



Quality Indicators in GSICS Satellite Inter-Calibration Products

Tim Hewison (EUMETSAT)

Presented by

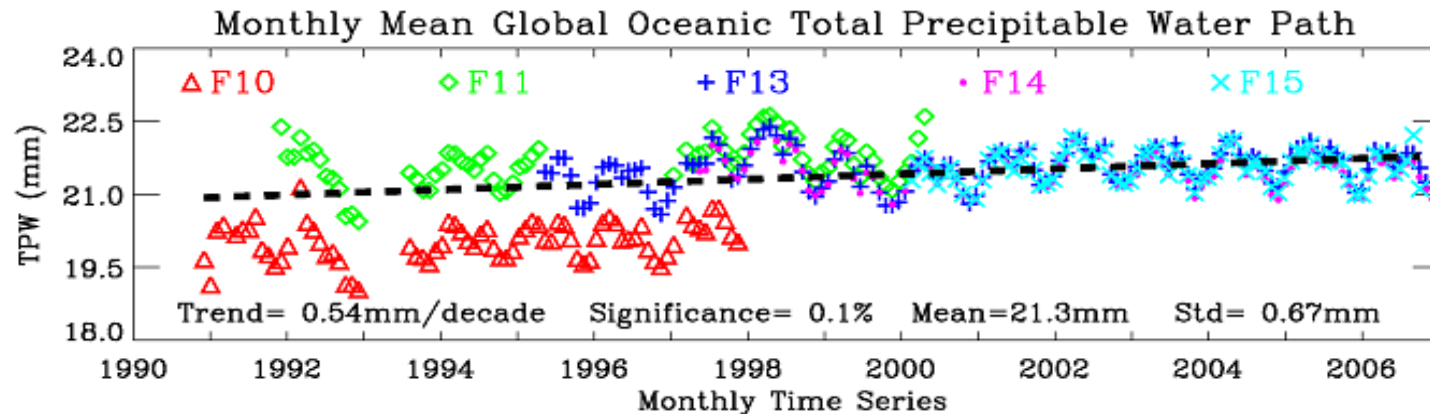
Jérôme Lafeuille (WMO)

Outline of Presentation

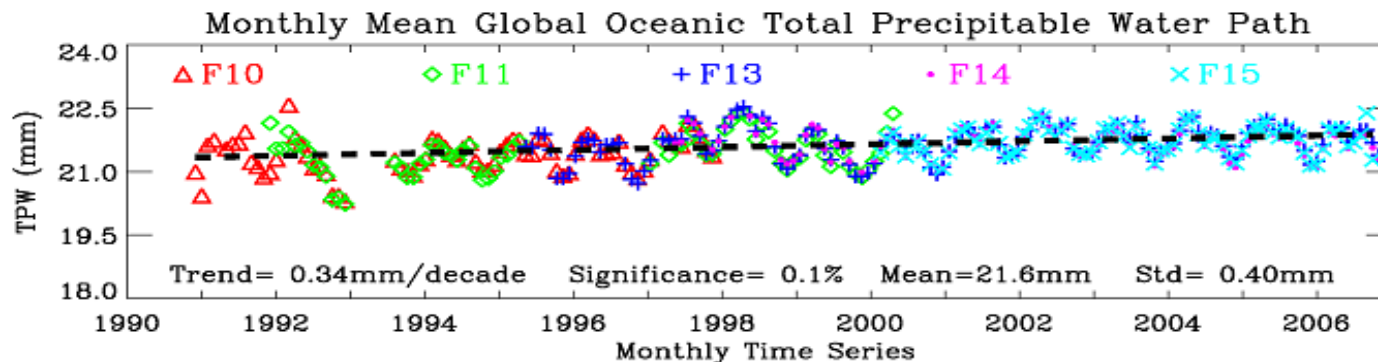
- Introduction to GSICS
 - Scope and principles
 - GSICS Procedure for Product Acceptance
- GSICS Products
 - GSICS Bias Monitoring
 - GSICS Correction
 - GSICS Guidelines
 - Accessing Products – GSICS Servers and Websites
- Quality Assurance of GSICS Products
 - Traceability Statement – Validating inter-calibration references
 - Uncertainty Analysis of GSICS Products – Validating the *Quality Indicator*
 - Users' Feedback
- Conclusion
 - Lessons Learnt, suggestions for Future QA4EO actions



Calibration is Critical for Climate Change Detection



Without
intercalibration:
Apparent trend is
0.54 mm/decade



After
intercalibration:
corrected trend is
0.34 mm/decade

Climate change detection A challenge for calibration!

Expected Decadal Changes (Ohring et al., 2004)

<i>Variable</i>	<i>Expected Change</i>
<i>Total Solar Irradiance</i>	1.5 W/m ²
<i>Outgoing Longwave Radiation</i>	1 W/m ²
<i>Atmospheric and sea surface temperature</i>	0.2 K
<i>Water vapor</i>	1.3 %
<i>Total ozone</i>	1 %
<i>Cloud cover (fraction of sky covered)</i>	0.01

Particular requirement on multi-decadal bias stability

Global Space-based Inter-Calibration System

- What is GSICS?
 - Global Space-based Inter-Calibration System
 - Initiative of CGMS and WMO
 - An 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-calibration system
 - Initially for GEO-LEO Inter-satellite calibration
 - Being extended to LEO-LEO
 - Using external references as necessary
 - Best practices for prelaunch characterisation (with CEOS WGCV)
- 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



EUMETSAT



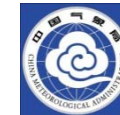
CNES



JMA



NOAA



CMA



KMA



ISRO



NASA



WMO



USGS

NIST

NIST



JAXA



ROSHYDROMET

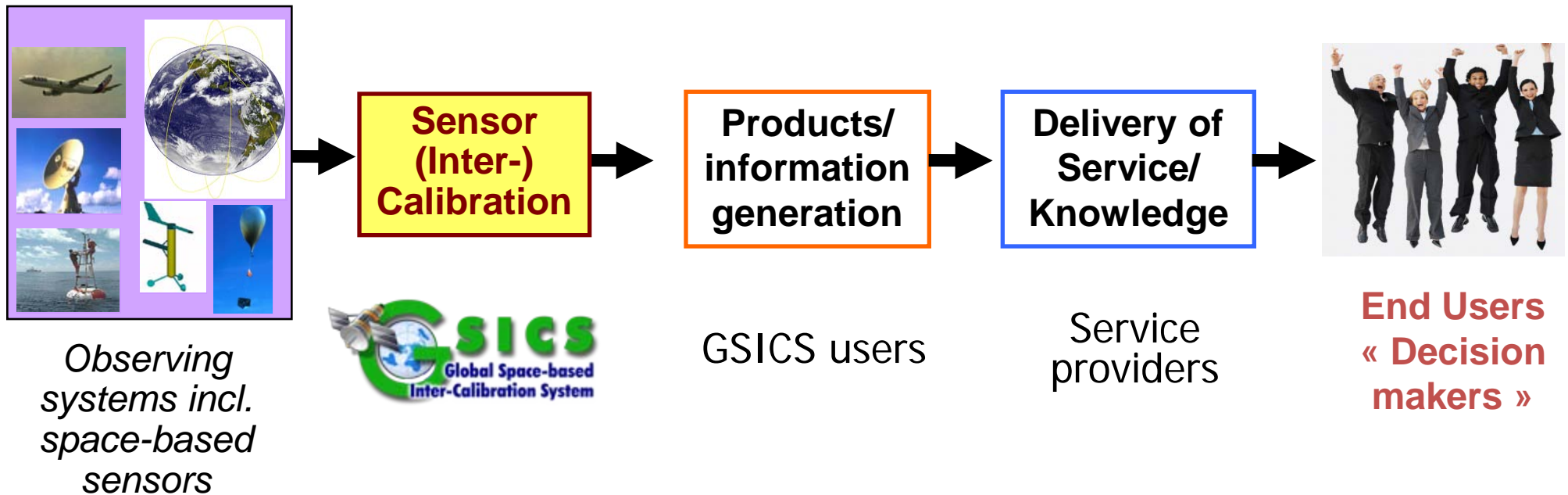


IMD



ESA

GSICS in the Information Value Chain



GSICS User Community

- Satellite Application Community
 - CDR generation for climate monitoring
“SCOPE-CM” framework, national/international programs
WCRP/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
- Satellite Operators
 - Prelaunch instrument characterization guidelines
 - Cal/Val Plans
 - Best practices for instrument monitoring and improved calibration
- Affiliation with partner programmes
 - CEOS WGCV, GPM X-cal, etc...



GSICS Principles

Generic Principles

- Traceability
 - to common references
 - through unbroken chain of comparisons
 - with specified uncertainty
- Systematic generation of inter-calibration products
 - To **compare** and **correct** calibration of *monitored* instruments to *references*
 - For both Near-Real-Time and Re-Analysis applications
 - Level 1 data (SDR, radiances..)

Science principles

- Transform observations to allow comparison
 - Spatially, Temporally,
 - Geometrically, Spectrally
- Multiple comparisons of observations to analyse stability/variability
- Generate correction coeffs.
- Review and publish

Data management principles

- Data access (servers)
- Community standards for
 - Data formats, naming
 - Metadata



GSICS Procedure for Product Acceptance

- 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

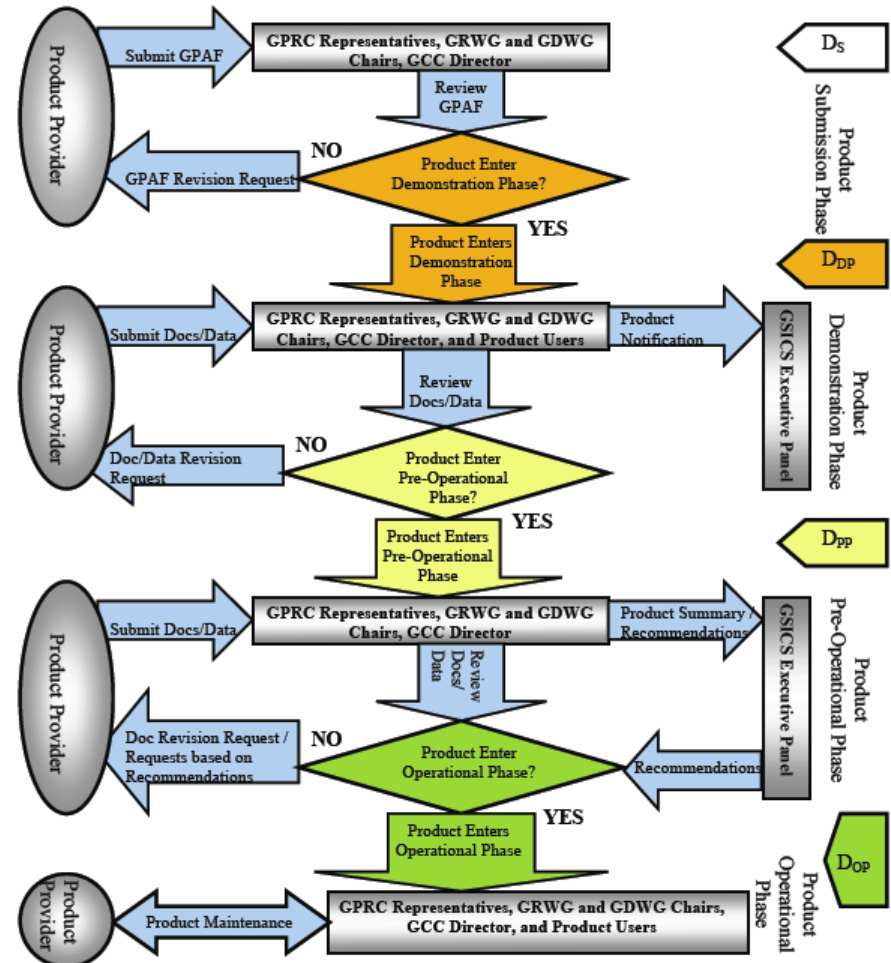


Figure 1: From top to bottom, the GSICS Procedure for Product Acceptance is described by four phases - Product Submission Phase, Demonstration Phase (DP), Pre-operational Phase (PP), and Operational Phase (OP) – and their review and revision cycles. The time markers at the far right, and their defined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

GSICS Product Acceptance Documentation (1/2)

- Product Algorithm Theoretical Basis Documentation (ATBD)
 - Discussion of physical principles supporting the product
- Software Document
- Algorithm flowchart
 - including data I/O, logic and software module descriptions
- Software that meets GSICS standards
 - On coding, I/O, filename, and documentation (TBD)
- Software verification results
- Version Control Plan
 - Describes process of performing software/model/measurement updates and archiving



GSICS Product Acceptance Documentation (2/2)

- **Operations/Distributions Plan**
 - Outlines how data or results are stored and shared
 - Statements about the level of access need to be included
 - e.g. Some Products routinely updated on GPRC websites (open), Others accessible from GSICS Data & Product Servers
- **Data Quality Assessment Documentation**
 - Documents the estimated value and sources of uncertainty in the product
- **Data User's Guide**
 - Documents detailed data format, quality flag and parameter descriptions.
 - Identifies how data format meets GSICS standards,
 - and the limitations of product use.

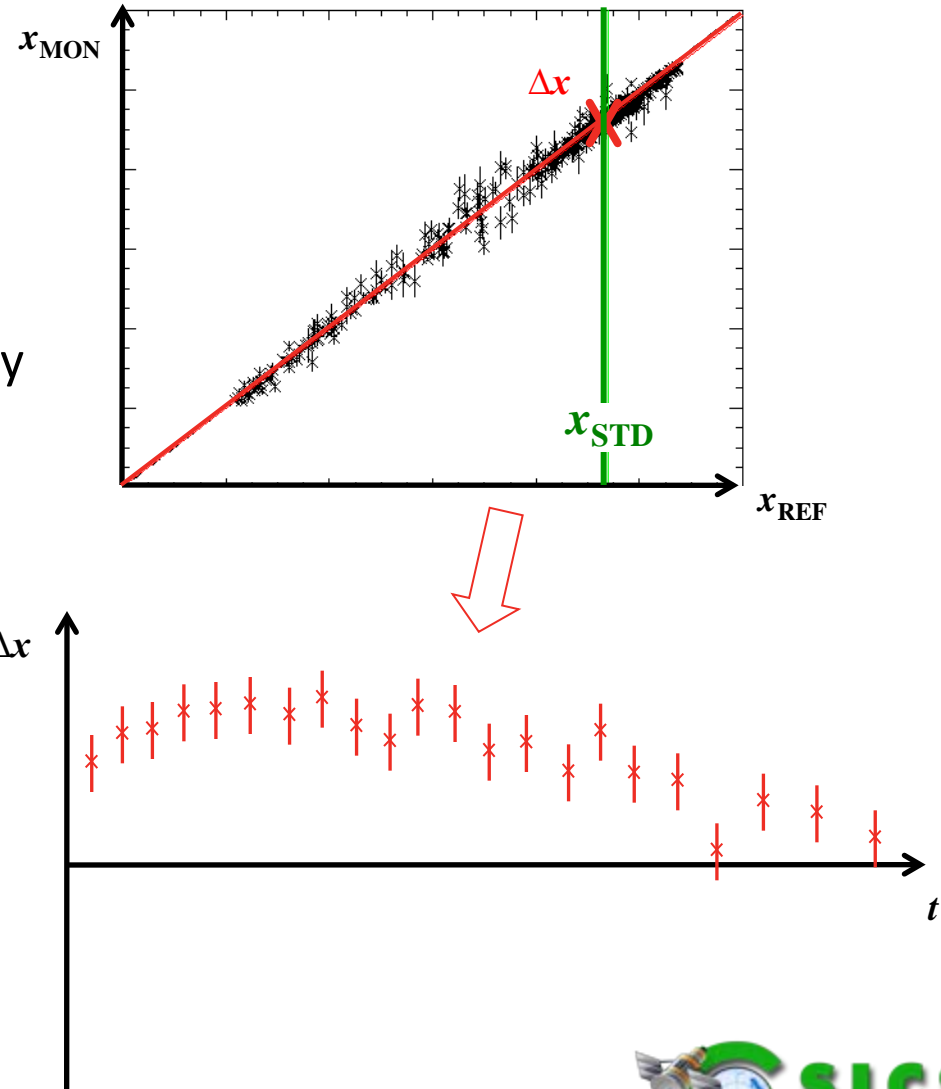
Outline of Presentation

- Introduction to GSICS
- **GSICS Products**
 - **GSICS Bias Monitoring**
 - **GSICS Correction**
 - **GSICS Guidelines and reports**
 - **Accessing Products – GSICS Servers and Websites**
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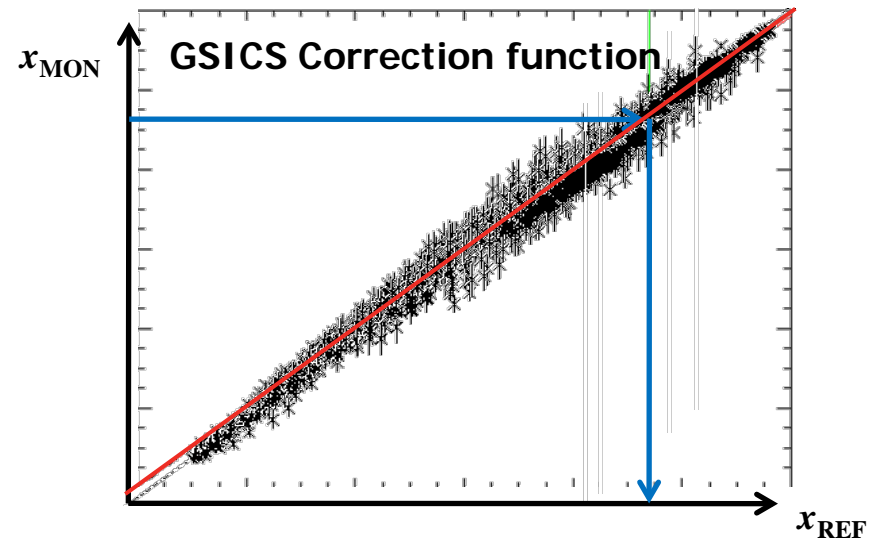
GSICS Products: (1/3) Bias Monitoring

- Comparing samples of x_{MON} , x_{REF}
 - Over fixed domain
 - Period (e.g. 1 orbit/1 day)
 - Typically ~ 1000 comparable samples/day
- Regression
- Calc bias, $\Delta x = x_{\text{MON}} - x_{\text{REF}}$
 - Δx at standard scene, x_{STD}
 - with uncertainty
- Plot time series of bias Δx
 - Compare recent results with long-term trend
 - Valuable for instrument monitoring



GSICS Products: (2/3) GSICS Correction

- Compare all x_{REF} , x_{MON} samples
 - over smoothing period (e.g. 2 weeks)
- Regression coefficients
 - with uncertainty (covariance)
- Provide a *function* users can apply
 - to convert level 1 data, x_{MON}
 - to be consistent with calibration of reference, x_{REF}
- Two versions:
 - Near Real-Time (asymmetric time window)
 - Re-Analysis (symmetric time window)



GSICS Products: (3/3) Guidelines

- Underlying assumption of GSICS Correction:
 - Small errors (e.g. SRF errors, blackbody temperature, ...) introduce small departures from 'true' calibration
 - If these are linearly related to a predictor (radiance, time, ...) we can apply empirical correction based on inter-calibration
- Guidelines can analyse GSICS products
 - to diagnose root causes of calibration errors
- Can derive recommendations to modify
 - operating practices (e.g. adopt new SRF definition),
 - pre-launch characterisation, etc.
- These GSICS Guidelines are distributed as written reports

GEO-LEO IR Product Status 2011-10

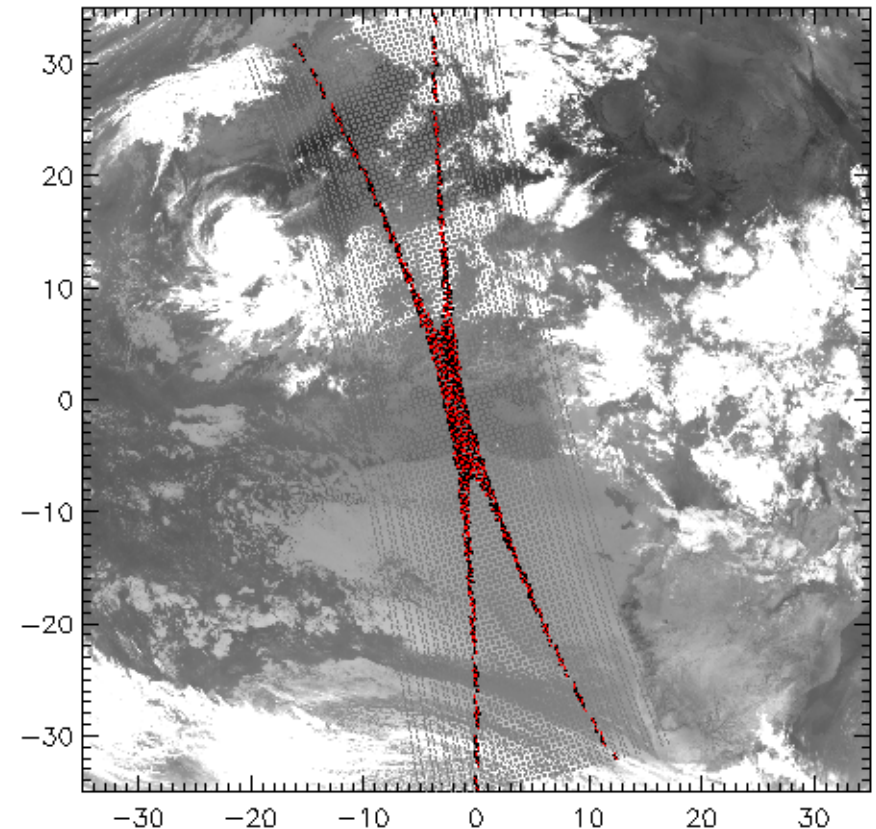
GPRC	Monitored Instrument	Reference Instrument	GSICS NRT Correction	GSICS Re-Analysis Correction	GSICS Bias Monitoring
EUMETSAT	Meteosat-9 } Meteosat-8 }-- Meteosat-7 }	IASI	Demonstration	Demonstration	Prototype
JMA	MTSAT-1R } MTSAT-2 }	IASI (+ AIRS)	Demonstration	Demonstration	Prototype
NOAA	GOES-11 Imager GOES-12 Imager	IASI (+ AIRS)	Demonstration	Demonstration	Prototype
	GOES Sounder	IASI (+ AIRS)	In development	In development	In development
CMA	FY2C } FY2D } -- FY2E }	IASI (+ AIRS)	In development	In development	Prototype
KMA	COMS	IASI (+ AIRS)	In development	In development	In development



Comparison of Collocated Radiances

Simultaneous near-Nadir Overpass
of GEO imager and LEO sounder

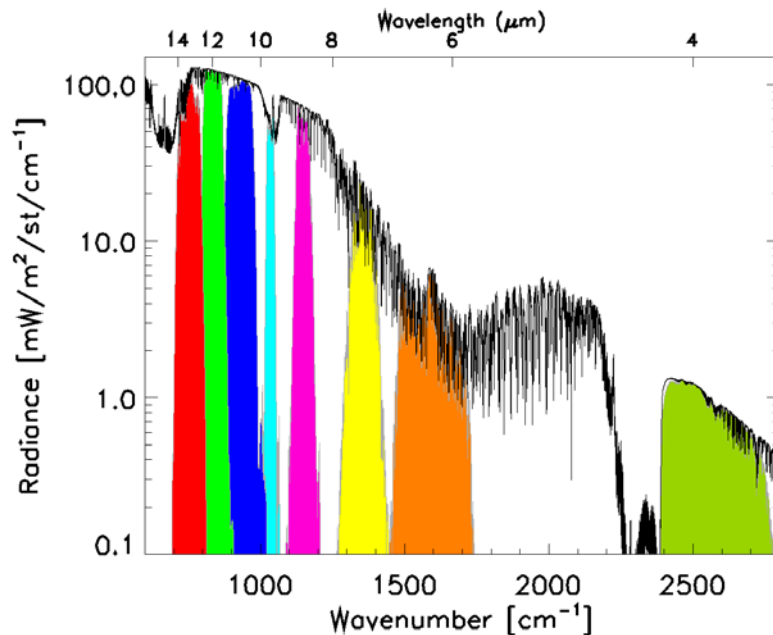
- Collocation Criteria:
- $\Delta\text{Lat} < 35^\circ$ $\Delta\text{Lon} < 35^\circ$
- $\Delta t < 5$ mins
- $\Delta\text{sec}\theta < 0.01$
(Atmospheric path diff.)
- Concentrated in tropics
- ~1000 collocations/orbit
- ~1 orbit/night



Data Transformations (Spectral and Spatial)

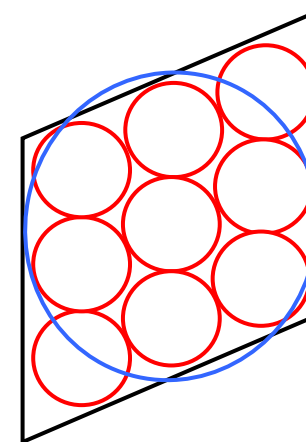
Spectral Convolution:

- Convolve LEO Radiance Spectra with GEO Spectral Response Functions
- to synthesise radiance in GEO channels



Spatial Averaging:

- Average GEO pixels in each LEO FoV
- Estimate uncertainty
 - due to spatial variability
 - as Standard Deviation of GEO pixels
- Use in weighted regression



LEO FoV ~ 10km

~ 3x3 GEO pixels

GSICS Data Access

- GSICS Bias Monitoring (prototype)
 - Hosted on websites of GSICS Processing & Research Centres (GPRCs)
- GSICS Corrections
 - GSICS Data & Products Servers
 - THREDDS-based system
 - netCDF format
 - WMO GTS standard file names
 - Unidata & CF conventions
 - See gsics.wmo.int for links

GSICS Portal
Provided by WMO Space Programme

GSICS Home

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 aims at ensuring consistent accuracy among space-based observations worldwide for climate monitoring, weather forecasting, and environmental applications.

This is achieved through a comprehensive calibration strategy which involves monitoring instrument performances, operational inter-calibration of satellite instruments, tying the measurements to absolute references and standards, and recalibration of archived data.

GSICS delivers calibration corrections needed for accurately integrating data from multiple observing systems into products, applications and services. GSICS contributes to the integration of satellite data within

GSICS in the Global Observing System

OPeNDAP Dataset Access Form

Tested on Netscape 4.01 and Internet Explorer 5.00.

Action:

Data URL:

Global Attributes: Conventions: "CF-1.4"
Metadata Conventions: "Unidata Dataset Discovery v1.0"
title: "MSG15 channel data in NetCDF."
summary: "MSG15 channel pixel counts with calibration coefficients and geo-location values."
units: "1"

Variables: ch4: Array of 16 bit Integers [yc = 0..2344][xc = 0..2355]
yc: xc:
standard_name: "satellite_geo_metadata_is_3.9_pixel_count"
long_name: "SEVIRI infrared 3.9 micron pixel counts"
scale_factor: 0.0036866666666666666
add_offset: -0.1865201034963685
units: "1"

ch5: Array of 16 bit Integers [yc = 0..2344][xc = 0..2355]

Example of GSICS Bias Monitoring

From EUMETSAT: Time Series of Meteosat9-IASI Standard Biases [K]

This page shows prototype GSICS Bias Monitoring resulting of the inter-comparison of infrared channels of geostationary **Meteosat imagers** and the polar-orbiting **IASI** sounder from collocated observations. The plots show the relative biases between these instruments for standard radiances, corresponding to clear sky scenes over the ocean in a standard atmosphere. The results from the **inter-calibration algorithm** can also be downloaded as **GSICS Correction Coefficients** in **netCDF format** from **EUMETSAT's GSICS and Product Server**.

See the **GSICS Product Status Summary** for further details or visit our **GSICS page** for a comprehensive list of resources.

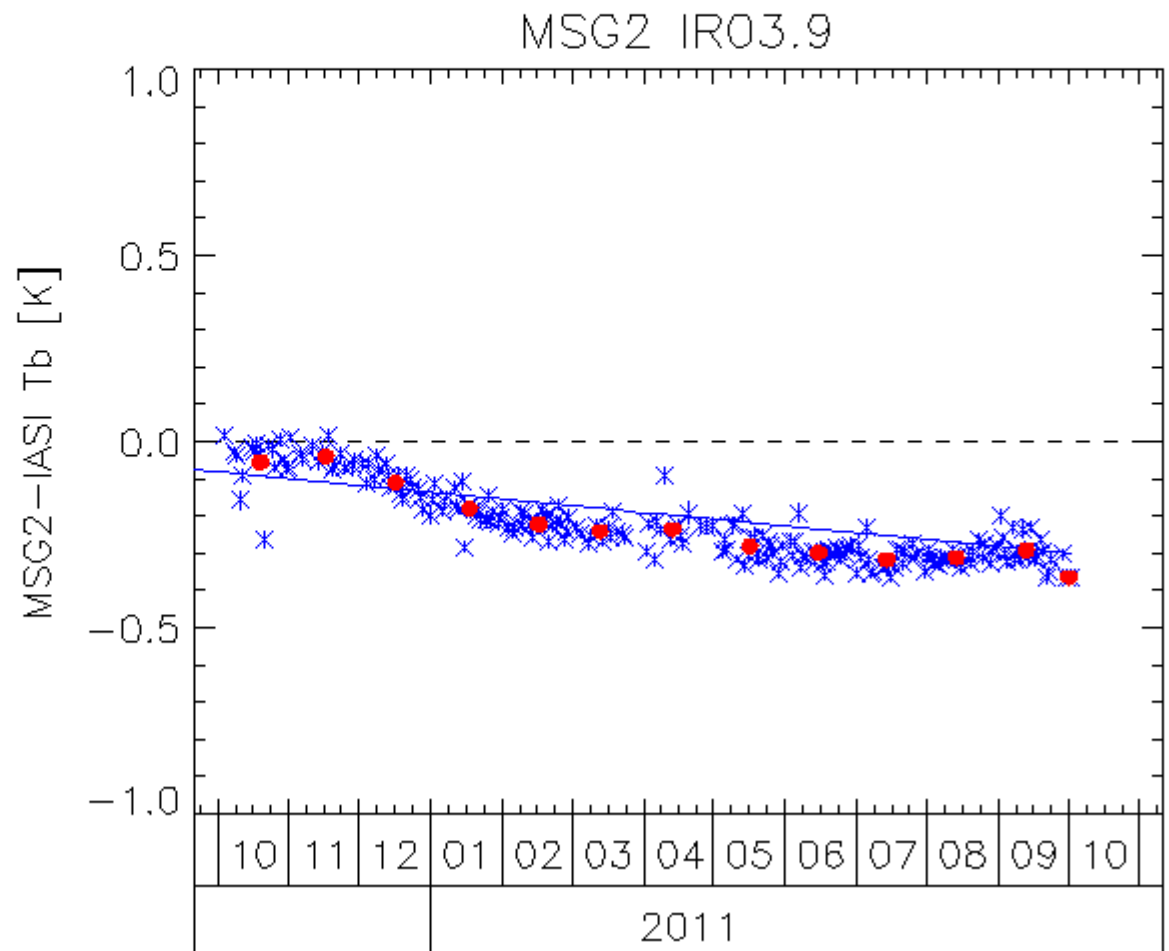
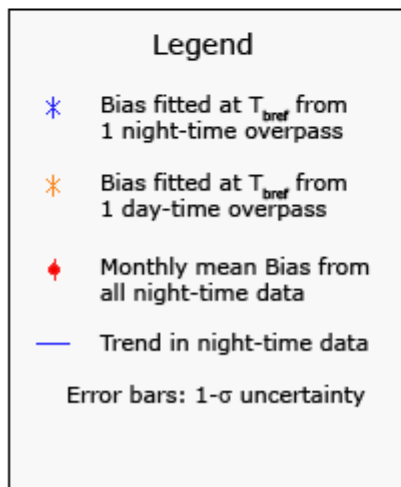
Satellite:

Channel:

Date: Year: Month: Day:

Time:

Display:



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Combining Multiple References

Advantages

- Robustness
 - In case of failure of one reference
 - Allows transition between references – e.g. MetopA->B
- Greater coverage of diurnal cycle
 - Both scene and instrument calibration variability
 - Important for 3-axis stabilized spacecraft
- Broader engagement of GSICS members

Disadvantages

- Segal's law:
 - "A man with a watch knows what time it is. A man with two watches is never sure." [Bloch, Arthur (2003). *Murphy's Law*. Perigee. p. 36.]
 - It refers to the potential pitfalls of having too much conflicting information when making a decision.
 - User confusion
- Not Metrologically Traceable
 - as the references can never be perfectly consistent

Define only one as the calibration reference
All others are regarded as calibration transfer standards

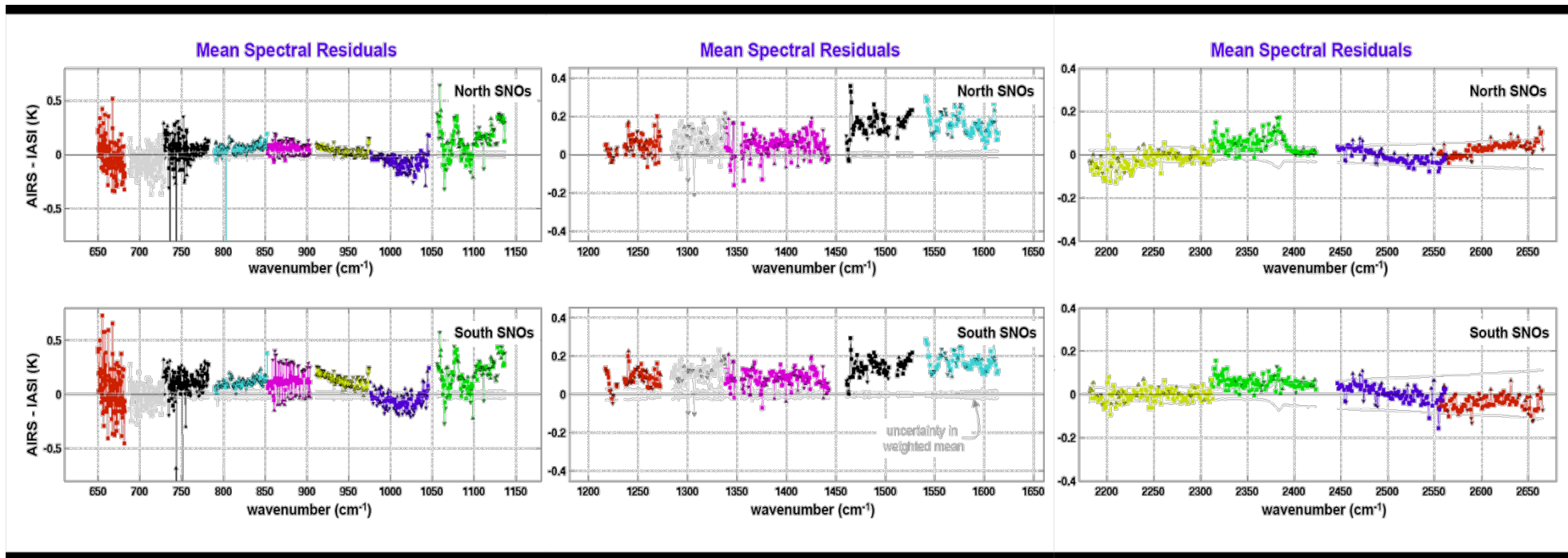


Traceability Statement for AIRS & IASI

- To provide evidence of applicability of our products
- Statement demonstrates AIRS and IASI suitable as inter-calibration references
 - Prepared collaboratively by GSICS partners
- Discusses various pre-flight and in-orbit tests performed on these instruments
- Focus on relative stability, as this is critical if they are to be used inter-changeably
- Various method described showing consistent calibration of AIRS and IASI
 - each with uncertainties $\sim 0.1K$ ($k=1$)
- Discusses traceability chain of AIRS and IASI to SI reference standards
 - Which is needed to achieve the long-term goal of GSICS
- *“GSICS Traceability Statement for IASI and AIRS”*
EUMETSAT Technical Report - EUM/MET/TEN/11/0157, 2011
 - http://www.eumetsat.int/groups/sir/documents/document/pdf_trace_stat_iasi_airs.pdf

Hyperspectral comparison of AIRS-IASI

- Based on SNO observations - Limited to polar regions
- However, can cover most of global range of radiances – over long period
- Mean differences generally \sim few tenth of degrees K or less over full spectrum

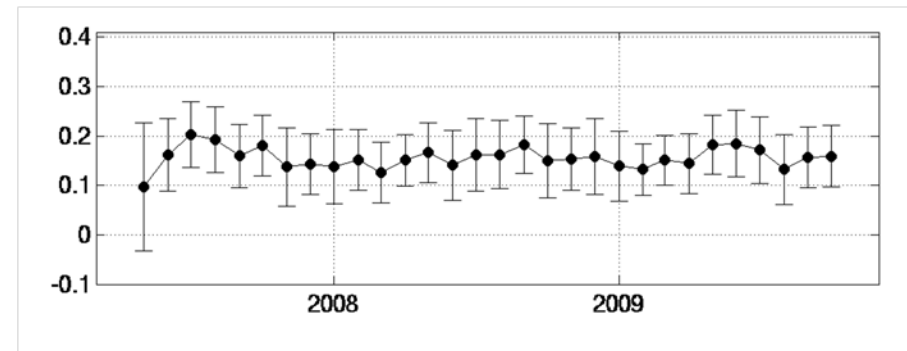


Mean AIRS-IASI Brightness Temperature Differences in comparable channels in three spectral bands
Courtesy of Dave Tobin (Space Science and Engineering Center)



Long term stability of AIRS-IASI

- Tobin showed mean BT difference between AIRS and IASI in the 1460-1527 cm^{-1} band was found to be 0.15K
- No significant long-term changes over the 3-year period: $0.9 \pm 5.6 \text{mK/year}$
- Also used during commissioning of IASI, as reported by Blumstein et al. [2007], who showed that comparisons with pseudo-channels from Simultaneous Nadir Overpasses (SNOs) with AIRS showed differences $<0.1\text{K}$.



Time Series of Monthly Mean Brightness Temperature Difference (1460-1527 cm^{-1})

**Shows no significant long-term changes over the 3-year period 2007 to 2010:
 $0.9 \pm 5.6 \text{mK/year}$**

Outstanding Issues with Traceability

- X. Xiong (NASA) to provide Traceability Statement for Aqua/MODIS
- GRWG need advice on application of traceability concept to
 - Model Results
 - Aircraft instruments
- Need for SI-traceable inter-calibration references in orbit
 - CLARREO not funded to Phase A
 - Mission and Science Definition teams are being funded by NASA to continue to advance the science of CLARREO, explore alternative implementation strategies, and reduce technical risk
 - Next decadal survey (2014) may review plans – CLARREO still highly recommended
 - TRUTHS is a similar mission, developed by NPL, covering solar band only, not selected yet as a mission on an ESA spacecraft

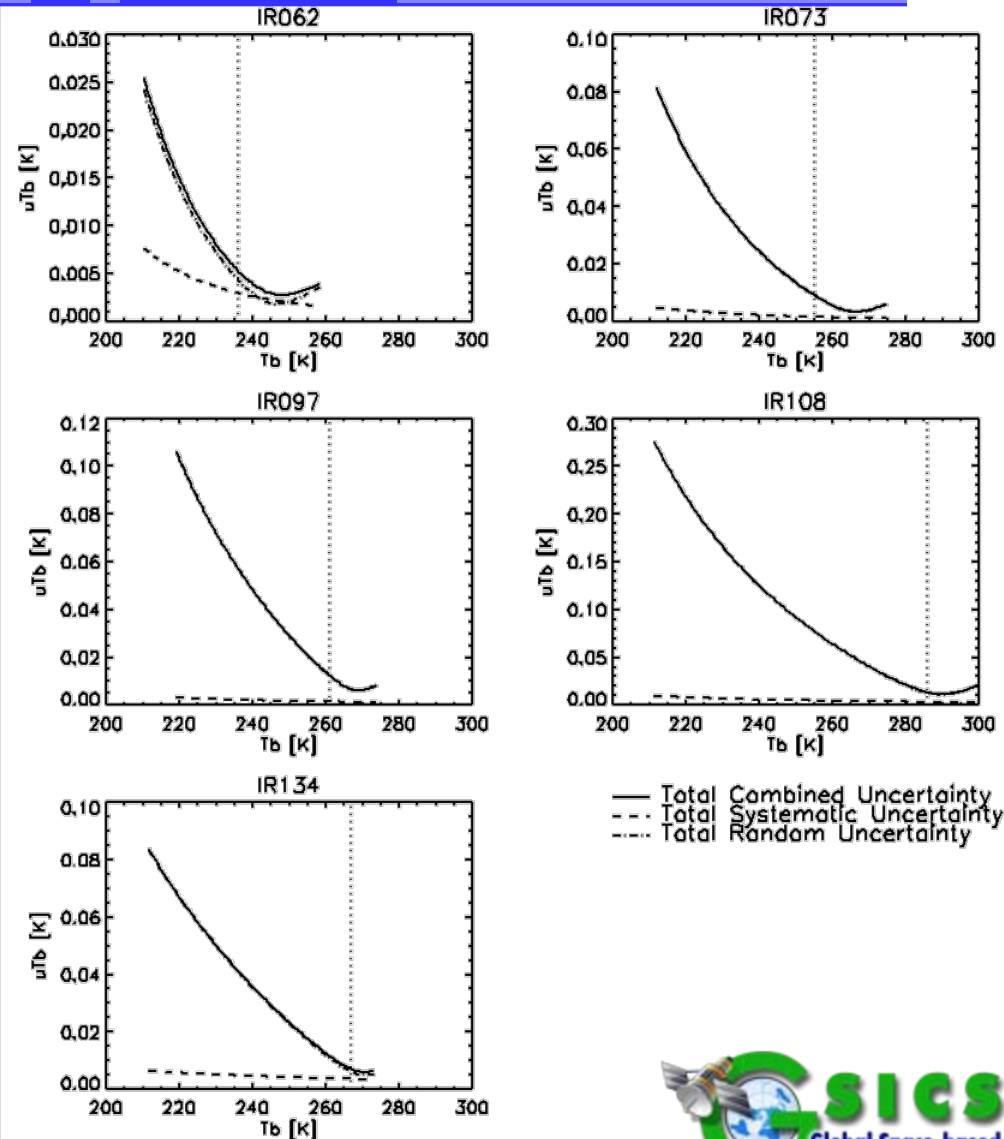


Quality Indicators in GSICS Products

- GSICS Correction Coefficients include
 - Estimates of uncertainties and covariances
 - From weighted linear regression
 - Using spatial variance and radiometric noise of each collocated observation as weighting
- Shown as error bars in GSICS Bias Monitoring plots
- But many other processes introduce uncertainty
 - Systematic and Random
- Need to validate these *quality indicators*

GEO-LEO IR Uncertainty Evaluation

- Extended Error Budget for Meteosat-IASI GSICS Corrections
- Following QA4EO / GUM
- Processes at each step of ATBD introducing:
 - Random Uncertainties
 - Dominated by spatial/temporal variability
 - over 3km/300s
 - Validated using time series statistics
 - Systematic Uncertainties
 - Dominated by spatial/temporal mismatches
 - Total uncertainties depend on radiance
 - Mostly dominated by random processes
- Errors much lower in WV channels
- See also poster by Tim Hewison



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2011 GSICS Users' Workshop

- The 3rd GSICS Users' Workshop took place at [EUMETSAT Meteorological Satellite Conference](#), in Oslo on 6 Sept 2011
- With GSICS Poster session
- Agenda:
 - Introduction to GSICS
 - Update on GSICS products
 - User Interaction
 - Feedback from beta testers
 - Cooperation with other groups



Impact on a JMA Product

SST Retrieval

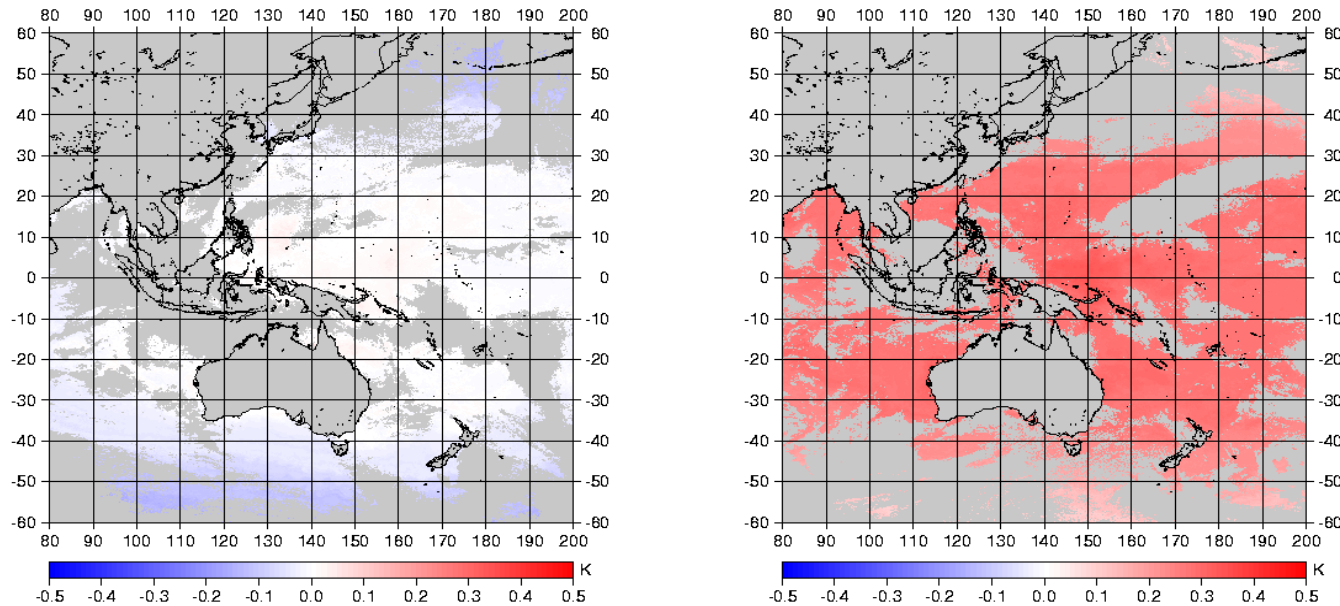


Fig-1 Differences between SSTs with and without GSICS correction (corrected SST – non corrected SST)

Left panel shows the result for 2011.1.8 and right panel shows it for 2011.3.1.

With thanks to Yukio Kurihara (JMA)

Impact on a JMA Product

SST Retrieval

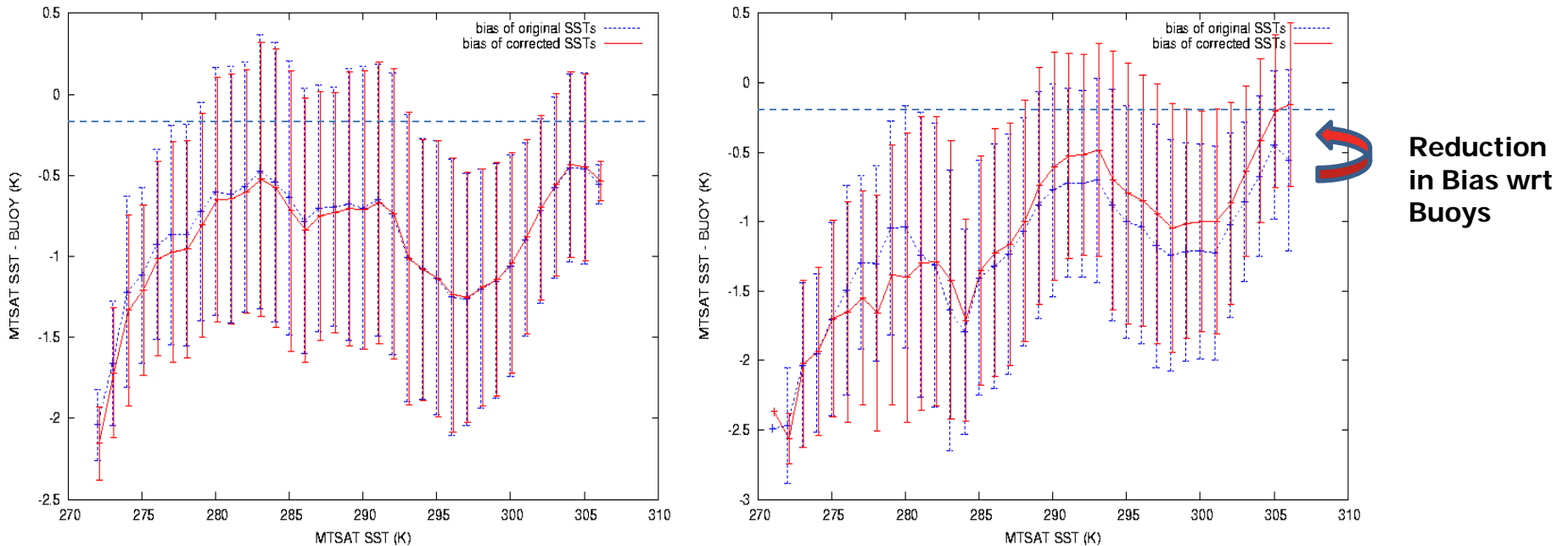


Fig-2 Mean differences (MTSAT SST minus in-situ SST) and standard deviation against in-situ SST

Statistics for the SST with and without GSICS correction are plotted with red and blue, respectively. Left panel shows the result for 2011.1.8 and right panel shows it for 2011.3.1.

With thanks to Yukio Kurihara(JMA)

Lessons Learnt

- Read the QA4EO guidelines and standards first!
 - They can save a lot of work in the long-run
- Construct a rough, but formal error budget first
 - Revise dominant terms later
 - Allows trade-offs to optimise algorithm
- QA Process is iterative
 - User Workshop highlighted need to evaluate our evaluation: Independent review for QA
 - Needs two-way communication with experts & users

Suggestions for Future QA4EO actions

- Set up training workshops on basic principles and/or specific guidelines
- GSICS Data Working Group will review data formats and standards
 - QA4EO representatives welcomed to join this review and for other *ad hoc* agenda items



Thank You