Prime GSICS Corrections, using double-differences of IASI-A and -B against the IR channels of Meteosat/SEVIRI

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Abstract

This paper introduces the basis of the GSICS algorithm to inter-calibrate the infrared channels of geostationary imagers, such as Meteosat/SEVIRI, to be consistent with Metop-A/IASI, and extends it to combine comparisons with other reference instruments. Double-differences of GSICS Corrections derived using the IASIs on Metop-A and -B are used to define a *delta correction*, which allows comparisons with multiple references to be combined, based on their relative uncertainties, in a way metrologically consistent with the *Anchor Reference*, to generate what are referred to as *Prime GSICS Corrections*. These support the creation of Fundamental Climate Data Records, spanning extended periods with multiple reference instruments.

These results show no significant differences between the calibration of the mid- and short-wave bands of IASI-A and -B were found over SEVIRI's relatively broad spectral bands. However, there are small (<0.05K), but statistically significant differences in the long-wave band, where IASI-B is consistently warmer than IASI-A. These differences are radiance-dependent, but stable over a 3 year period starting in March 2013.

Global Space-based Inter-Calibration System (GSICS)

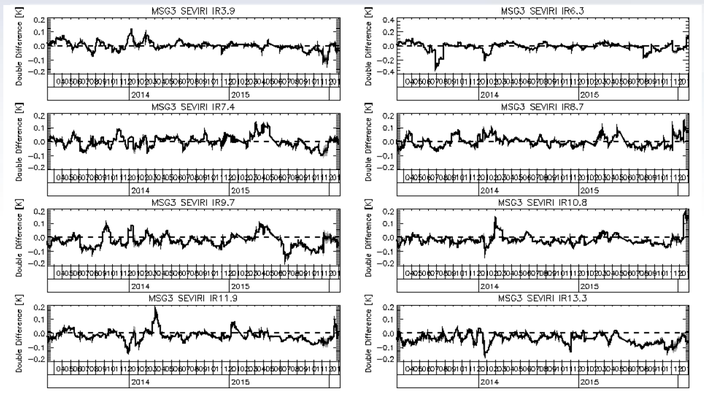
What is GSICS?
- Initiative of CGMS and WMO
- An effort to produce consistent, well-calibrated data from the international constellation of environmental satellites[1]

What are the strategies of GSICS?
- Best practices/requirements for prelaunch characterisation
- Improve on-orbit calibration by developing an integrated inter-calibration system

This allows us to:
- Better understand current instruments
- Better specify future instruments
- Improve consistency between instruments
- Produce less bias in Level 1 & 2 products
- Retrospectively re-calibrate archive data

IASI-A/B Double Difference Analysis

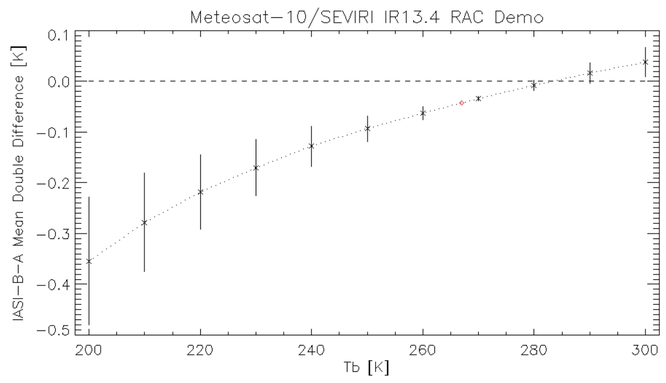
- (MSG3/SEVIRI-MetopA/IASI)-(MSG3/SEVIRI-MetopB/IASI)
- All 8 infrared channels
- GSICS Re-Analysis Corrections over 3 years:



- No Obvious Trend in Any Channel! ☺
- Small differences in long-wave channels ☹

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

Results for Mean Double-Difference Analysis:
- No statistically significant trend in any channel
- within standard uncertainty of 10mK/yr
- Consistent results from other Meteosats
- No statistically significant difference in any channel between IASI-A and -B in Short- and Mid-bands
- Small, but significant difference in long-wave band
- Differences are larger for colder scenes

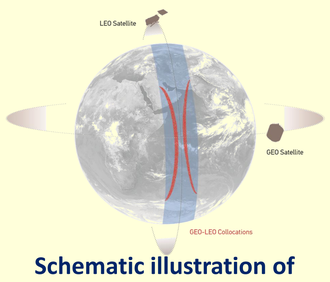


Radiance-dependence of IASIB-IASIA Double Difference
Calculated over 3 years 2013-03/2016-03
Error bars represent k=1 uncertainty on mean difference
Red diamond = standard scene

Results for Radiance-Dependence Analysis:
- IASIB-A double difference larger for cold scenes
- Must be careful comparing results from different domains!
- <ΔTb> from polar SNOs ≠ <ΔTb> from global QSNOs
- Should compare in radiance bins!
- Consistent with CNES SIC Tool
- Due to non-linearity differences?

GSICS GEO-LEO IR Inter-Calibration

- Simultaneous near-Nadir Overpass of GEO imager and LEO sounder
- Metop-A/IASI as *anchor* reference
- Metop-B/IASI, Aqua/AIRS, S-NPP/CrIS, & NOAA/HIRS as *transfer* references

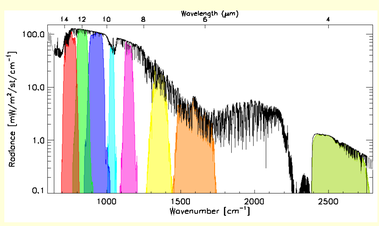


Schematic illustration of geostationary orbit (GEO) and polar low Earth orbit (LEO) satellites and distribution of their collocated observations [2]

1. Select Collocations
- Δlat <35° Δlon <35°
- Δt < 5 min
- $\Delta \sec\theta$ < 0.01
- Concentrated in tropics
- ~1000 collocations/orbit

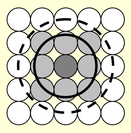
2. Spectral Transformation

For Hyperspectral References:
- Convolve LEO Radiance Spectra with GEO Spectral Response Functions
- to synthesise radiance in GEO channels



Radiance spectra measured by IASI (black), convolved with the Spectral Response Functions of SEVIRI channels 3-11 (shaded)

3. Spatial Transformation
- 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~12km

~ 5x5 GEO pixels

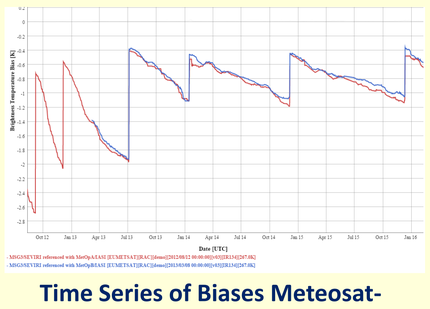
Small circles represent the GEO FoVs and the two large circles represent the LEO FoV for SEVIRI-IASI

4. Calculate GSICS Corrections
- Regression of collocated observations
- GEO radiance
  - Spatially averaged
- Compare with LEO radiance spectra,
  - after Spectral Conversion
- Weighting=Noise+Var(GEO radiances)

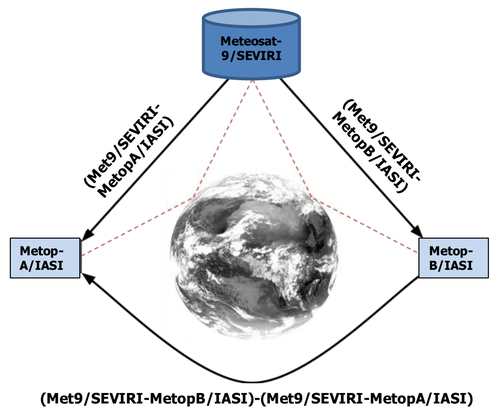
Weighted linear regression of Radiances observed by 13.4μm channel of Meteosat-9 and synthesised from IASI spectra

5. Calculation of Bias
- From regression coefficients
- For standard scene radiances
- Clear sky, standard atmosphere

6. Evaluate Bias Time Series
- Time series of Bias
  - in Meteosat-10/ SEVIRI IR13.4
  - wrt IASI-A , wrt IASI-B
  - For standard scene (267K)
  - Over 3 yr overlap
- Biases vary from -0.4 to -2.7K
  Ice contamination
- Differences <0.1K



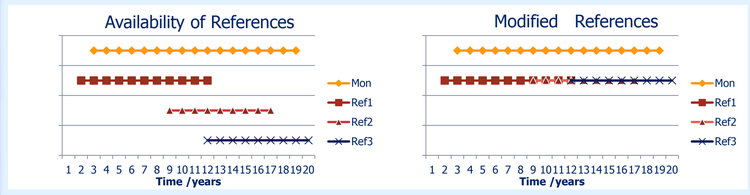
Time Series of Biases Meteosat-10/IR13.4 wrt IASI-A , IASI-B

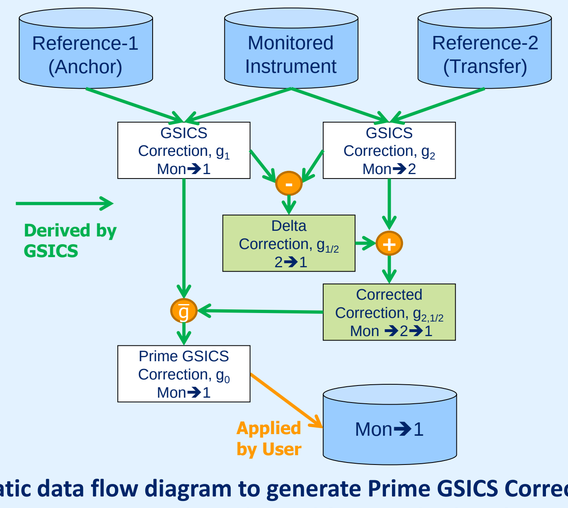


Schematic Concept of Double-Differences against geostationary imager

Introducing Prime GSICS Corrections

- Define one *Anchor* GSICS Reference
  - for each spectral band/application
  - by consensus agreement in 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 *anchor* reference
- Simplifies implementation





Schematic data flow diagram to generate Prime GSICS Correction, merging GSICS Corrections derived from multiple references, after applying Delta Corrections, based on their double differences, transforming them to the common scale of the anchor reference

Conclusions

- IASI-A is reference for first operational GSICS product:
  - Inter-calibration corrections for IR channels of Meteosat/SEVIRI
- Extended concept to merge results from other references
  - Correcting all to be consistent with *Anchor* Reference – IASI-A
  - Based on series of double-differences wrt SEVIRI
- Analysis of IASI-B and IASI-A Double Differences:
  - IASI-A and IASI-B calibration stable in all channels over 3 years
  - **No significant differences,**
    – except in long-wave channels (<0.05K for standard scene Tbs)
  - **Difference is radiance-dependent**
    – care when comparing different methods!

References

1. Goldberg , M. *et al.*, 2011: "The Global Space-based Inter-Calibration System (GSICS)", *Bulletin Am. Meteorol. Soc*, doi:10.1175/2010BAMS2967.1
2. Hewison, T. J., *et al.*, "GSICS Inter-Calibration of Infrared Channels of Geostationary Imagers using Metop/IASI", *IEEE Trans. Geosci. Remote Sens.*, vol. 51, no. 3, Mar. 2013, doi:10.1109/TGRS.2013.2238544.

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