Introduction to GSICS and inter-calibration monitoring at EUMETSAT

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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 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

• **Delivery to users**
  - Free and open access
  - Adopting community standards

• **GSICS Products**
  - Currently empirical corrections to operational calibration coefficients (or alternative cal coeffs)
  - Defined in Radiance-space (could also be spectral)
  - Promote greater understanding of instruments’ absolute calibration, by analysing the root causes of biases
  - Allow Inter-operability

  for more accurate environmental, climate and weather forecasting products
Who are the targeted users?

- Satellite users interested in accurate/consistent calibration
  - Stable Level 2 product generation, Level 3 multi-satellite products
  - Climate Data Record generation (e.g. “SCOPE-CM”, WCRP/ISCCP)
  - Reanalysis
  - Assimilation in NWP models: bias characterization of radiances

- Satellite operators sharing developments, best practices, and tools
  - Prelaunch instrument characterization
  - In-orbit commissioning and Cal/Val plans
  - Instrument monitoring, detection/analysis of anomalies
  - Improved calibration

- Partner programmes: CEOS WGCV, GPM X-cal, GHRSST, GRUAN, etc...
Definition of GSICS Deliverables

- GSICS Products for users of satellite data, including calibration corrections/coefficients
- GSICS Algorithms, which describe inter-calibration processes, (described by ATBD)
- GSICS Monitoring Reports, assessments
- GSICS Reference datasets, including Solar spectrum, ...
- GSICS Tools for use by inter-calibration developers, (GIRO, SBAF, ...)
- GSICS recommended standards, conventions and guidelines,
- GSICS User Services, information
Evolving scope of GSICS

• Started with IR calibration corrections (GEO-LEO)
• Continued with VIS/NIR domain
• Now addressing also the UV and MW domains

• Started with Near Real-Time correction functions
• Added Re-analysis corrections

• Considering now a wider variety of deliverables depending on user requirements
## GSICS GEO Products 2017-08

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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).**
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- Spatial Averaging
  - Average GEO pixels in each LEO FoV
  - Standard Deviation of GEO pixels as weight

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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  - 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 $<L_{GEO}>$ for Meteosat-9 13.4$\mu$m channel based on single overpass of IASI
GEO-LEO IR - Hyperspectral SNO

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  - of GEO imager and LEO sounder
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  - Convolve LEO Radiance Spectra with GEO Spectral Response Functions
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  - 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
  - GSICS Plotting Tool
  - Monitor calibration of SEVIRI, HIRS, ... SLSTR

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
Meteosat-7

- Meteosat-7 End of Life
- Long-term drift in IR channel bias
  - -1.75K in 2008-06
  - -3.5K in 2017-02
- Prime suspect: ice contamination
  - Build-up of ice layer on optics
  - Absorption band ~12µm
  - Modifies SRF
  - Apparent bias in IR
- Decontamination 2016-03
  - 1st since move to IODC
- Sudden change in bias
  - Need to reprocess!
Meteosat-10/SEVIRI/IR13.4

- Metop-A/IASI – Metop-B/IASI

• Long-term drift in IR13.4 channel
  – Ice Contamination

• Small differences IASI-A/B
  – But constant over 4 years
  – Improved non-linear correction
  – Will update for IASI-A in 2018

2017-08-02 Changed IASI-B on-board processing

- MSG3/SEVIRI referenced with MetOp-A/IASI [EUMETSAT][RAC][2013/03/10 00:00:00][v01][IR134][267.0K]
- MSG3/SEVIRI referenced with MetOpB/IASI [EUMETSAT][RAC][2013/03/10 00:00:00][v01][IR134][267.0K]
LEO-LEO IR- Monitoring MetopA/HIRS
LEO-LEO IR- Monitoring SLSTR

**ALL**

SLSTR_Band_S8_td5_zsiaisi20.0_N362444_v8:ALL:362444

bias: 0.0724
med: 0.0638

SLSTR_Band_S8_td5_zsiaisi20.0_N362444_v8:std<0.4:362444

bias: 0.1374
med: 0.0722

**Homogenous: (std<0.4 K)**

SLSTR_Band_S8_td5_zsiaisi20.0_N362444_v8:std<0.4:102513

**Theoretical uncertainty**

After Smith et al., 2014
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 & Normalise
- 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

Drift = 2.19 ± 0.02% per year
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

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

• GSICS Implementation of the ROLO model (GIRO)
  – Lunar irradiance model
  – Developed at EUMETSAT
  – Validated against USGS original with support from Tom Stone

• GSICS Lunar Observation Dataset (GLOD)
  – Contains Moon observations from all instruments using GIRO
  – Builds consensus on absolute calibration of GIRO
  – Helps develop inter-calibration methods

• Second Lunar Calibration Workshop
  – 13-16 November 2017 in Xi’an, China
  – Define future observations requirements
  – Refine international lunar calibration reference
  – Develop calibration & inter-calibration
  – New applications – e.g. MTF characterisation
  – Register by 31 August!

Examples of Moon observations from instruments represented in First Lunar Calibration Workshop, EUMETSAT, 1-4 December 2014
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: 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 (Ds), and the number of days from Ds to fulfill requirements to enter DP (Ds + 90 days), PP (Ds + 365 days), and OP (Ds + 180 days).
Where to get the data?

• GSICS Bias Monitoring
  – 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](http://gsics.wmo.int) for links

GTS = Global Telecommunication System
CF = Climate and Forecast
Closer CEOS-GSICS Interaction

WGCV is encouraged to

- Test impact of existing GSICS products & provide feedback
- Jointly develop inter-calibration products with GSICS
  - Applying existing algorithms to meteorological sensors
- Lead development of inter-calibration products
  - For „moderate- to high-resolution“ EO satellite sensors
  - Based on respective expertise
e.g. Using Pseudo Invariant Calibration Sites
- Could review through GSICS Procedure for Product Acceptance
  - Need to identify users to provide feedback
- Could promote and distribute through GSICS
  - GSICS Data and Products Servers (EUMETSAT, NOAA, CMA)
  - GSICS Product Catalog
Thank You