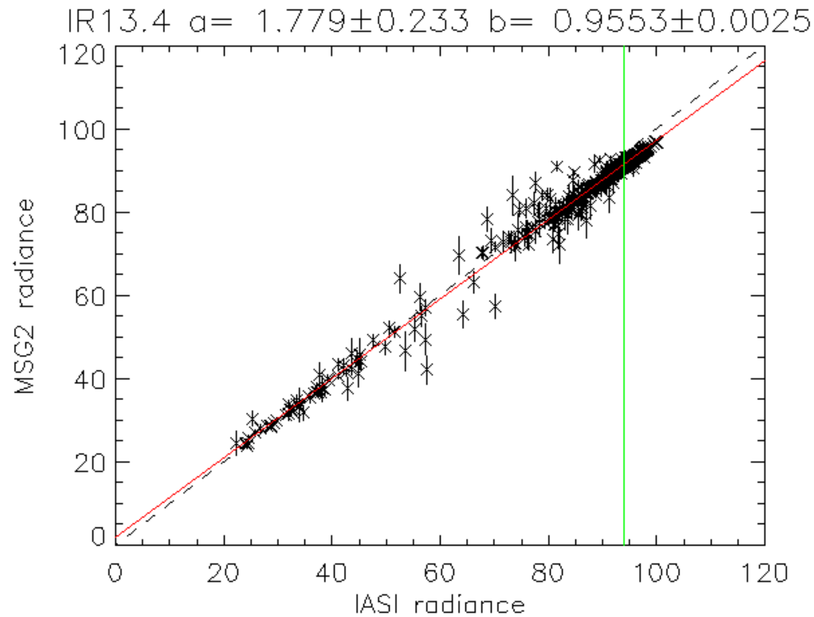
~ 3x3 GEO pixels

Illustration of spatial transformation. Small circles represent the GEO FoVs and the two large circles represent the LEO FoV for the extreme cases of FY2-IASI, where nxm=3x3 and SEVIRI-IASI, where nxm=5x5.

GSICS Global Space-based Inter-Calibration System

GEO-LEO IR - Hyperspectral SNO

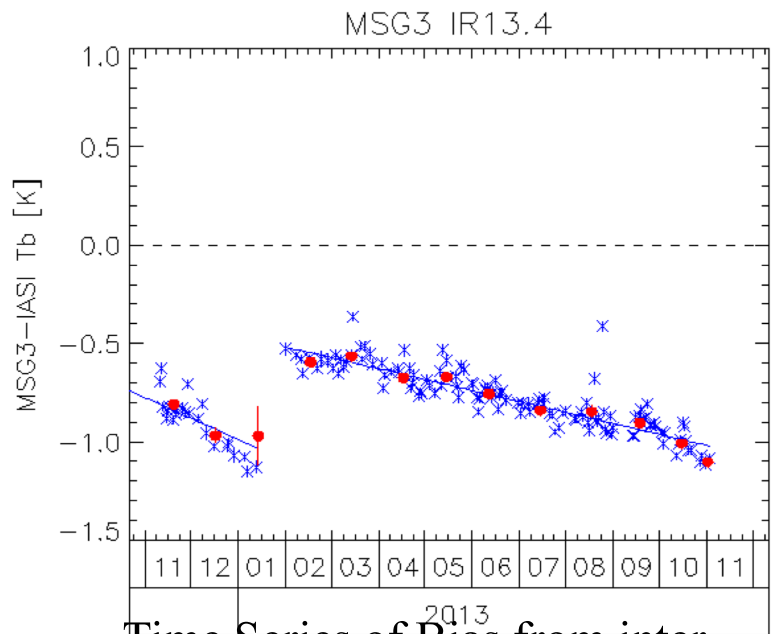
- **Simultaneous near-Nadir Overpasses**
  - of GEO imager and LEO sounder
- **Select Collocations**
  - Spatial, temporal and geometric thresholds
- **Spectral Convolution:**
  - Convolve LEO Radiance Spectra with GEO Spectral Response Functions
  - to synthesise radiance in GEO channels
- **Spatial Averaging**
  - Average GEO pixels in each LEO FoV
  - Standard Deviation of GEO pixels as weight
- **Weighted Regression of LEO v GEO rads**
  - Evaluate Bias for Standard Radiance Scene



Weighted linear regression of $L_{GEO|REF}$ and $\langle L_{GEO} \rangle$ for Meteosat-9 13.4µm channel based on single overpass of IASI

GEO-LEO IR - Hyperspectral SNO

- **Simultaneous near-Nadir Overpasses**
  - **of GEO imager and LEO sounder**
- **Select Collocations**
  - **Spatial, temporal and geometric thresholds**
- **Spectral Convolution:**
  - **Convolve LEO Radiance Spectra with GEO Spectral Response Functions**
  - **to synthesise radiance in GEO channels**
- **Spatial Averaging**
  - **Average GEO pixels in each LEO FoV**
  - **Standard Deviation of GEO pixels as weight**
- **Weighted Regression of LEO v GEO rads**
  - **Evaluate Bias for Standard Radiance Scene**
- **Plot time series of Bias**

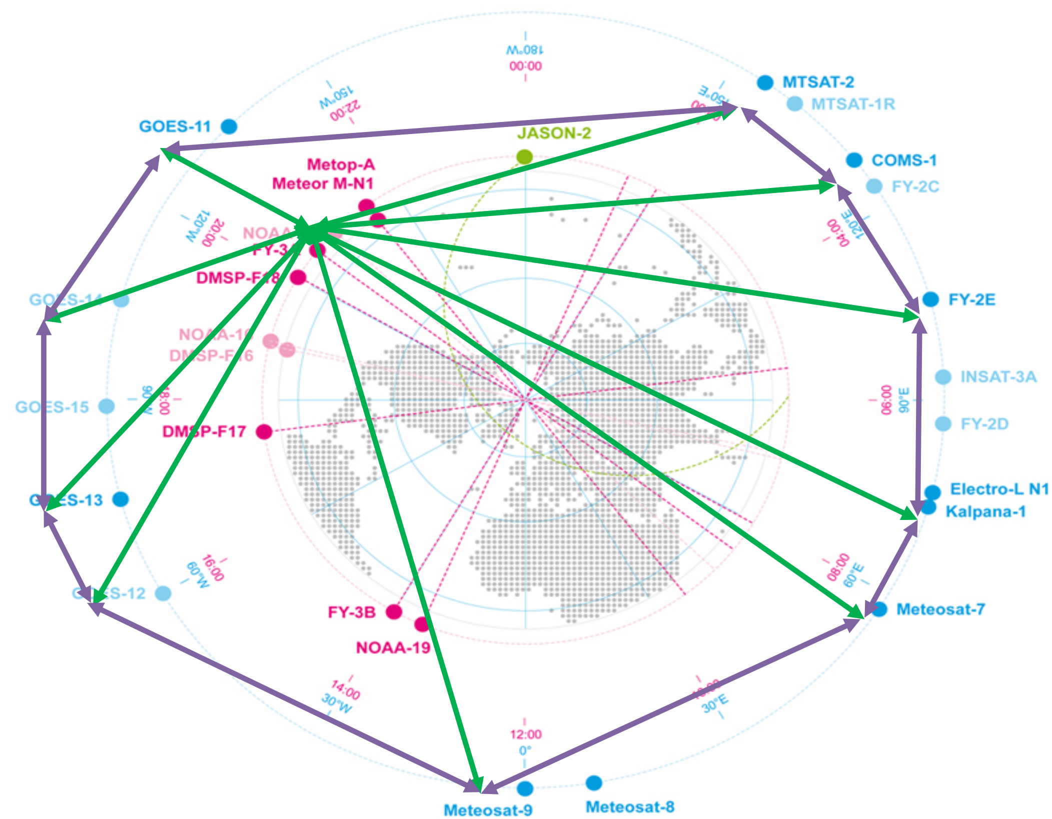


Time Series of Bias from inter-calibration of 13.4μm channel of Meteosat-10/SEVIRI with Metop-A/IASI expressed in Brightness Temperature Bias for Standard Scene Radiance, Blue x = Daily Result, Blue Line=trend, Red dot = Monthly Average

GSICS Global Space-based Inter-Calibration System

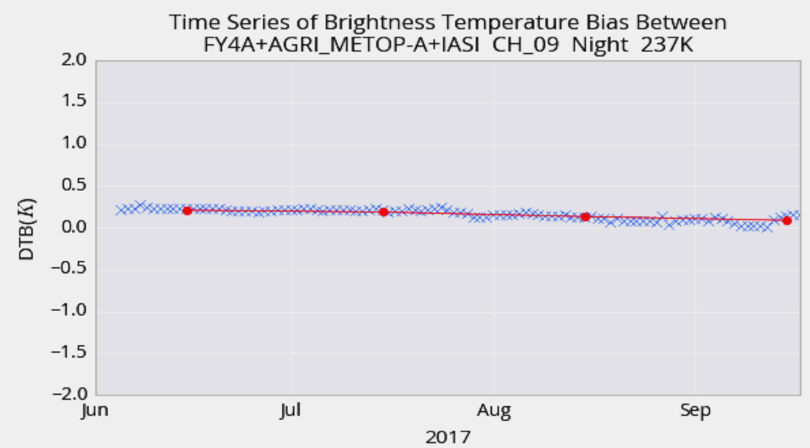
GEO-ring Demonstration Dataset

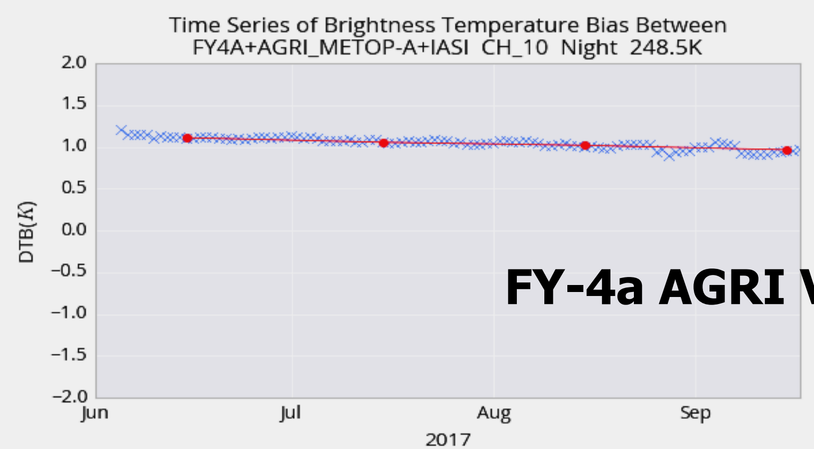
- GSICS Corrections for all GEO imagers
- Inter-calibrate to common reference
  - (Metop-A/IASI)
- Generating GEO-ring demo dataset
  - 2014-03-01 – Every 3hr
  - 2014-03-20 – Every 3hr
- Baseline Channels
  - IR: 4µm, 7µm, 11µm, 13µm
  - VIS: 0.6µm
- SCOPE-CM IOGEO to re-grid & distribute
- Test impact on L2 products
- Other beta testers welcome!
- GEO-GEO Comparisons
  - Based on collocated observations
  - GEO imager pairs
  - Need SBAFs
  - Check internal consistency & Uncertainties

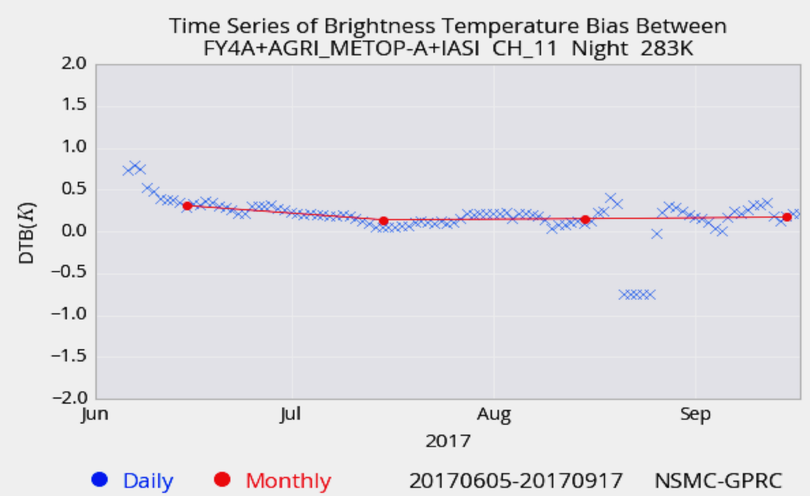


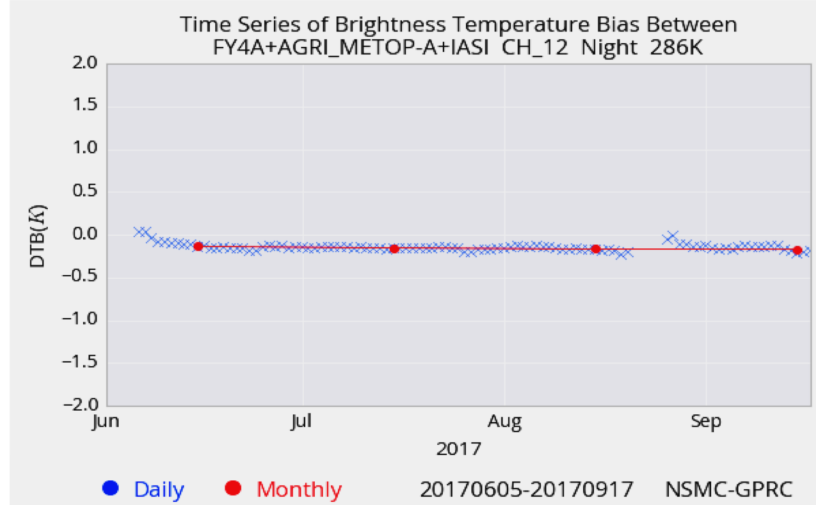
Courtsey Tim Hewison

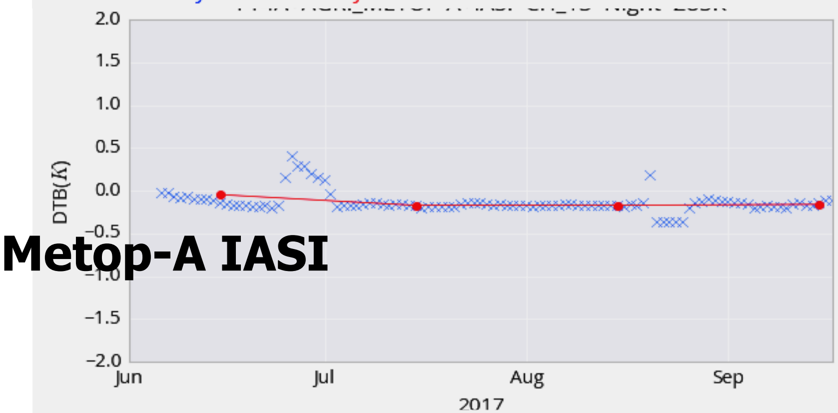
FY-4a AGRI Versus Metop-A IASI

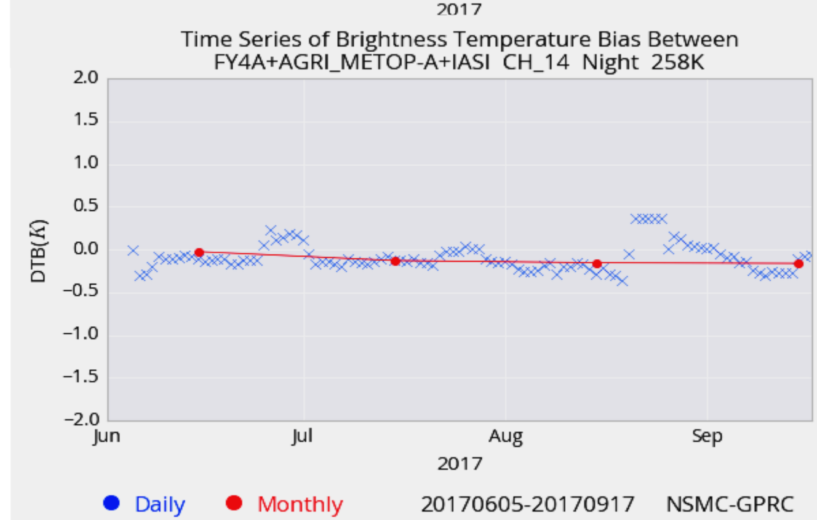






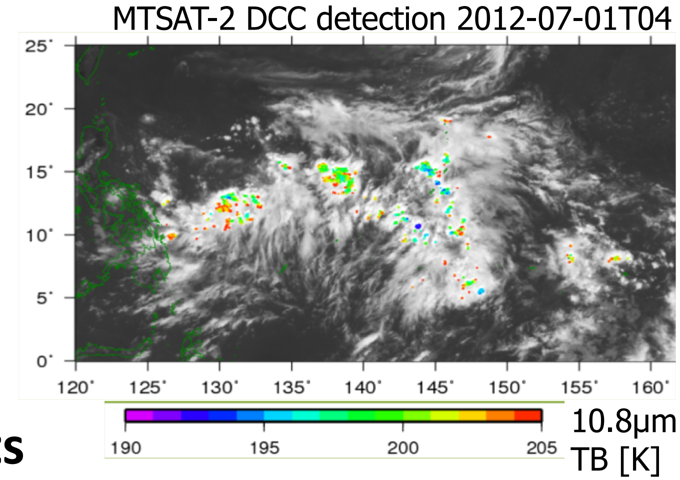


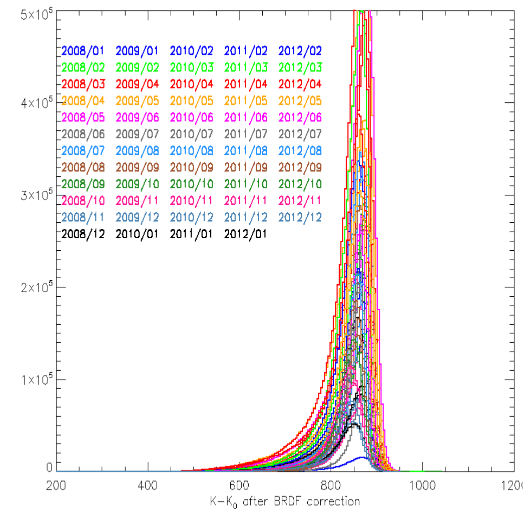




GEO-LEO VIS - Deep Convective Clouds (DCCs)

- **Bright, natural solar diffusers**
- **Near Top Of Atmosphere**
  - Little water vapour, aerosol
- **Globally available**
  - In Equatorial Band
- **Use as Pseudo Invariant Targets**
  - to transfer calibration MODIS->GEO
- **Select coldest, brightest pixels**
  - Identify using T_{IR} threshold
  - Homogeneity Tests
  - Limit viewing and solar geometry & Normalis
- **Build up monthly PDF statistics**
- **Compare mode/mean with ref obs**
- **Derive Calibration Coefficients**
  - Seasonal and Land/Sea Variations





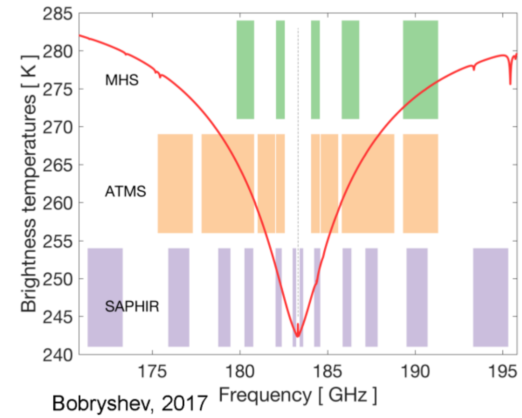
Gains for Meteosat-7/VIS using Aqua/MODIS Reference via DCCs

Microwave Calibration – Challenges, Methods, Progress

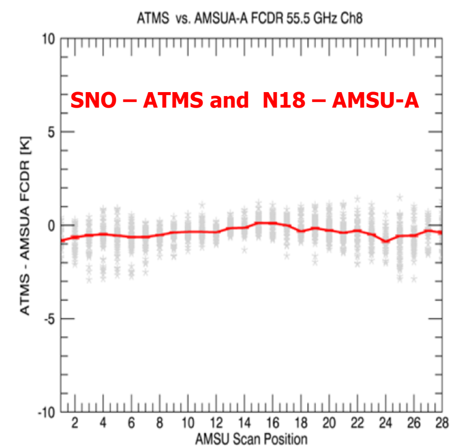
- **Lack of "true" reference for MW**
  - US/NIST is developing on-ground reference for use with JPSS/ATMS
- **Diversity of channel suites and sensors**
  - Window, O_2, H_2O channels
  - Conical/Imagers; cross-track/sounders
- **Progress being made with:**
  - SNO – used by many groups
    - Need "standard" co-location criteria
  - Lunar calibration (M. Burgdorf, Univ. Hamburg)
  - GPM Microwave Imager (W. Berg, Colo. State Univ/NASA X-Cal team)
  - GRUAN observations with RTM (T. Reale, NOAA; H. Lawrence, UKMO)
  - MW FCDR's (K. Fennig, EUMETSAT; C-Z. Zou, NOAA)

The Moon as Reference (I)

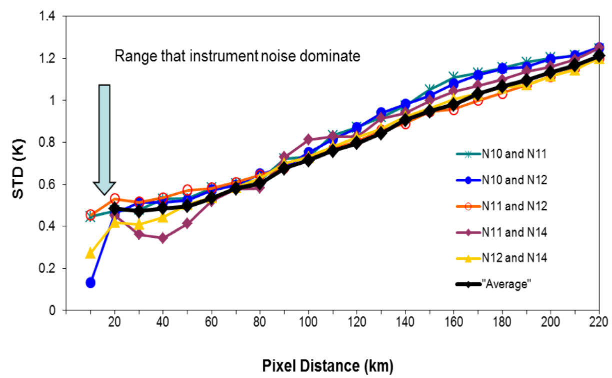
- Common reference for all satellites, past, present, and future
- Potential replacement of SNO for inter-calibration
- No atmosphere => no spectral lines => channels with the same central ν get the same R_ν



Bobryshev, 2017



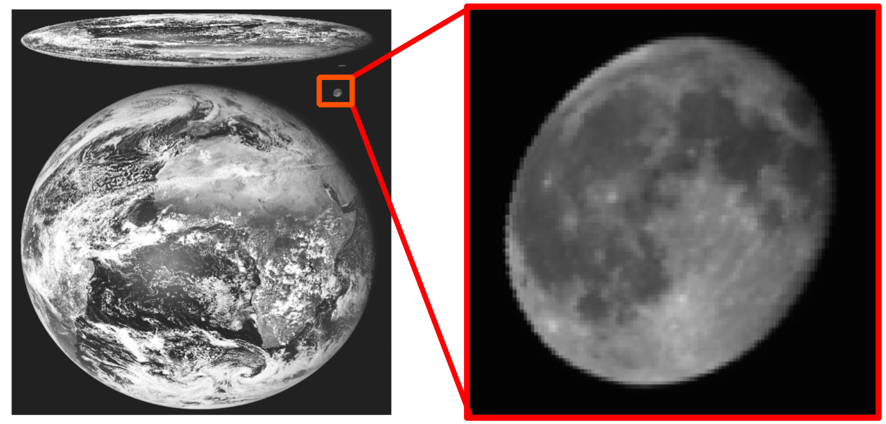
Instrument noises can be used to determine the distance criteria when collecting collocated datasets between GRUAN and MW Sensors

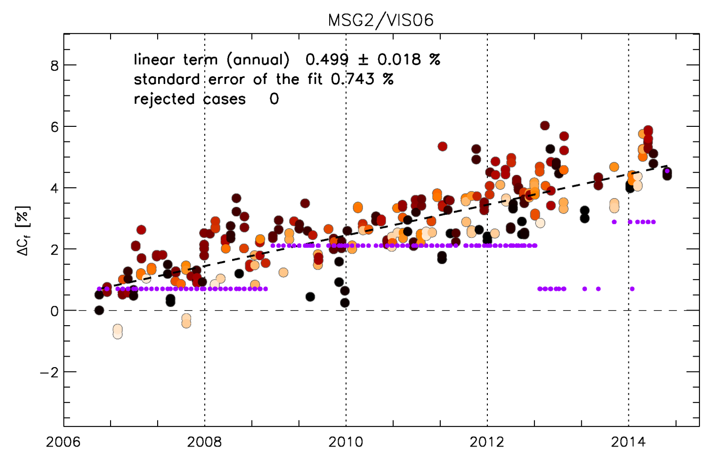


GEO-LEO VIS/NIR - The Moon

- Dark, natural solar diffuser
  - No kind of atmosphere
- Extremely stable
  - Can apply retrospectively to generate FCDRs
- Globally available
- Select pixels of Moon
  - Applying threshold to IR image
  - Calculate integrated irradiance
- Compare with model
  - ROLO developed by USGS
  - <1% relative uncertainty
- Applicable to full Reflected Solar Band
- Use as Pseudo Invariant Targets
  - to transfer calibration MODIS->GEO

SEVIRI L1.0 image





Meteosat-9/VIS06 Bias Change wrt ROLO Model Lunar Irradiance(after phase angle correction)

GSICS Global Space-based Inter-Calibration System

Conclusions

- GSICS is a mature system for generating inter-calibration products.
- The first products have been declared operational.
- Continuing to develop new inter-calibration methods products,
- While cooperating with related activities.

Backup

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

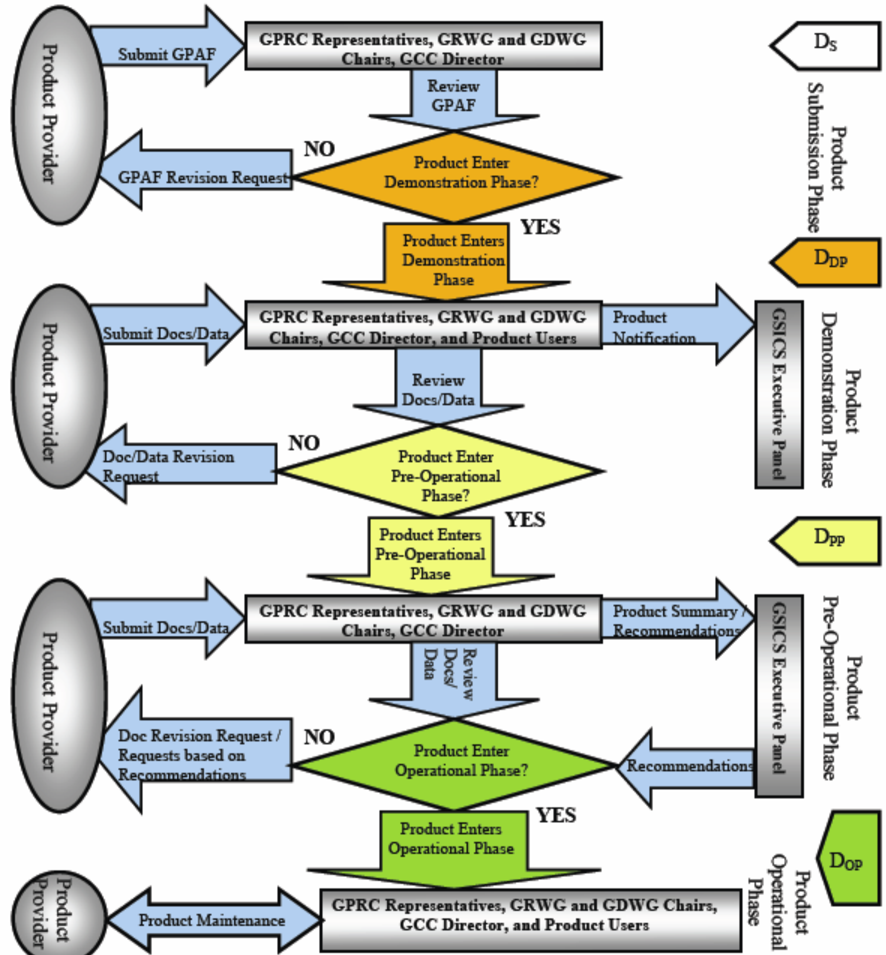
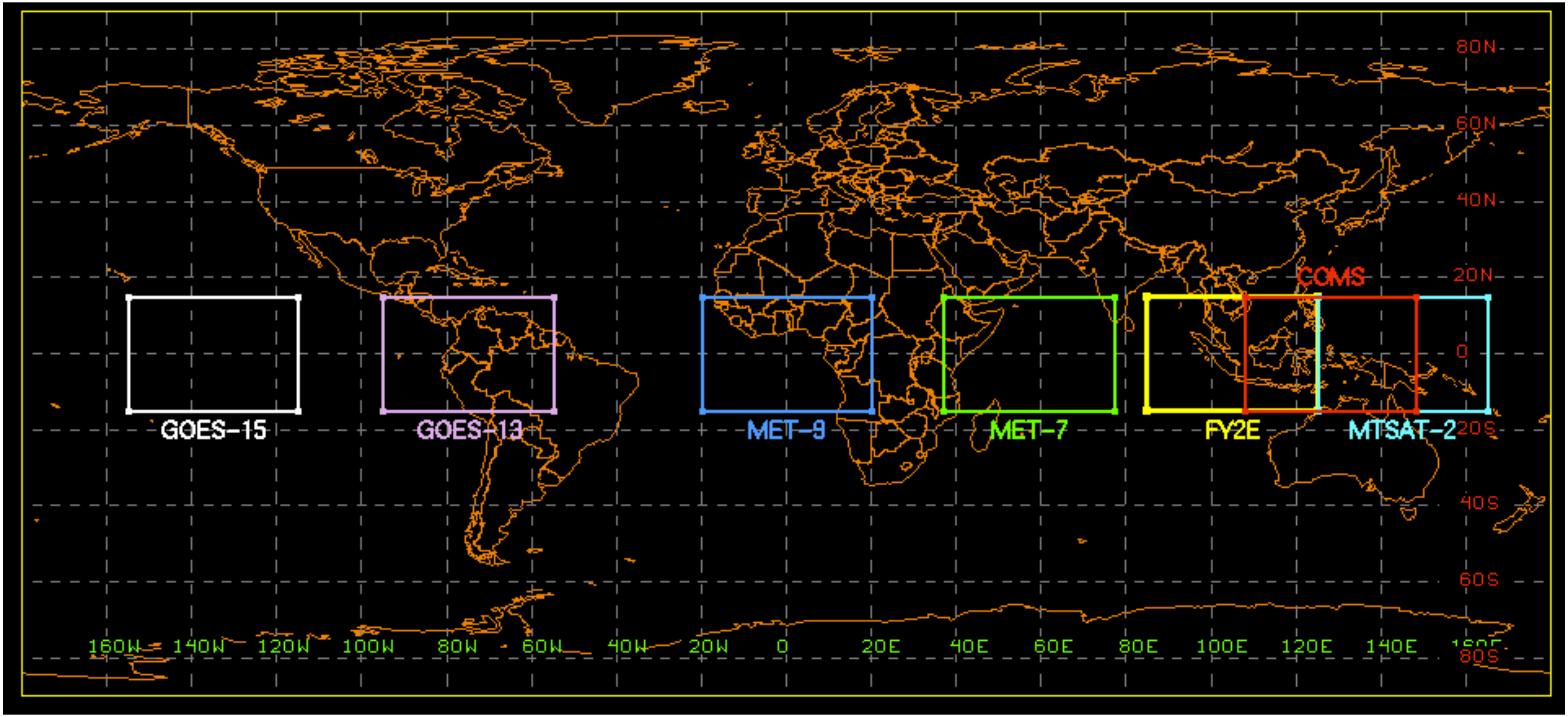


Figure 1: From top to bottom, the GSICS Procedure for Product Acceptance is described by four phases - Product Submission Phase, Demonstration Phase (DP), Pre-operational Phase (PP), and Operational Phase (OP) – and their review and revision cycles. The time markers at the far right, and their defined limits, are: date of submission (D_S); and the number of days from D_S to fulfill requirements to enter DP ($D_{DP} \leq D_S$+90days), PP ($D_{PP} \leq D_{DP}$+365days), and OP ($D_{OP} \leq D_{PP}$+180days).

GEO DCC domain (VIS/NIR)



	GOES-15	GOES-13	MET-9	MET-7	FY2E	COMS	MTSAT-2
Orbit	135°W	75°W	0W	57°E	105°E	128°E	145°E

DCC calibration Status (VIS/NIR)

- **Started in 2014**
  - **NASA Langley provided all GPRCs verification data to validate the proper implementation according to ATBD submitted in 2011**
- **The DCC method has been implemented by all GPRCs by 2015 and reported on their status and issues of the implementation**
- **The DCC methodology provides excellent estimate of the relative degradation of the monitored instrument, however the GEO domain specific DCC methodology noise can be reduced by adjusting DCC methodology components as needed**

1) **DCC BRDF**
   - ✓ **KMA has evaluated BJ Sohn model**
   - ✓ **CNES has defined the more Lambertian part of the BRDF**
2) **DCC deseasonalization**
   - ✓ **NOAA, EUMETSAT, CMA have developed methods**
3) **DCC statistic (mean, mode, median) and identification (to provide sufficient sampling)**

- **The DCC method has been implemented by most GPRCs in 2015**
  - Continue to work with KMA and IMD
- **Continued to improve the DCC invariant target method, by evaluating the DCC BRDF, deseasonalization methods, DCC PDF statistic, BT threshold, the inter-annual variability of the DCC reflectance**

GSICS Products and their Applications

Manik Bali, Lawrence E. Flynn and Tim Hewison
GSICS Coordination Center, NOAA

Outline

- Introduction
- GSICS Principals and Method
- How good are GSICS references
  - Infrared in-orbit reference
  - Microwave in-orbit reference
- GSICS Products
- Application of GSICS Inter-Calibration Products.
- New Concept GSICS GEO-Ring
- Conclusion

Citation 1: Bali, M., Mittaz, J. P., Maturi, E., and Goldberg, M. D.: Comparisons of IASI-A and AATSR measurements of top-of-atmosphere radiance over an extended period, Atmos. Meas. Tech., 9, 3325-3336, doi:10.5194/amt-9-3325-2016, 2016.

Citation 2 : Weng, F.; Yang, H. (2016). Validation of ATMS Calibration Accuracy Using Suomi NPP Pitch Maneuver Observations. *Remote Sens.*, *8*, 332

GSICS Global Space-based Inter-Calibration System

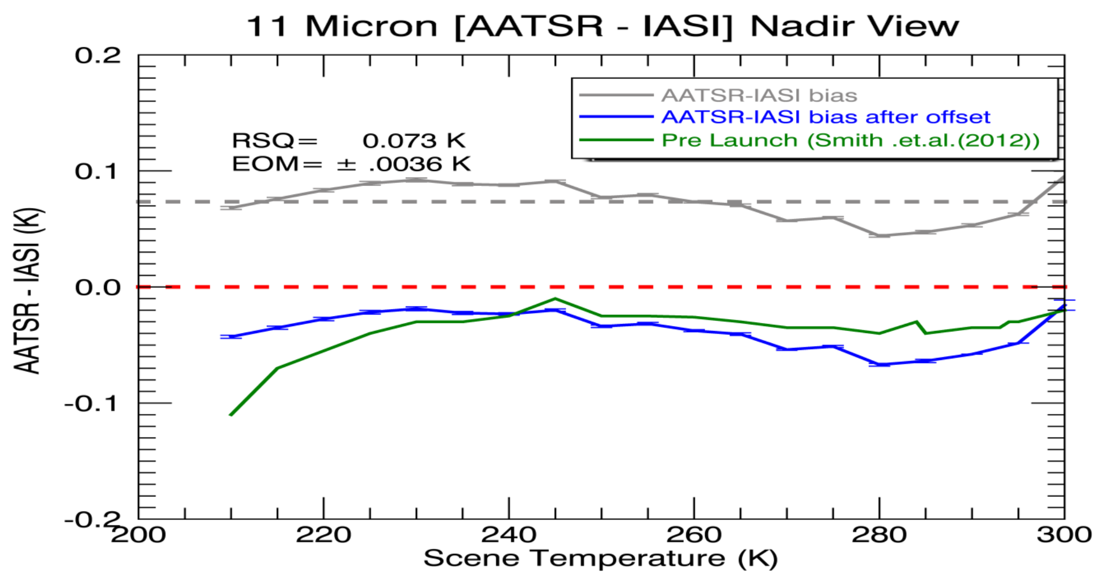
How good are GSICS References

Infrared In-Orbit Reference (IASI-A and AIRS)

Inter-compared IASI-A and AIRS with AATSR – ATSR-2 (instruments of better stated accuracy

- **Temperature dependence of bias**
- **Long term trends in bias**
- **Scan Angle Dependence were evaluated**

Nearly no scan angle dependence and no temporal trends were detected in IASI-A AATSR bias (Bali et. al. 2016)

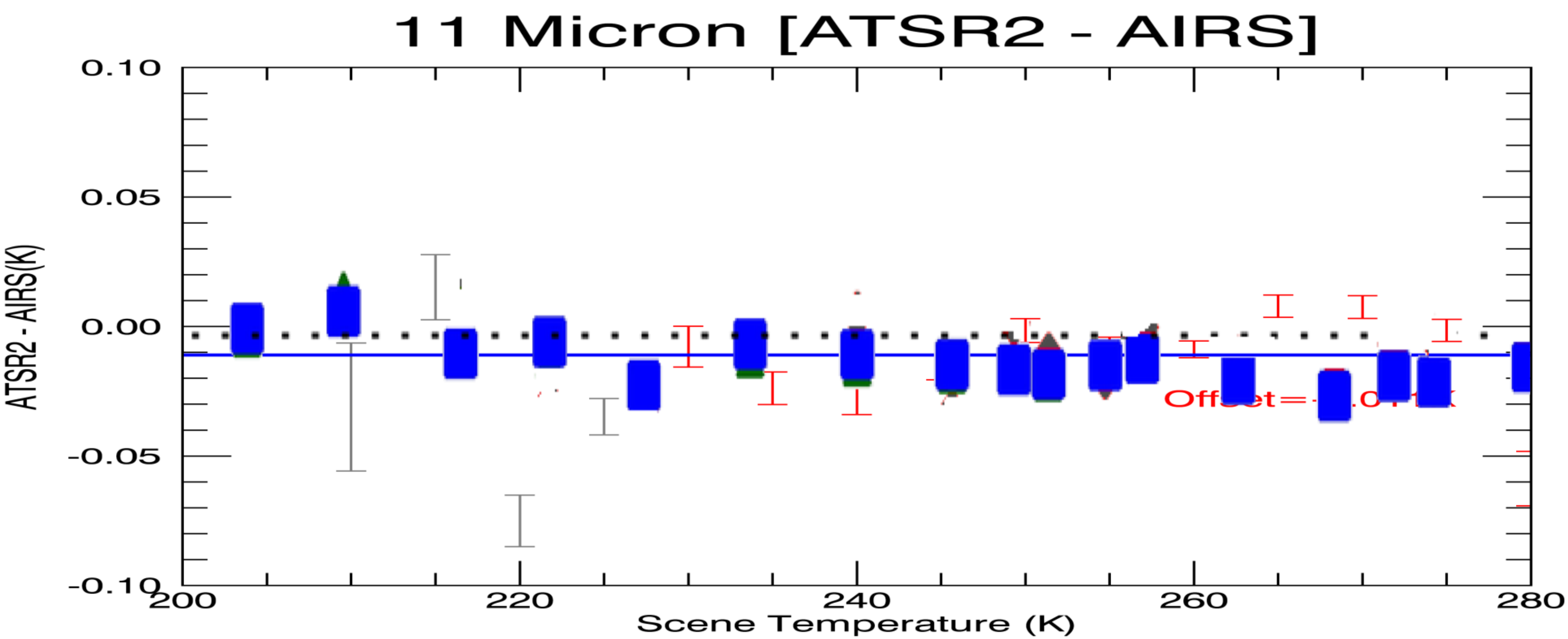


IASI-A nearly as good as pre-launch reference with a small offset 0.07K

GSICS Global Space-based Inter-Calibration System

How good are GSICS References

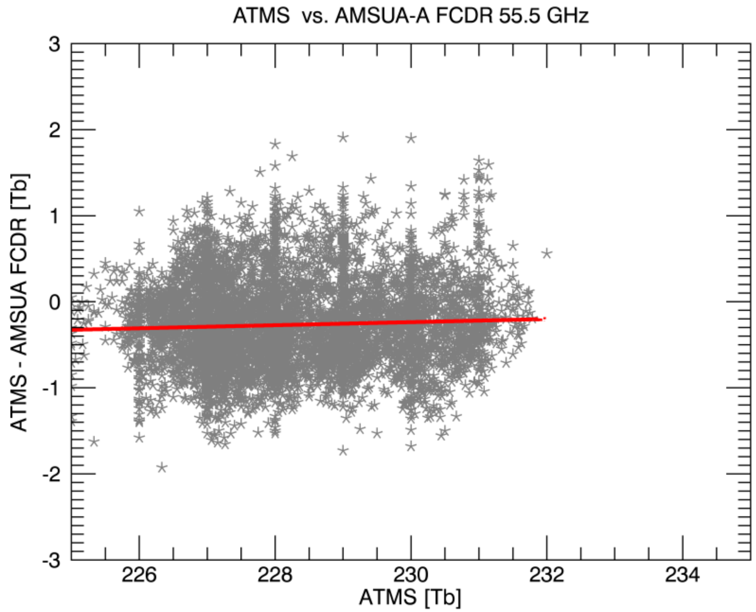
Infrared In-Orbit Reference (IASI-A and AIRS)

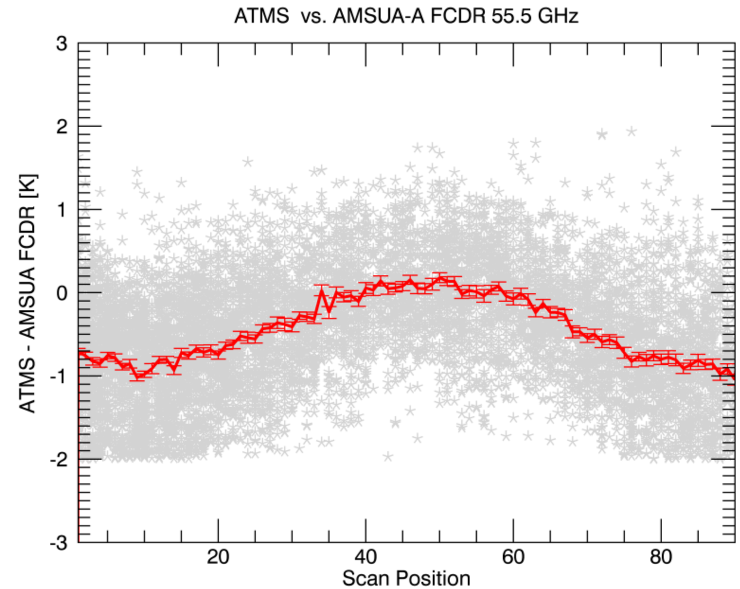


Pre-launch ATSR-2 and post launch inter- comparison with AIRS match to within a 100th of K

How good are GSICS References

Microwave In-Orbit Reference





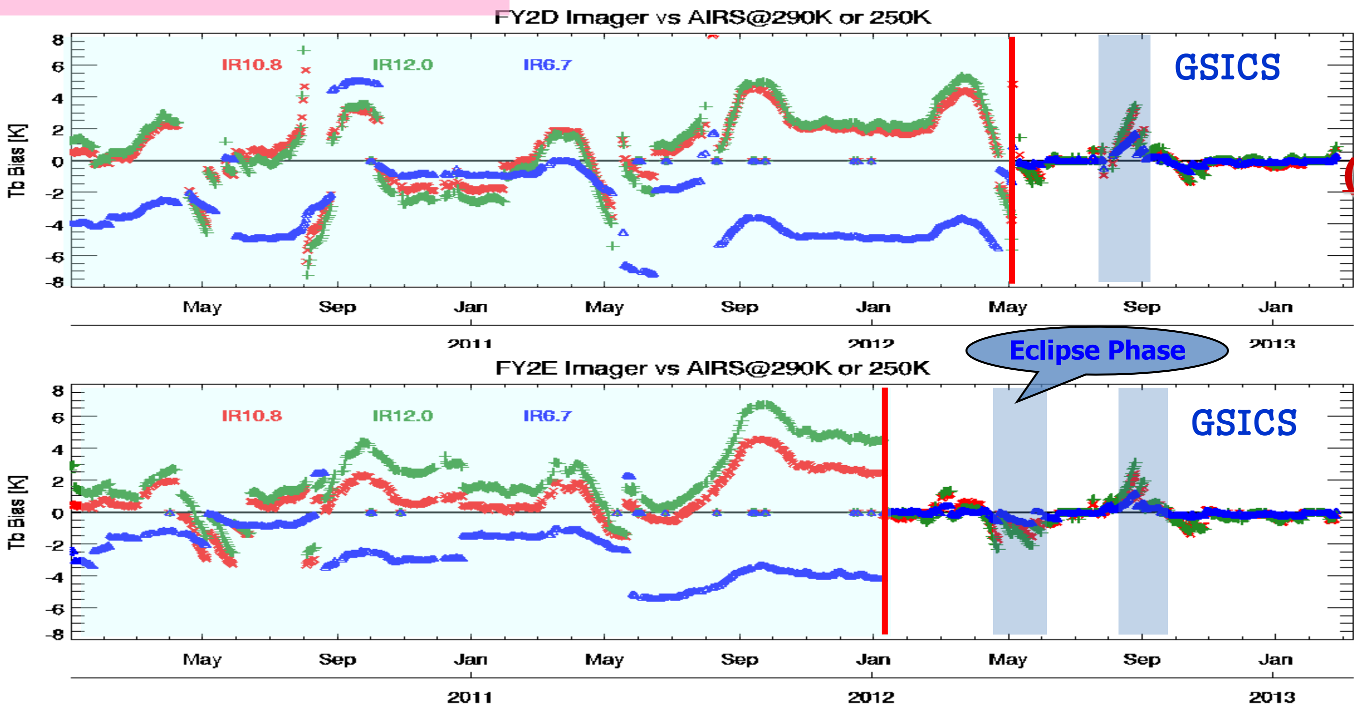
Further investigation for other channels in MW underway

AMSU –MSU Fundamental Climate Data Records have been FCDR has been validated using direct comparisons with GPS-RO and has shown an accuracy of (0.1K-0.2K) and stability of (0.02-0.03K/dec). Has been corrected for Scan Angle bias

FCDR – ATMS (SDR) inter- comparisons reveal near pre-launch accuracy (Weng et al 2016). ATMS(SDRR) and AMSU-MSU FCDR can act as stable in-orbit reference for MW instruments

IR Calibration Bias of FY-2 VISSR

FY-2 vs IASI+AIRS



Significant progress was made in FY-2 operational calibration
(Changed to GSICS in 2012)

Operational calibration of FY-2D/2E was upgraded using GSICS inter-calibration algorithm in 2012-04 and 2012-01 separately.

The calibration biases were sharply decreased, and reduced to about 0.5~1K@290K (@250K) without eclipse period.

Time series of TBB biases for IR1~3 channels vs AQUA/AIRS reference scenes (290 K for IR1 and IR2, 250 K for IR3).

Courtesy: Xiuqing (Scott) Hu (CMA)

Conclusion

- GSICS references (IASI-A -AIRS) highly stable , provide pre-launch level of radiances.
- AMSU-MSU Fundamental Climate Data Record is being evaluated as a pre-launch reference in Microwave
- GSICS style monitoring has helped agencies in monitoring and correcting biases in GEO (IR) and LEO (VIS) instruments
- Agencies produce cross calibration products using GSICS style monitoring available freely.
- GEO Ring has been proposed that would give global view of corrected GEO radiances.

IR Product Development within GSICS (IR)

- GEO-LEO IR hyperspectral
  - Progress existing products to Operational Status
  - Promote new products to Demonstration Status
  - Application of Prime GSICS Correction concept
  - To merge multiple reference instruments
    - To allow corrections to cover diurnal cycle
    - Other Agencies' plans for Prime GSICS Corrections?
- Scope potential new GSICS products/deliverables
  - Alternative inter-calibration algorithms
  - Retrieved SRFs
  - GEO-GEO inter-calibration (part of GEO-ring)
  - LEO-LEO inter-calibration
- Traceability of Reference Instruments
  - Plans for TANSO-FTS/2 & CLARREO
  - GSICS IR Reference Sensor Traceability and Uncertainty Report

GSICS Global Space-based Inter-Calibration System

GSICS and CEOS IVOS recommended solar spectra

- **Recommend a solar spectra for the GSICS community in collaboration with CEOS IVOS**
  - Engaged Nigel Fox and IVOS community with this effort
  - Had GSICS sponsored web meetings in December 2016 and February 2017
  - IVOS held a solar spectra discussion as part of their annual meeting in Arizona last week
  - Short term approach to construct a solar spectra based on the best solar spectra datasets, which have been scaled to a common TSI reference in the more temporal stable part of the spectra. (Thuillier and COSI datasets)
  - Long term approach to account for the variability in the UV radiation, the solar sunspot cycle, and higher spectral resolution using both observed and modeled datasets

VIS/NIR Reference Instrument

- **We are in the process of migrating to NPP-VIIRS as the reference instrument**
  - NPP-VIIRS is the best characterized, stable, and freely available VIS/NIR sensor
  - No major RVS or degradations have been identified
- **VIIRS has very similar channels as the current and future 3rd generation GEOs.**
  - Suggest NPP-VIIRS I1 band rather than M5 band, since the spectral response function is nearly identical with Aqua-MODIS Band 1
  - The NPP-VIIRS LandPEATE version 001 I1 band has been radiometrically scaled to the calibration of Aqua-MODIS B1
- **Future will need to transfer the calibration between reference successive MODIS and VIIRS instruments**
  - **Each MODIS and VIIRS channel is independently calibrated**
  - **Need to establish traceable chain of calibration transfers between successive reference instruments ultimately tied to CLARREO or TRUTHS**

GSICS Global Space-based Inter-Calibration System

Develop new VIS/NIR calibration approaches

- Having multiple calibration methods, which produce consistent calibration coefficients, validates all techniques
  - An individual method maybe more suitalbe for the user application
  - Methodology success is dependent on the monitored and reference instrument
- Need to prepare for new 3rd generation GEO calibration methodologies
  - GRPCs priorities are for current instrumentation
  - Have onboard calibration, which as not the case with 2nd generation, and have very similar channel bandwidths as the reference instrument, making other methodologies more reliable than earth invariant targets
- Will discuss the development of other calibration VIS/NIR methods, which can be applied consistently across sensors
  - Methodologies that take advantage of the 3rd generation GEOs
  - Is there a need to calibrate other instrument records other than GEOs?

GSICS Global Space-based Inter-Calibration System

VIS/NIR Combining Methods

- **The VIS/NIR product to contain the individual calibration approach coefficients**
- **Combine the multiple calibration approaches to provide users calibration coefficients with the least uncertainty**
- **Combining methods proposed**
  - Bertrand, evaluate consistency calibration results among methods and optimize weighting for final coefficients with respect to the uncertainty of the absolute calibration transfer of the reference instrument, and the noise of the method with respect to the degradation
  - Fangfang, iterative recursive filtering technique, this takes the more stable part of all methods to estimate the final instrument degradation
- **This year goal to define combining of methods for the DCC and lunar calibration methods among GPRCs**
  - In the future more calibration methods will be developed and will be added to the VIS/NIR product

GSICS products and plotting

- **VIS/NIR Product file format is nearly finalized**
  - File naming convention following WMO format
  - File parameters and coefficients structures finalized, to include variables that describe the calibration method adjustments for each GEO in order to reproduce the calibration coefficients faithfully
  - One VIS/NIR calibration file containing all calibration from multiple methods and channels
  - Frequency Update being resolved
    - Dependent on calibration method sampling: DCC can be updated daily and Lunar monthly
    - Dependent on the magnitude of the monitored instrument on orbit degradation
- **Bias monitoring plotting being developed similar to the IR bias monitoring**
  - JMA has presented protoype
  - Do we plot the relative degradation, the correction?

GSICS UV Solar Spectra Project (UV)

- The purpose of this project is to compare solar measurements from BUV (Backscatter Ultraviolet) instruments.
- The first step is to catalog high spectral resolution solar reference spectra and agree on a common one to use for the project
- For each instrument, participants should provide the following datasets:
  - Solar measurement for some date (wavelength scale, irradiance) adjusted to 1 AU
  - Wavelength scale and bandpass (Δλ, # of points, bandpass centers, normalized bandpass weights)
  - Synthetic spectrum from common reference (wavelength scale, irradiance)
  - Synthetic for wavelength scale perturbations (±0.01 nm) from common reference (wavelength scale, irradiance)
  - Synthetic from alternative reference spectra (wavelength scale, irradiance)
  - Solar activity pattern (wavelength, relative change)
  - Mg II index (if 280 nm is covered) Mg II 279.6 Mg I 285.2 (date, index)
  - Ca H/K index (if 391 nm to 399 nm is covered) CA II 393.4 and 396.8.
- Goals:
  - Agreement at 1% on solar spectra relative to bandpass-convolved high resolution spectra as a transfer after identifying wavelength shifts and accounting for solar activity
  - Long-term solar spectral measurement drift and instrument degradation by using OMI solar activity pattern (with internal confirmation from Mg II Indices and scale factors)

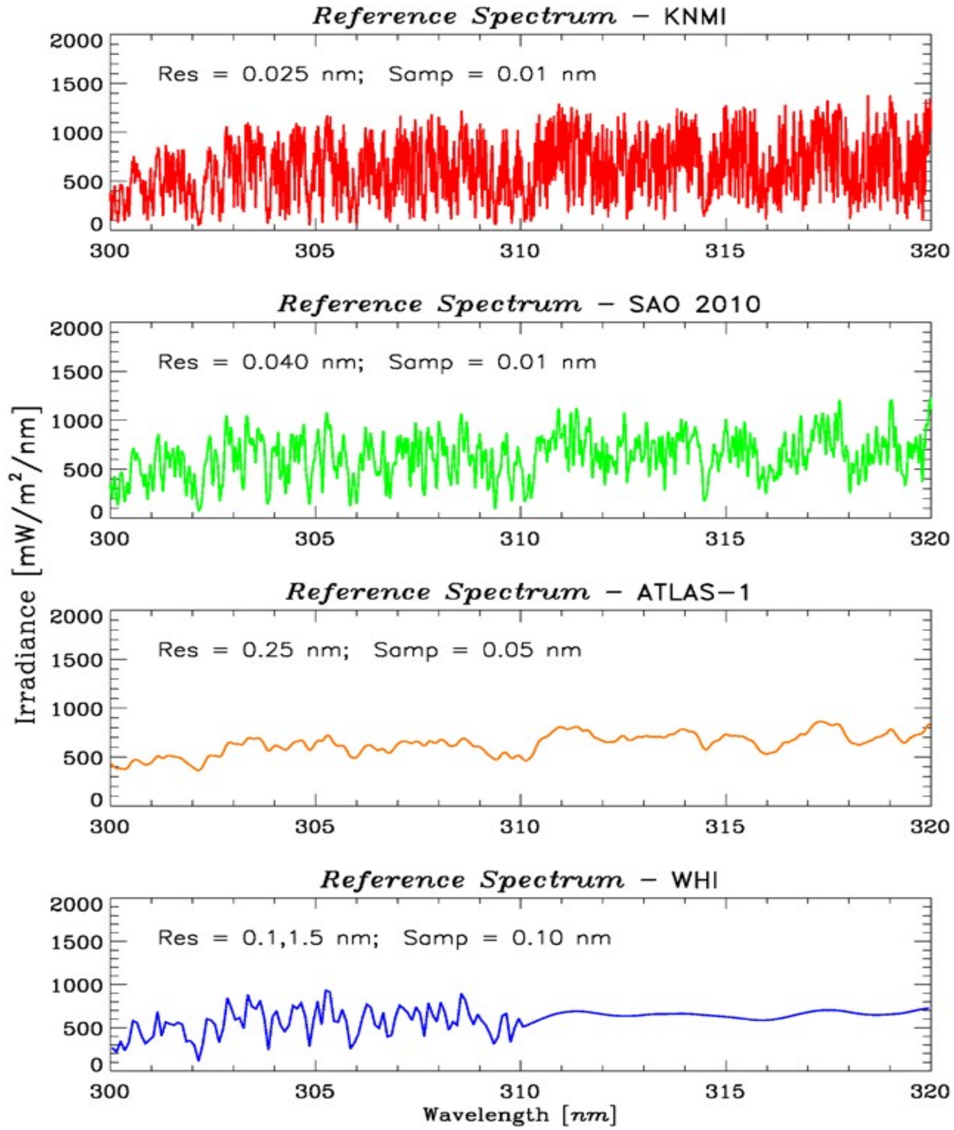
Project to Compare Solar Measurements (UV)

- High resolution solar reference spectra
  - Reference high resolution solar Spectra (SOLSTICE, SIM, Kitt Peak, etc.
    – Everybody has a favorite. How do they compare?)
  - Mg II Index time series, Scale factors at high resolution
- Instrument data bases
  - Bandpasses, wavelength scales (Shift & Squeeze codes)
  - Day 1 solar, time series with error bars (new OMI product) (Formats, Do pler shifts, 1 AU adjustments)
  - Mg II Indices and scale factors at instrument resolution
  - Reference calibration and validation papers
- Using the information from above we can compare spectra from different instruments and times

GSICS Global Space-based Inter-Calibration System

Solar UV Spectra Project

- **Same spectral region (300-320 nm) and absolute scale used for all panels in this figure.**
- **Effect of bandpass change between KNMI and SAO is apparent, even with same input data set.**
- **Satellite measurements (bottom two panels) have lower resolution.**
- **WHI spectrum shows change in original instrument resolution when SIM data begin at 310 nm.**



Interaction with other groups

Joint GRWG-UVSG and CEOS WGCV-ACSG Meeting

- Joint GSICS Research Working Group UV Sub-Group (GRWG-UVSG) and CEOS Working Group on Calibration and Validation - Atmospheric Composition Sub-Group (CEOS WGCV-ACSG) meeting
  - ✓ NOAA/NCWCP, College Park, MD, on the 8th and 9th October 2015
- Organised around a set of questions which form the basis of a user survey designed to assess the most appropriate focus for the GSICS sub-group activities:
  - ✓ internal measurements, internal consistency methods, measurement characterizations, external methods and measurements, external resources etc

Joint GRWG and CEOS WGCV for the climate monitoring

- [Action] The GRWG Chair 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

GSICS Goals, Organization, Products and Resources

Manik Bali and Lawrence E. Flynn

GSICS Coordination Center, NOAA

(Compiled from GSICS participants presentations)

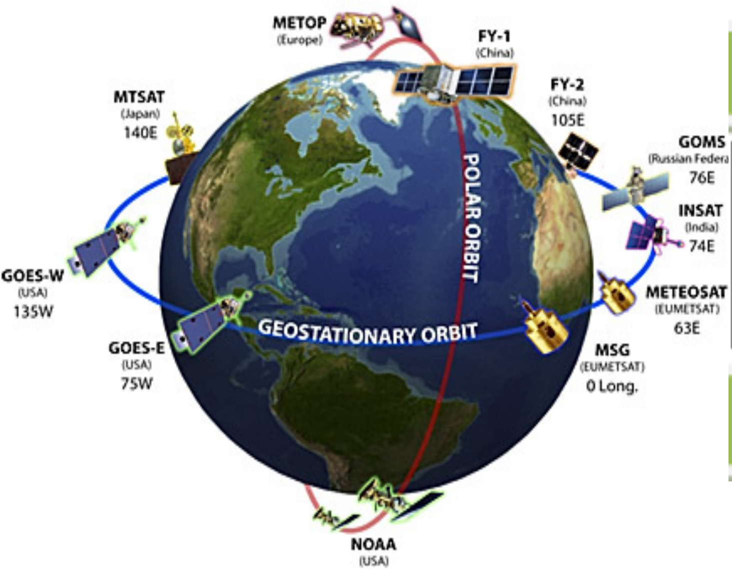
AOMSUC-8, Vladivostok, Russia

Outline

- **Introduction**
- **GSICS Member agencies and observers**
- **Participation in GSICS activities**
- **Friends of GSICS**
- **Opportunities in GSICS**
    - GSICS Coordination Center
    - GSICS Data Working Group
    - GSICS Research Working Group
- **Example Use of GSICS Corrections(SRF Retrieval , In-orbit Reference for Microwave Instruments)**
- **Conclusion**

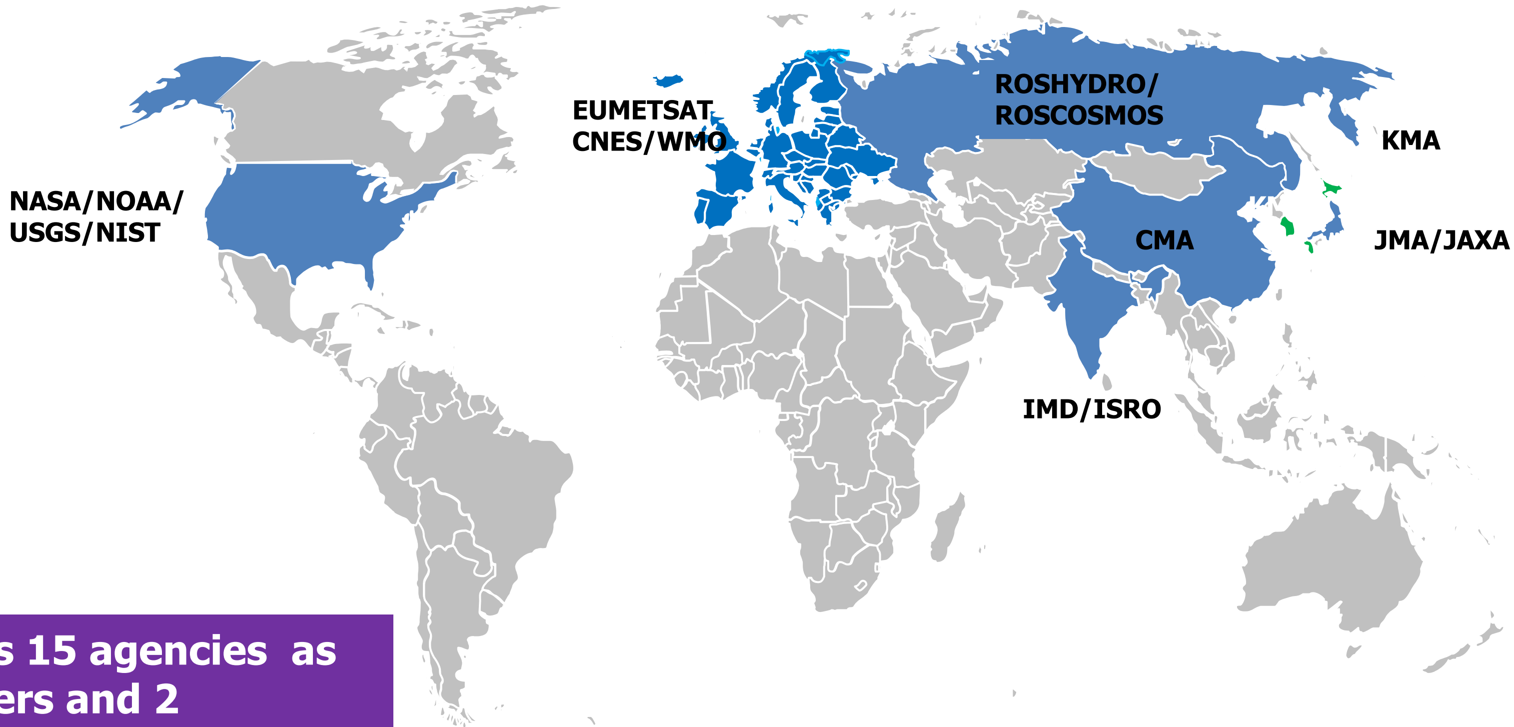
GSICS Introduction

Global Space Based Inter-calibration System (GSICS) is an international collaborative effort initiated in 2005 by WMO and the CGMS to monitor, improve and harmonize the quality of observations from operational weather and environmental satellites of the Global Observing System (GOS)



GSICS now a Component of WIGOS through the CGMS

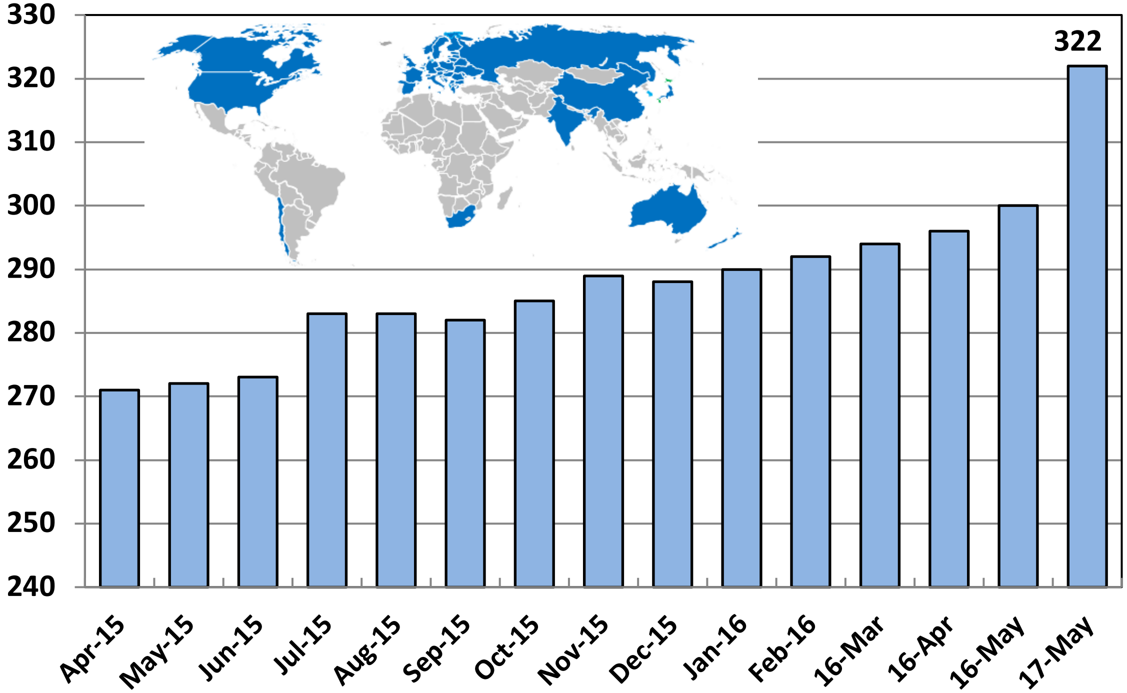
GSICS Executive Panel Membership



GSICS has 15 agencies as its members and 2 observers

Participation in GSICS Activities

GSICS individual Subscription



Annual Meeting attendance: ~60 attendees

Web-meeting attendance: ~15 attendees

Topics:

- SNO algorithms
- Lunar Solar spectrum as reference targets, Ray matching
- SRF Retrievals, Best Practices
- In-orbit References
- Traceability
- Solar Spectrum

Interest in GSICS activities goes beyond its EP membership

GSICS Global Space-based Inter-Calibration System

GSICS Coordination Center

GCC Facilitates

- Support webmeetings (global participation)
- Publication of GSICS Quarterly Newsletter [https://www.star.nesdis.noaa.gov/smcd/GCC/newsletters.php] over 320 subscribers
- Annual meeting support
- GSICS Product review and acceptance

Opportunity:

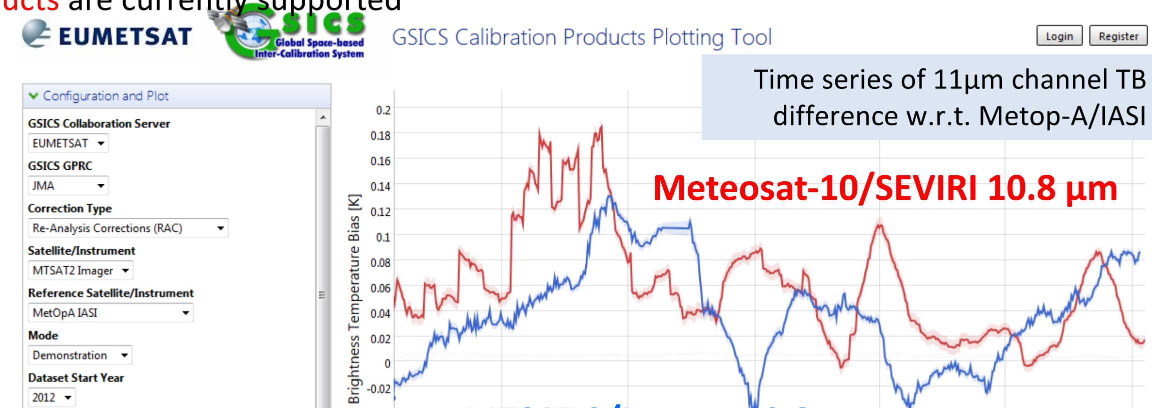
Cite like a typical publication (Small turnaround time < 3 months)

Participate as a contributor or as a reviewer of articles or Guest Editor

Contribute as a reviewer of GSICS products and get letter of recognition

GSICS Data Working Group Accessing/Visualizing GSICS Products

- GSICS Collaboration servers
  - Inter-calibration products (netCDF) which passed GSICS internal review are available
    - ✓ EUMETSAT/JMA/KMA products / NOAA products
    - ✓ GSICS Wiki / GSICS Actions Tracker , GSICS Product Catalogue and Mirroring
- GSICS Bias Plotting Tool (http://gsics.tools.eumetsat.int/plotter/)
  - Product users/developers can quickly assess GSICS inter-calibration products
    - ✓ Common look and feel among different sensors
    - ✓ Infrared products are currently supported



Curtesy : Takahashi, GDWG Chair

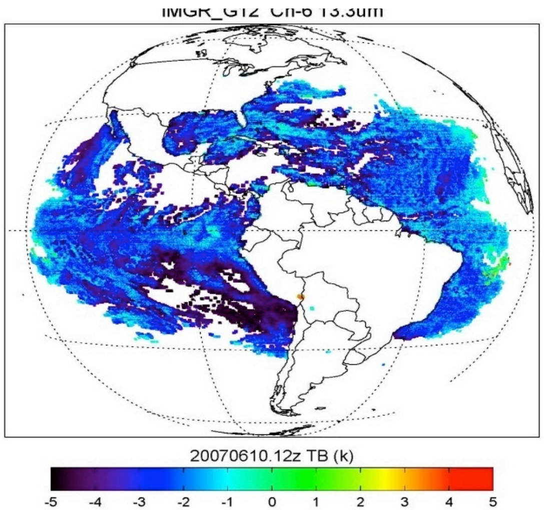
Opportunity:

Harmonize inter-calibration

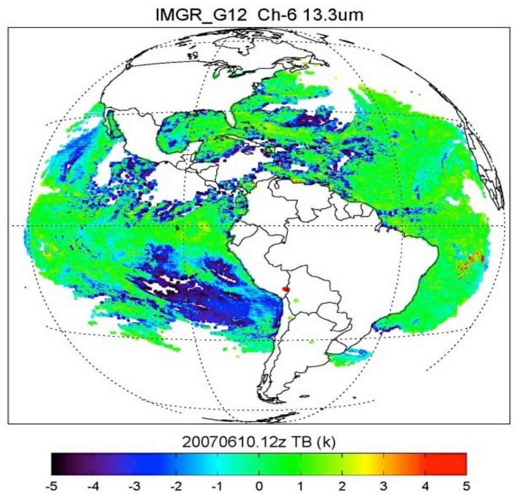
GDWG is on OSCAR Task force instrument landing pages and beta testers

Example-1: Use of GSICS Correction

Before Correction 3K Bias



After Correction ~ 0K Bias



Apply GSICS correction in simple step

Corrected radiance (GOES)
= HSD radiance (GOES) / $C_1 - C_0 / C_1$

C_1 and Co are regression coefficients

Example of application of GSICS Correction on GOES-12 (Goldberg et. al., 2012)

Products helpful in correcting bias w.r.t stable reference

Applied on GEO(AHI, GOES, MTSAT, SEVIRI, FY-2E, INSAT) and LEO (AVHRR)

GSICS Global Space-based Inter-Calibration System

Conclusion

The Global Space Based Inter-Calibration System (gsics.wmo.int) is a group of 15 Satellite agencies that have come together under the aegis of WMO to monitor GEO and LEO instruments.

Monitoring is done by inter-comparing with stable in-orbit references such as IASI-A/B, CrIS, AIRS in IR, MODIS, VIIRS in VIS, OMPS in UV and FCDR in Microwave.

GSICS algorithms have played a vital role in monitoring, detecting anomalies and correcting them in GEO and LEO instruments.(For eg post launch GOES-13, Himawari-8 and FY-2E)

GSICS community is growing and platforms have been created that can give an opportunity to monitor instruments across channels in the IR, VIS, MW and UV spectrum across polar, equatorial, GEO orbits.

You are Welcome to participate in GSICS Collaboration and monitor your instruments (Web Meetings and Annual meeting, Users Workshop and Newsletter)

GSICS Global Space-based Inter-Calibration System

GSICS Data Working Group

- Develop consensus on GSICS Product Meta Data.
- Maintain GSICS Wiki
- Maintain GSICS Actions Tracker.
- Maintain GSICS Product Catalog.
- Support 24/7 running of collaboration servers
- Support product acceptance and promotion
- Maintain the GSICS Plotting tool