Defining IASI as the Infrared Anchor Reference for the Global Space-based Inter-Calibration System (GSICS)

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Overview

1. Introducing GSICS
2. GSICS Corrections for Meteosat IR channels
    - Uncertainty analysis
3. Prime GSICS Corrections
    - Merging results from multiple references
    - Anchor Reference Concept
4. Reference Instrument Selection Criteria
    - Scoring Scheme
5. Inter-comparison of Reference Instruments
6. Conclusions

Global Space-based Inter-Calibration System

- **What is GSICS?**
  - Global Space-based Inter-Calibration System
  - Initiative of CGMS and WMO
  - Effort to produce consistent, well-calibrated data from the international constellation of Earth Observing satellites
- **What are the basic strategies of GSICS?**
  - Improve on-orbit calibration by developing an integrated inter-comparison system
    - Initially for GEO-LEO Inter-satellite calibration
    - Being extended to LEO-LEO
    - Using external references as necessary
  - Best practices for calibration & characterisation
- **This will allow us to:**
  - Improve consistency between instruments
  - Reduce bias in Level 1 and 2 products
  - Provide traceability of measurements
  - Retrospectively re-calibrate archive data
  - Better specify future instruments

GSICS Global Space-based Inter-Calibration System

EUMETSAT CNES JMA
NOAA CMA KMA
ISRO NASA WMO
USGS NIST JAXA
ROSHYDROMET IMD ESA

GSICS Principles

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

TRACEABILITY / UNBROKEN CHAINS OF COMPARISONS

- **Delivery to users**
  - **Free and open access**
  - **Adopting community standards**
- **To promote**
  - **Greater understanding of instruments' absolute calibration, by analysing the root causes of biases**
  - **More accurate and more globally consistent retrieved L2 products**
  - **Inter-operability for more accurate environmental, climate and weather forecasting products**

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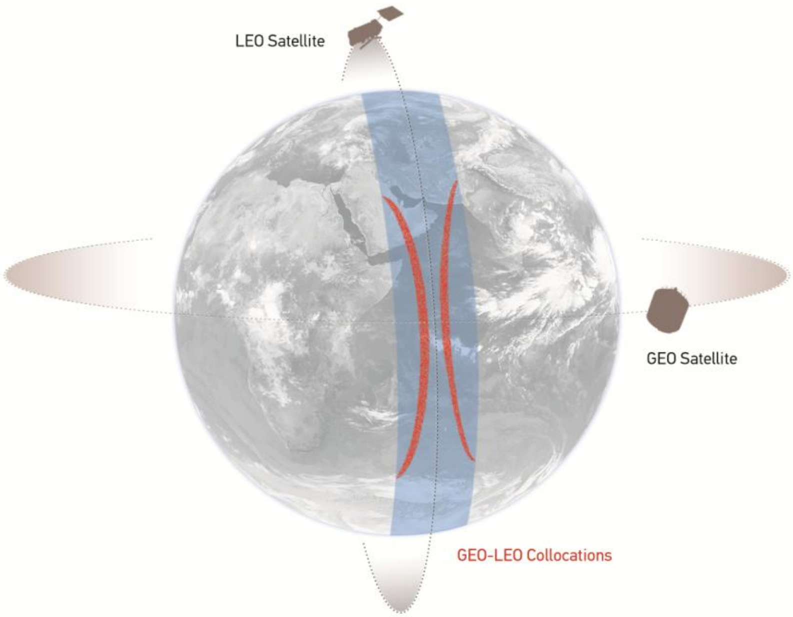
GEO-LEO IR - Hyperspectral SNO

- Simultaneous near-Nadir Overpasses
  - of one GEO imager and one 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

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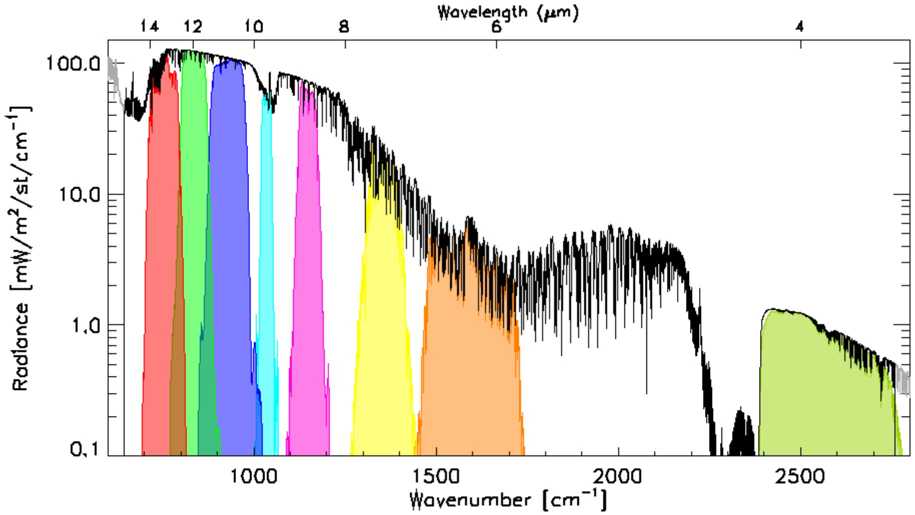
  - of one GEO imager and one LEO sounder
- Select Collocations
  - Spatial, temporal and geometric thresholds
- Spectral Convolution:
  - Convolve LEO Radiance Spectra
    with GEO Spectral Response Functions
  - to synthesise radiance in GEO channels



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

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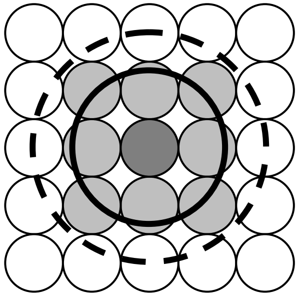
  - Convolve LEO Radiance Spectra with GEO Spectral Response Functions
  - to synthesise radiance in GEO channels
- Spatial Averaging
  - Average GEO pixels in each LEO FoV
  - Standard Deviation of GEO pixels as weight



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.

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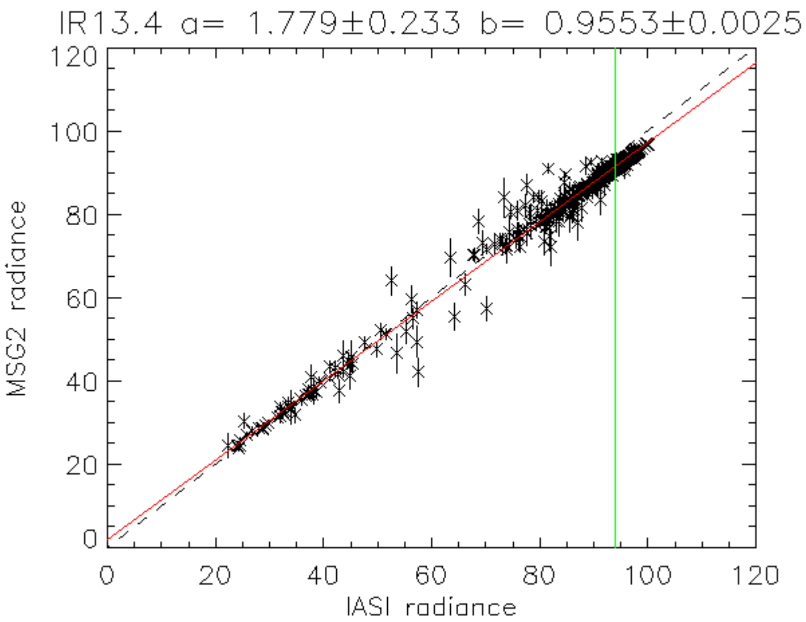
- Spatial Averaging
  - Average GEO pixels in each LEO FoV
  - Standard Deviation of GEO pixels as weight
- Weighted Regression of LEO v GEO rads
  - Evaluate Bias for Standard Radiance Scene
  - Regression coefficients with uncertainty
- GSICS Correction = Function
  - to convert level 1 data to be consistent with calibration of reference
  - Re-Analysis (symmetric time window)
  - Near Real-Time (asymmetric time window) - alternative cal coefficients in L1.5 HDR



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

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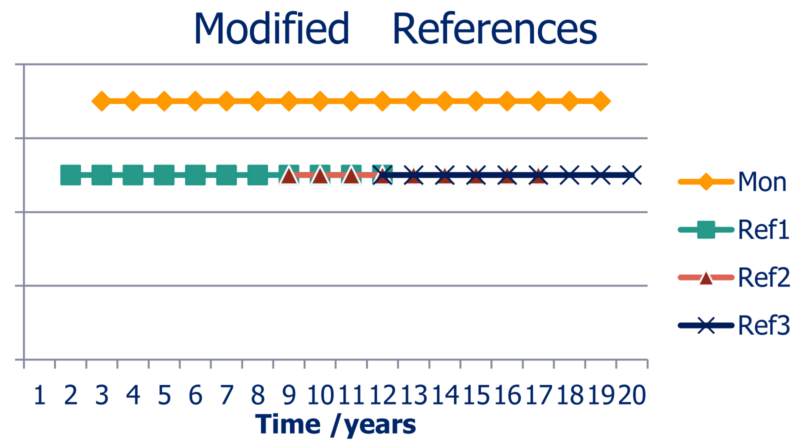
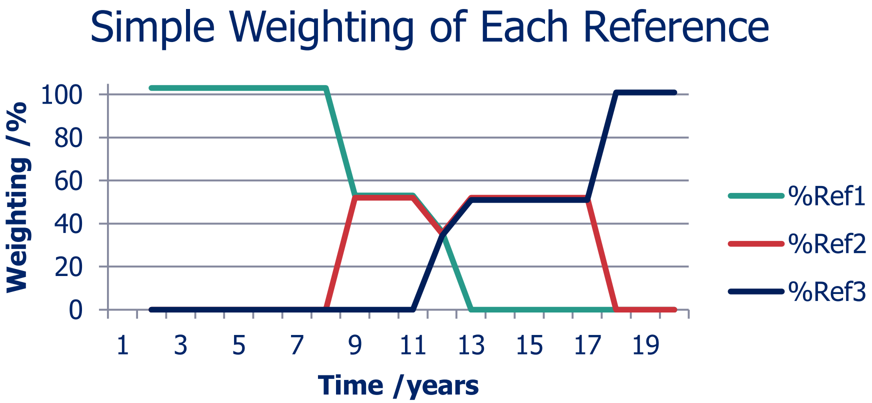
Introducing *Prime GSICS Corrections*

- Define one *Anchor GSICS Reference*
  - For each spectral band/application
  - By consensus agreement within GSICS
- Use others as *Transfer References*
- **Blend** corrections from all references
  - After modifying Corrections to *Anchor GSICS Reference*
- Ensures long-term continuity
  - Without calibration jumps
- Ensures Traceability
  - back to single Anchor Reference
- Simplifies users' implementation





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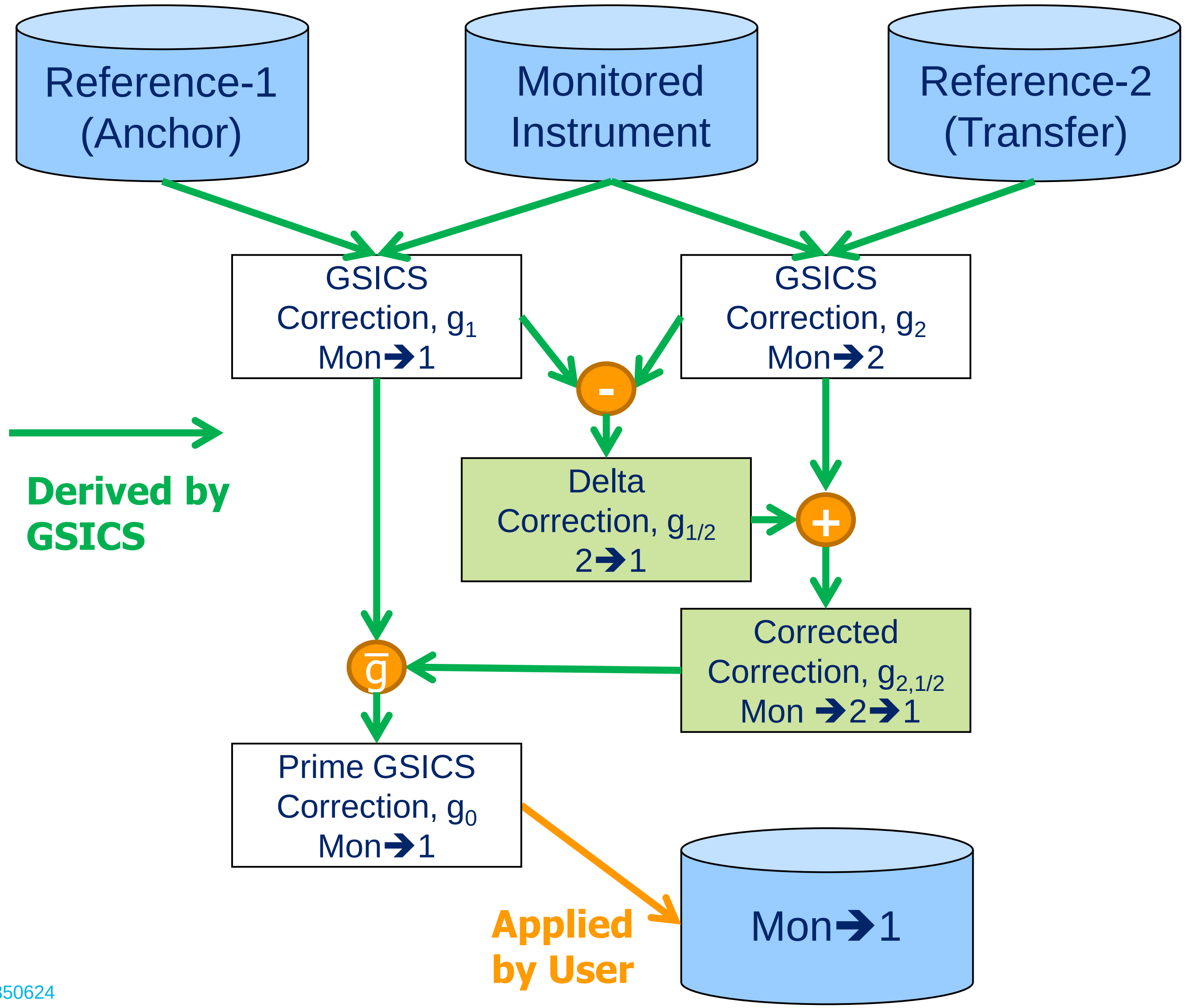
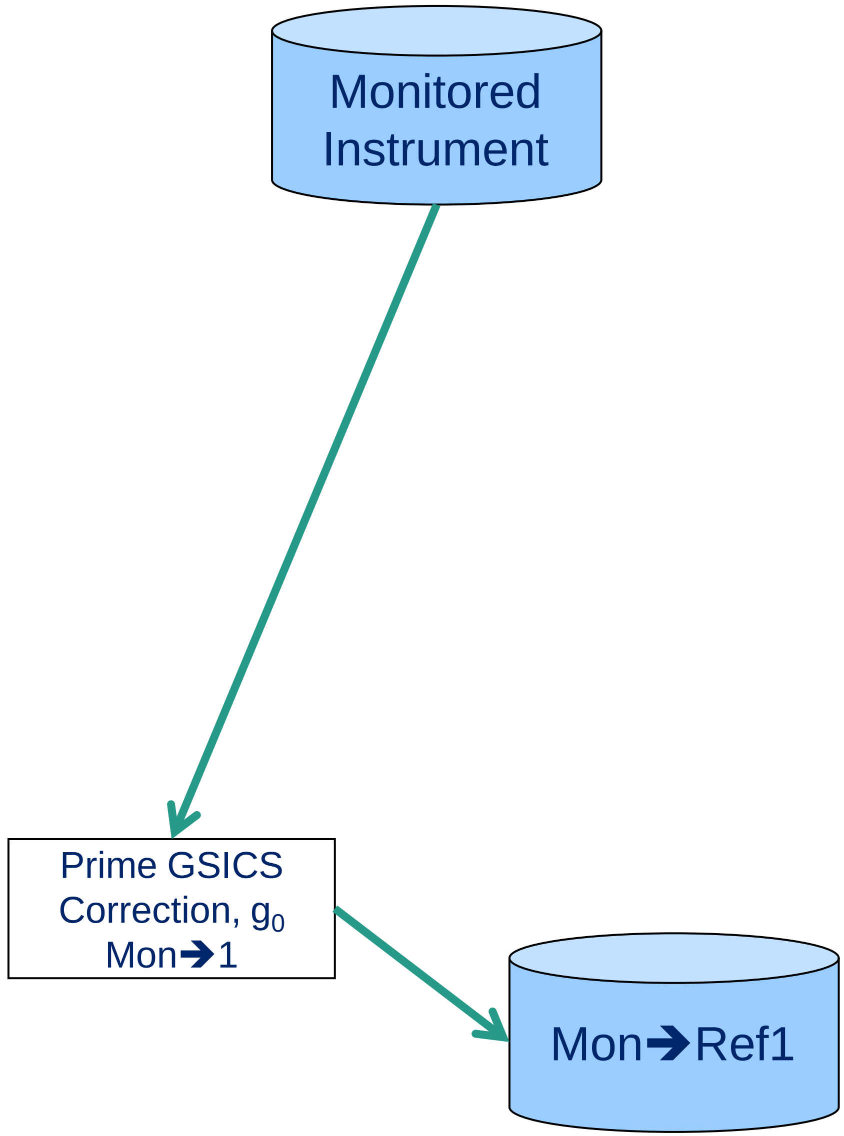
Correcting the Corrections & Blending References



Users' Application of Prime GSICS Correction



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Reference Instrument Selection Criteria

- Most basic requirements are **essential** properties:
  - Is it available for the date in question?
  - Does it cover *at least part of* the spectral range?
  - Does it generate *sufficient* collocations?
  - Is its calibration *sufficiently* stable?
  - Can it transfer the calibration to other Reference sensors?

- Additional **desirable** requirements
- reflect reduced uncertainties in inter-calibration,
- up to a *saturation* point:
  - Does it cover the *full* spectral range?
  - At *sufficiently* high spectral resolution?
  - Is the full supporting documentation published?
  - Is it routinely monitored against other Reference sensors?
  - Does it belong to a committed series of sensors?

Draft Scoring Scheme

		Threshold		Saturation		
	Unit	Min	Max	Min	Max	Weight
Date Range	Year	2015	2015	2006	2030	10
Spatial Coverage: Lat	deg	-10	10	-90	90	1
Spatial Coverage: Lon	deg	-10	10	-180	180	1
Dynamic Range	K	270	300	180	330	2
Spectral Range SWIR	µm	3.75	3.92	3.48	4.36	2.2
Spectral Range MWIR	µm	6.25	7.35	5.35	7.85	2.6
Spectral Range LWIR	µm	8.70	13.40	8.30	14.40	5.2
Geometric Range: VZA	deg	5	15	0	90	2
Diurnal Coverage	hr	9	10	0	12	10
# Collocations	/d	1		10000		4
Spatial resolution	km		100		10	0
Spatial sampling	km		100		10	1
Geolocation accuracy	km		10		0.1	5
Radiometric Stability	K/yr		1		0.001	10
Radiometric Noise	K		10		0.1	1
Uncertainty from SBAF	K		1		0.01	10
Spectral Resolution	cm-1		100		0.5	0
Spectral Stability	cm-1/yr		2		0.01	0
Absolute Cal Acc	K		1		0.001	10
Total						**100.0**

Draft Scores for GSICS GEO-LEO IR NRTC

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Scoring Scheme for GSICS Near-Real-Time Correction for 2015 Geostationary Imager IR Channels

		Threshold		Saturation			Metop/IASI		Aqua/AIRS		SNPP/CrIS (in FSR mode)		NOAA/HIRS/2	
	Unit	Min	Max	Min	Max	Weight	OK?	Score	OK?	Score	OK?	Score	OK?	Score
Date Range	Year	2015	2015	2006	2030	10	OK	7.1	OK	5.8	OK	3.8	NOK	10.0
Spatial Coverage: Lat	deg	-10	10	-90	90	1	OK	1.0	OK	1.0	OK	1.0	OK	1.0
Spatial Coverage: Lon	deg	-10	10	-180	180	1	OK	1.0	OK	1.0	OK	1.0	OK	1.0
Dynamic Range	K	270	300	180	330	2	OK	1.7	OK	1.7	OK	1.7	OK	1.7
Spectral Range SWIR	µm	3.75	3.92	3.48	4.36	2.2	OK	1.6	OK	1.2	NOK	1.1	OK	1.4
Spectral Range MWIR	µm	6.25	7.35	5.35	7.85	2.6	OK	2.6	OK	1.4	OK	2.1	NOK	0.2
Spectral Range LWIR	µm	8.70	13.40	8.30	14.40	5.2	OK	5.2	NOK	2.6	NOK	2.6	NOK	2.6
Geometric Range: VZA	deg	5	15	0	90	2	OK	1.2	OK	1.2	OK	1.2	OK	1.2
Diurnal Coverage	hr	9	10	0	12	10	OK	2.8	OK	2.8	OK	2.8	OK	2.8
# Collocations	/d	1		10000		4	OK	4.0	OK	4.0	OK	4.0	OK	4.0
Spatial resolution	km		100		10	0	OK	0.0	OK	0.0	OK	0.0	OK	0.0
Spatial sampling	km		100		10	1	OK	0.4	OK	0.7	OK	0.6	OK	0.4
Geolocation accuracy	km		10		0.1	5	OK	0.2	OK	0.2	OK	0.2	OK	0.2
Radiometric Stability	K/yr		1		0.001	10	OK	0.2	OK	0.2	OK	0.2	OK	0.2
Radiometric Noise	K		10		0.1	1	OK	0.7	OK	0.5	OK	0.5	OK	0.5
Uncertainty from SBAF	K		1		0.01	10	OK	10.0	OK	1.0	OK	1.0	OK	0.3
Spectral Resolution	cm-1		100		0.5	0	OK	0.0	OK	0.0	OK	0.0	NOK	0.0
Spectral Stability	cm-1/yr		2		0.01	0	OK	0.0	OK	0.0	OK	0.0	OK	0.0
Absolute Cal Acc	K		1		0.001	10	OK	0.2	OK	0.2	OK	0.2	OK	0.0
Total						**100.0**	**97%**	**52%**	**91%**	**37%**	**88%**	**36%**	**82%**	**39%**

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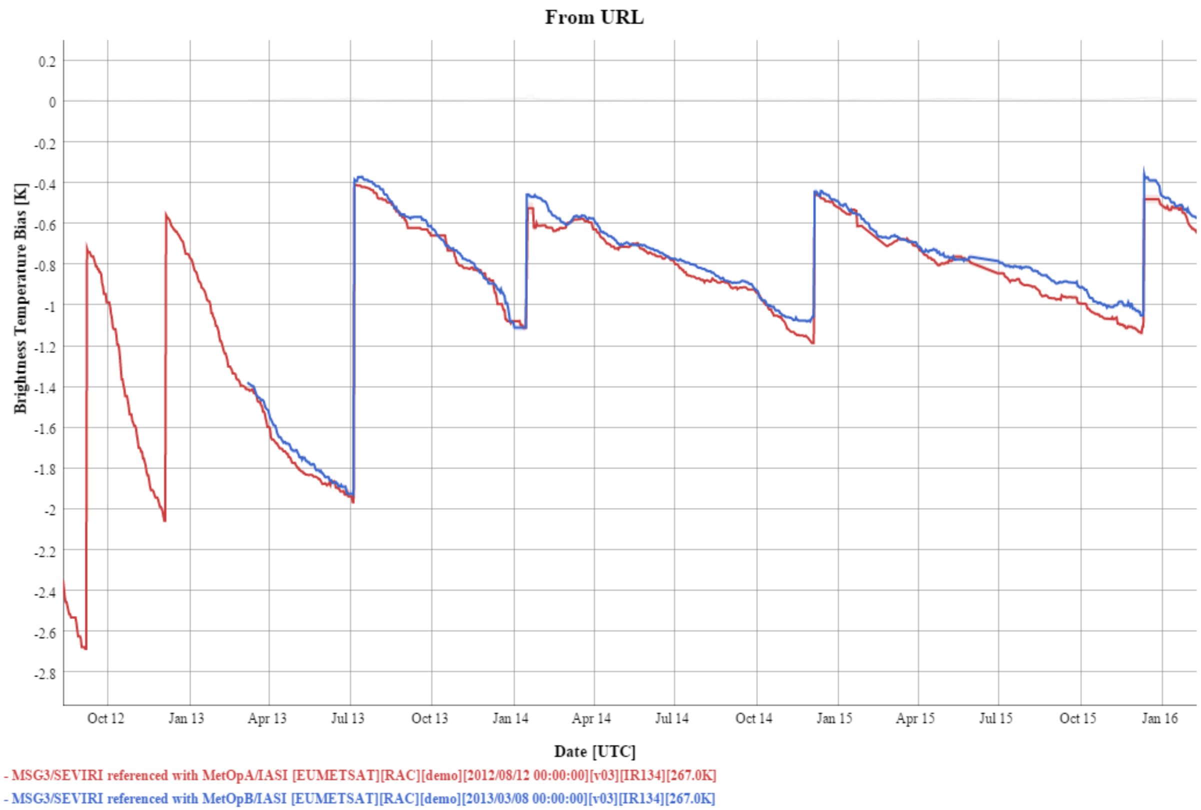
GSICS GEO-LEO IR Double Differences

- Time series of Bias
  - in Meteosat-10/ SEVIRI IR13.4
  - wrt IASI-A
  - wrt IASI-B
  - For standard scene radiance (267K)
  - Over 3 yr overlap

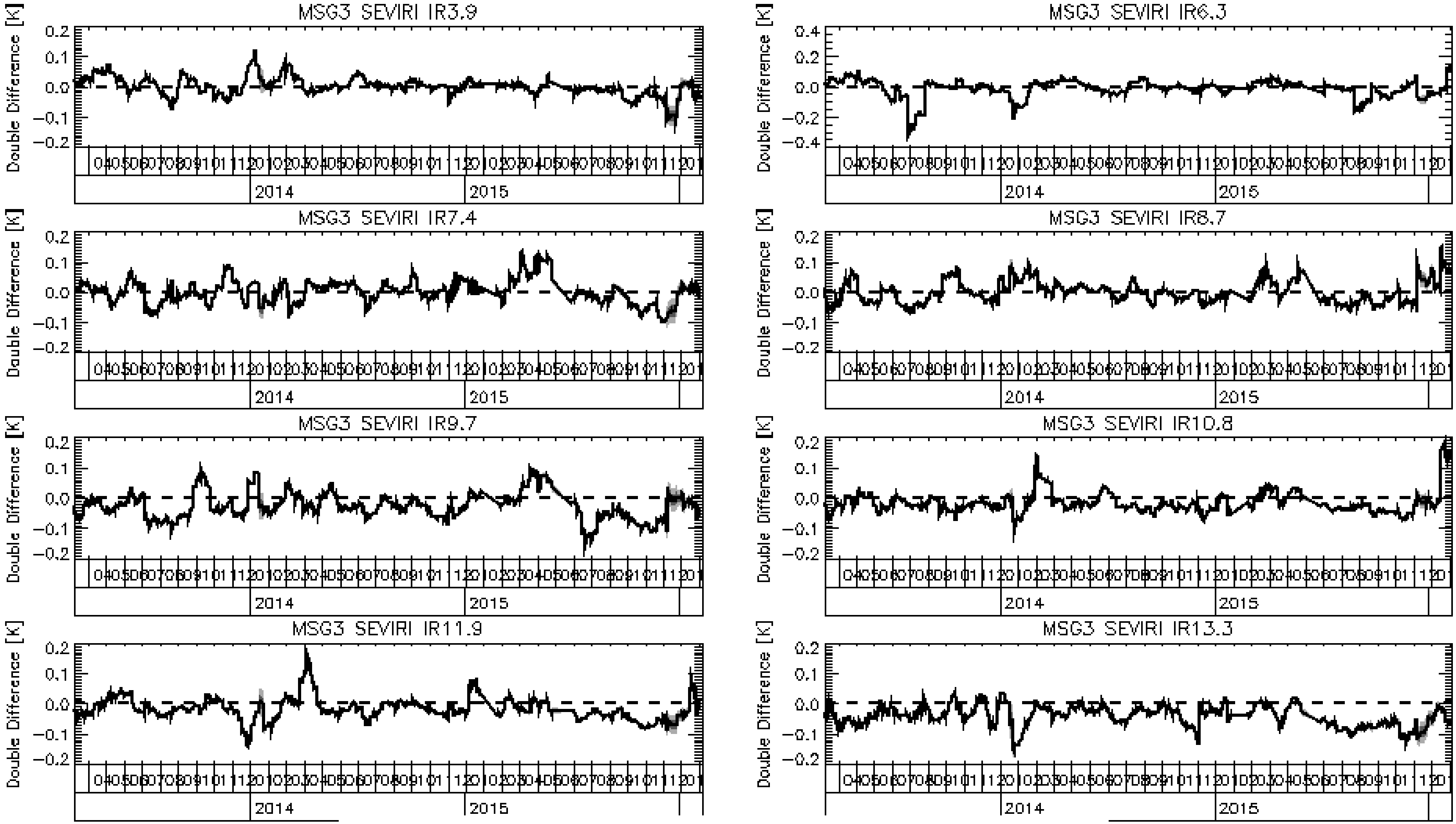


- Biases vary
  - Ice contamination
  - Range -0.4 to -2.7K

- Differences <0.1K

Time series of Double Differences

No Obvious Trend in Any Channel! ☺



Small differences in long-wave channels ☹

Statistics of Double Difference Time Series

(MSG3-IASIA)-(MSG3-IASIB) Demo RAC Standard Bias over 2013-03/2016-02:

Channel	Double Difference Trend [K/yr]	Mean Double Difference [K]
IR3.9	-0.016 ± 0.008	0.001 ± 0.005
IR6.3	-0.003 ± 0.015	-0.015 ± 0.010
IR7.4	-0.002 ± 0.010	0.002 ± 0.007
IR8.7	0.002 ± 0.008	0.000 ± 0.006
IR9.7	-0.005 ± 0.011	-0.027 ± 0.007
IR10.8	0.004 ± 0.009	-0.016 ± 0.006
IR12.0	-0.009 ± 0.009	-0.018 ± 0.006
IR13.4	-0.011 ± 0.008	-0.042 ± 0.006

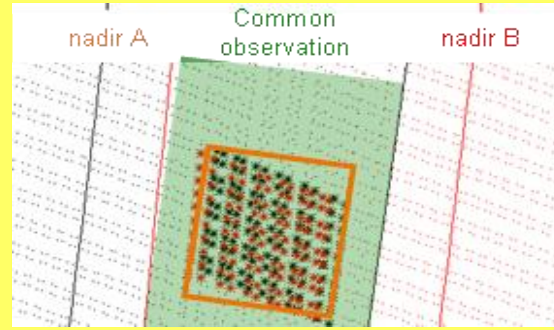
- No statistically significant trend
  - in any channel
- Within standard uncertainty of 10mK/yr

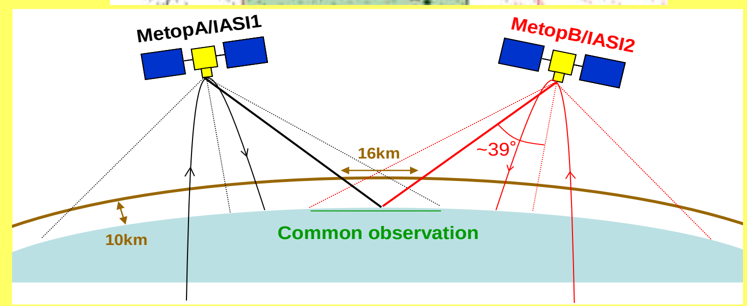
- Consistent results from other Meteosats
  - But larger uncertainties

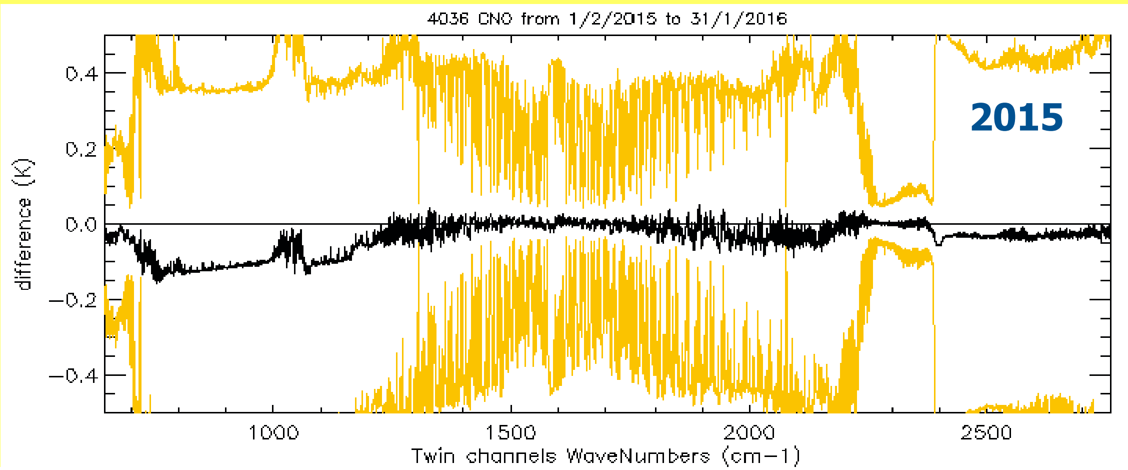
- No statistically significant difference
  - between IASI-A and -B
  - in Short- and Mid-bands
  - in any channel
- Small, but significant difference
  - in long-wave band
  - Larger for colder scenes

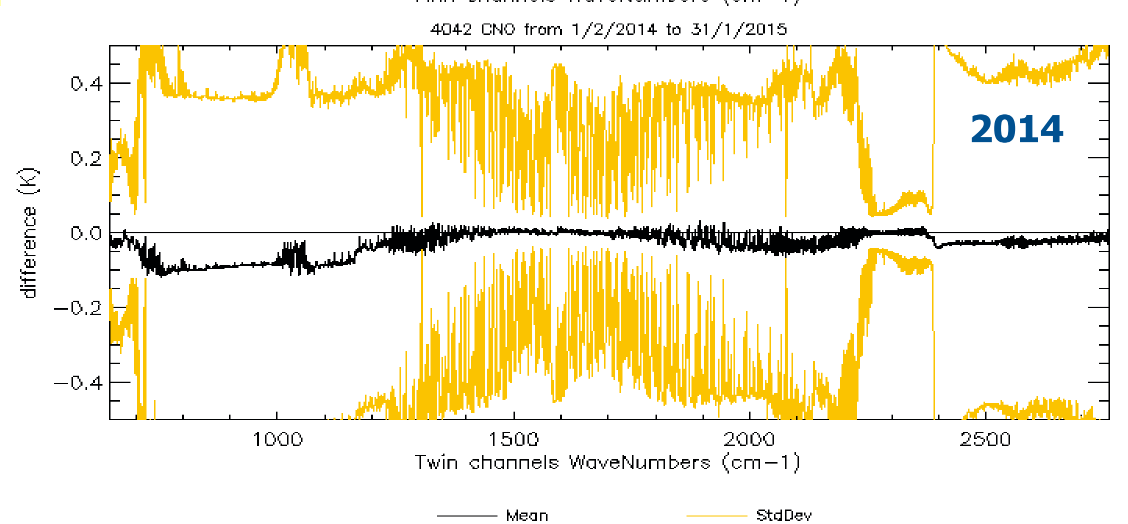
IASI-A / IASI-B 2015 comparison: CNES SIC Tool

- **Statistics on "quasi-SNOs" (50min delay, ~off-nadir)**
- **Focus on homogeneous and stable scenes, night, as many "A before B" as "A after B"**









Results:

- **Biases between 0 and ~0.1K**
- **Highest bias for long wavelengths**

➔ **Very good cross calibration**

➔ **Same behaviour as the previous years, no degradation**

➔ **Shape in B1 under investigation**

[Slide from Denis Jouglet, CNES]

Radiance Dependence of IASI-A/B Double Difference

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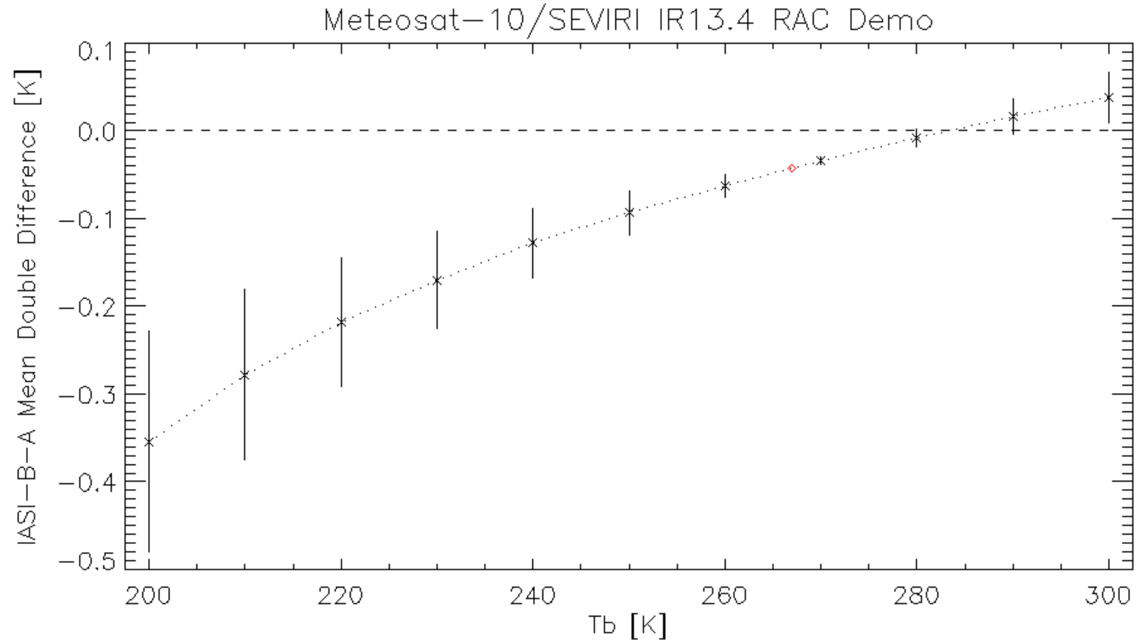
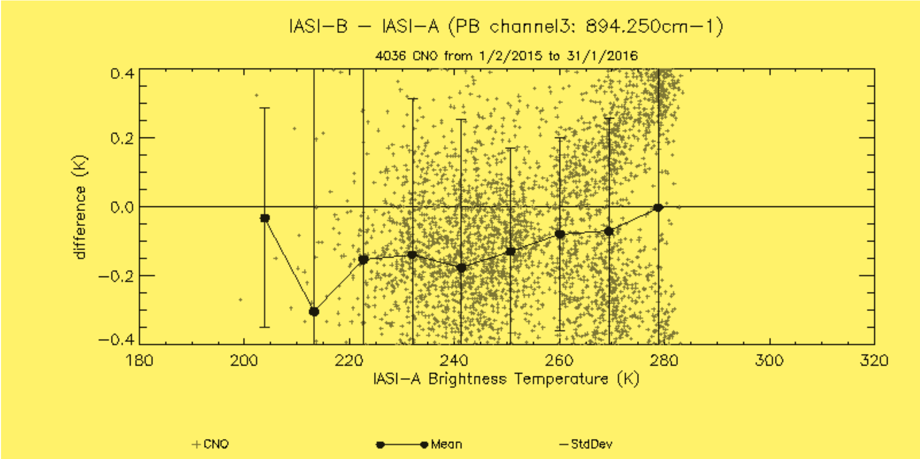
- (MSG3-IASIA)-(MSG-IASIB) larger for cold scenes
- Must be careful comparing results from different domains!
  - Mean ΔTb from polar SNOs ≠ Mean ΔTb from global QSNOs
  - Should compare in radiance bins
- Due to non-linearity differences?



- Consistent with CNES SIC Tool:



Radiance-dependence of (MSG3-IASIA)-(MSG-IASIB) Double Difference

Error bars represent k=1 uncertainty on mean difference

Red diamond = standard scene

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Conclusions

- Metop-A/IASI used as reference for first operational GSICS product:
  - Inter-calibration corrections for IR channels of Meteosat/SEVIRI
- Extension of concept to merge results from multiple references
  - Correcting all to be consistent with one *Anchor Reference* – Metop-A/IASI
  - Based on series of double-differences wrt SEVIRI
  - IASI-B and IASI-A calibration stable in all channels over 3 years
  - No significant differences in short- and mid- wave bands
  - Small differences in long-wave channels (<0.05K) – Radiance-dependent
- Selection of Anchor reference based on coverage/performance
  - According to uncertainty contributions
  - To be supported by error budgets
  - Inter-comparisons of different reference instruments
- GSICS Infrared Reference Sensor Traceability & Uncertainty Report
  - Error Budgets, Traceability and Inter-Comparisons

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Thank You!