Feedback between GSICS and NWP Community on Radiometric and Spectral Biases

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On behalf of

GSICS Research Working Group

Overview

- Introduction to GSICS
  - and GSICS products
- Radiometric Biases
- Spectral Biases
- Reference Observations
- Discussion Points

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Global Space-based Inter-Calibration System

What is GSICS?

- Global Space-based Inter-Calibration System
- Initiative of CGMS and WMO: gsics.wmo.int
- 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
- Best practices for calibration & characterisation

This will allow us to:

- Improve consistency between instruments
  - Towards Interoperability
- Reduce bias in Level 1 and 2 products
- Support Cal/Val of new instruments
- 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**

Traceability = Unbroken Chain of Comparisons with Associated Uncertainties

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' calibration, by analysing the root causes of biases**
- **Allow Inter-operability:**
    - **Near real-time application for more accurate weather forecasting products**
    - **Re-Analysis application for improved understanding of climate processes**
    - **Re-Calibration of archive data to generate Fundamental Climate Data Records**

GSICS Corrections for GEO imagers’ IR channels

DIRECT INTER-CALIBRATION

Collocate in Space, Time, Angle

- Collect **S**imultaneous **N**adir **O**verpasses (SNOs)
- Tie to contemporary reference instrument
- with very small uncertainty

Hyperspectral Reference (IASI)

- Convolve IASI spectrum with **S**pectral **R**esponse **F**unction (SRF) of *monitored instrument*
- Can diagnose SRF errors

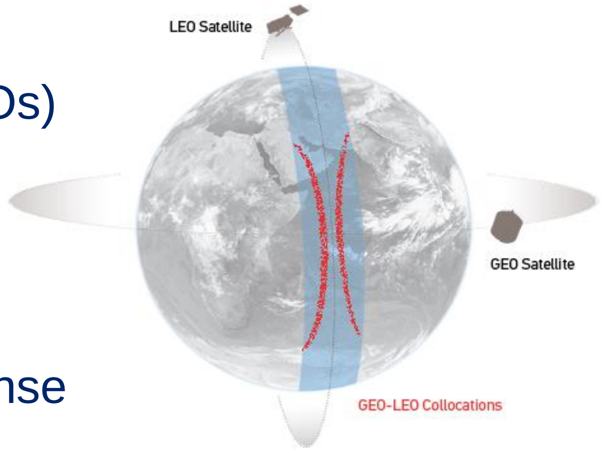
Compare

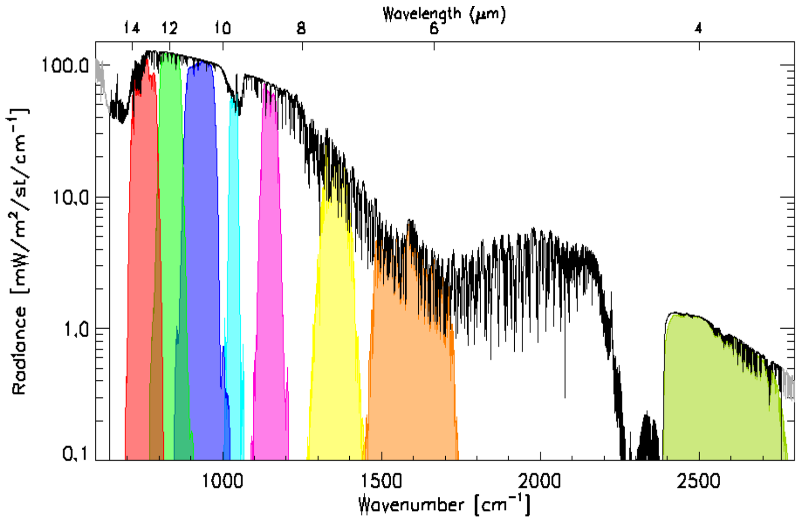
- Apply weighted regression to collocated radiances
- Evaluate uncertainties

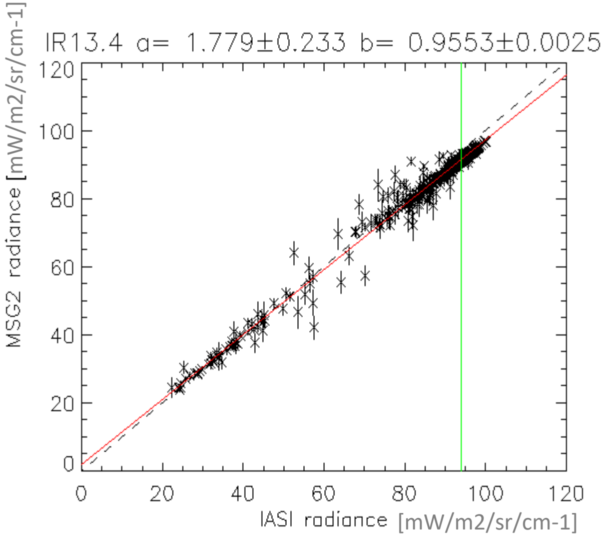
Generate GSICS Correction

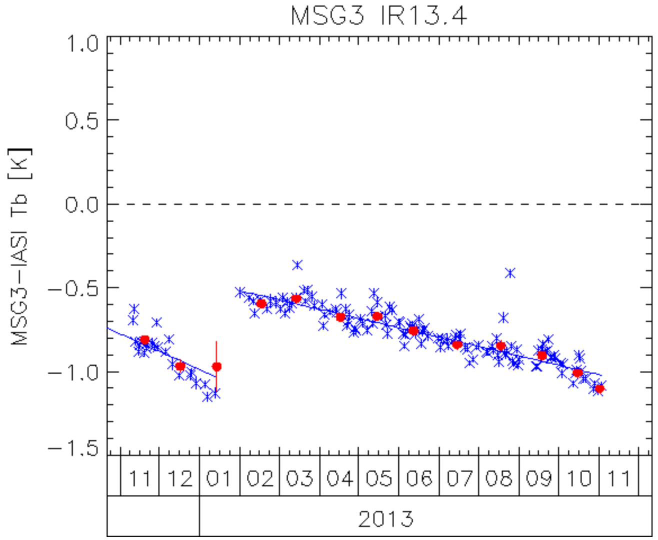
- Update daily
- Distribute via GSICS Servers

Evaluate & Monitor Bias









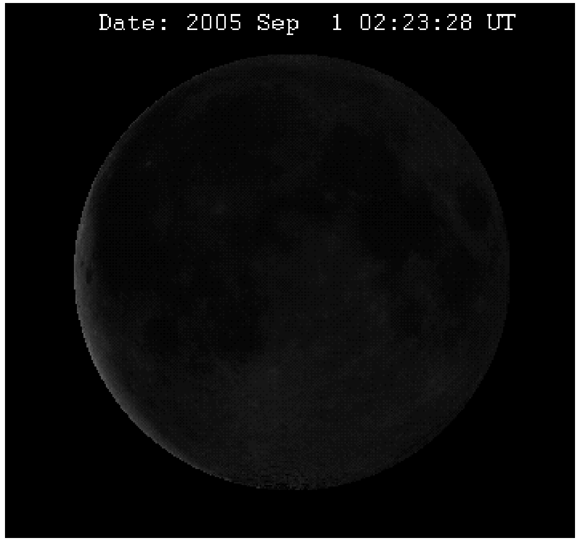
GSICS Calibration of GEO imagers' VIS/NIR channels

INDIRECT INTER-CALIBRATION, using

- *Pseudo Invariant Calibration Targets* (PICTs) = DCCs + Moon + Sites (PICS) + …
- To transfer calibration from single reference instrument
  - Currently NOAA-20/VIIRS
  - Using its observations over a static period (when reference calibration is stable)
- But no suitable hyperspectral reference covering full VIS/NIR band
  - Need Spectral Band Adjustment Factors (SBAFs)
- Uncertainties derived from time series statistics of invariant targets' observations
  - Difficult to propagate uncertainties through RTMs

GSICS Calibration for GEO imagers' VIS/NIR channels = Blend of methods:

- Deep Convective Cloud (DCC)
  - Globally available in equatorial band
  - Selected based on IR, SZA, VZA thresholds - Invariant Reflectance – up to ~1µm
  - Long-term stability unknown – needs monitoring
- Moon
  - Based on GSICS Implementation of ROLO lunar irradiance model (GIRO)
  - Applicable between 350 and 2500nm, Phase angles ~±(2-90)°
- Still under development – may be complemented by Ray-Matching methods



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Radiometric Calibration Dependences

- For GEO imagers, GSICS corrections only depend on scene radiance and time
  - Vary slowly based on ~monthly rolling window
- In general the radiometric biases can also be functions of
  - date, time of day,
  - instrument scan and solar geometry, latitude, longitude,
  - radiance, airmass, water vapour burden, scene type (including polarisation),
  - …
- Diagnose the sensitivity of instrument’s calibration to these
- Similar to NWP bias correction schemes
- Some bias variations may be due to the instrument’s calibration
  - Or reference instrument, inter-calibration algorithm, or NWP and/or RTM
  - Comparison of GSICS results and NWP biases can provide valuable insight

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Radiometric – or Spectral Errors?

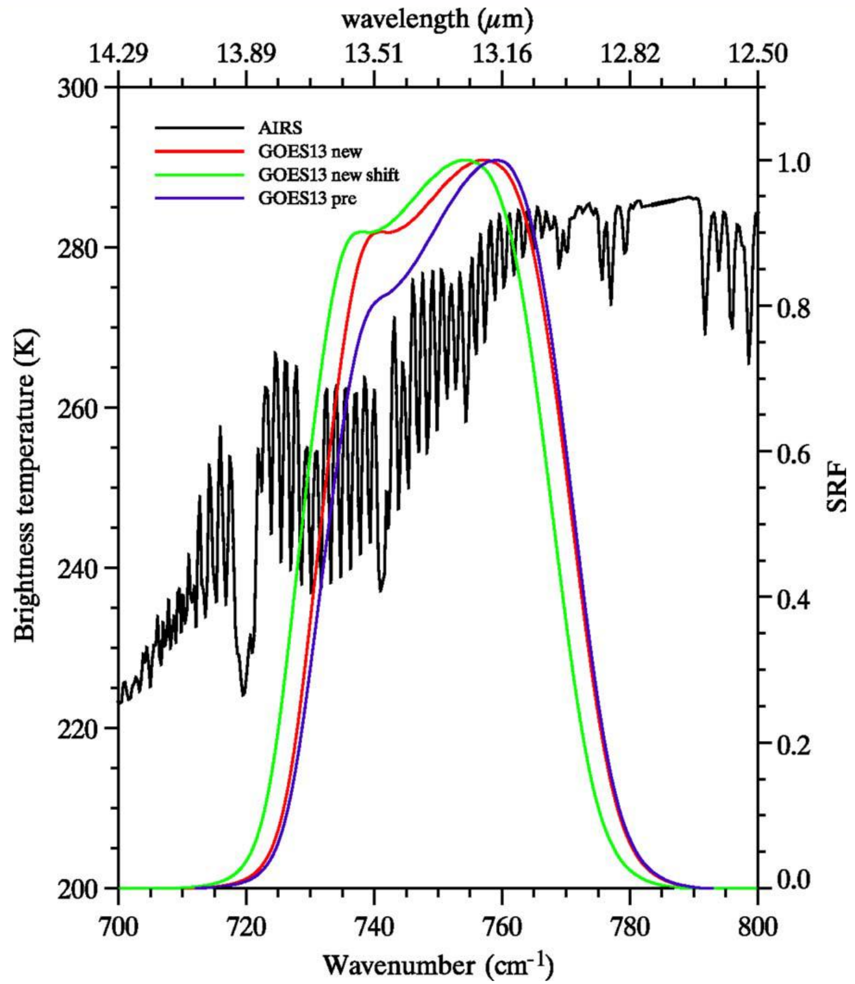
- GSICS focused on characterising errors as radiometric biases
- Some cases better explained as errors in spectral space
  - e.g. due to modification of SRF (Spectral Response Function)
- e.g. Meteosat/SEVIRI 13.4μm bias
- Varies with time
- Due to ice contamination
- Ice libration band modifies SRF
- Appears as radiometric bias
- Users preferred correction in radiance-space (still?)
  - No need to update RTMs

Time Series of Bias in Meteosat-10/SEVIRI IR13.4 channel from GSICS Re-Analysis Correction for standard scene (267K) based on inter-calibration with Metop-B/IASI.
From GSICS Plotting Tool: gsics.tools.eumetsat.int/plotter

GSICS – SRF Updates

- GSICS was instrumental in refining SRFs for IR channels of GOES & AMI imagers
  - By optimising differences in inter-comparison with hyperspectral reference instrument
  - During Commissioning
  - Important test

- GSICS investigating SRF retrievals
  - Based on comparison with hyperspectral ref
  - At least for non-window channels



GOES-13 Imager Channel 6 SRFs, (blue) original and (red) revised from the instrument vendor, and (green) NOAA-recommended SRF, superimposed on (black) AIRS spectral radiance. From Wu & Fu 2013, 10.1109/TGRS.2012.2236100

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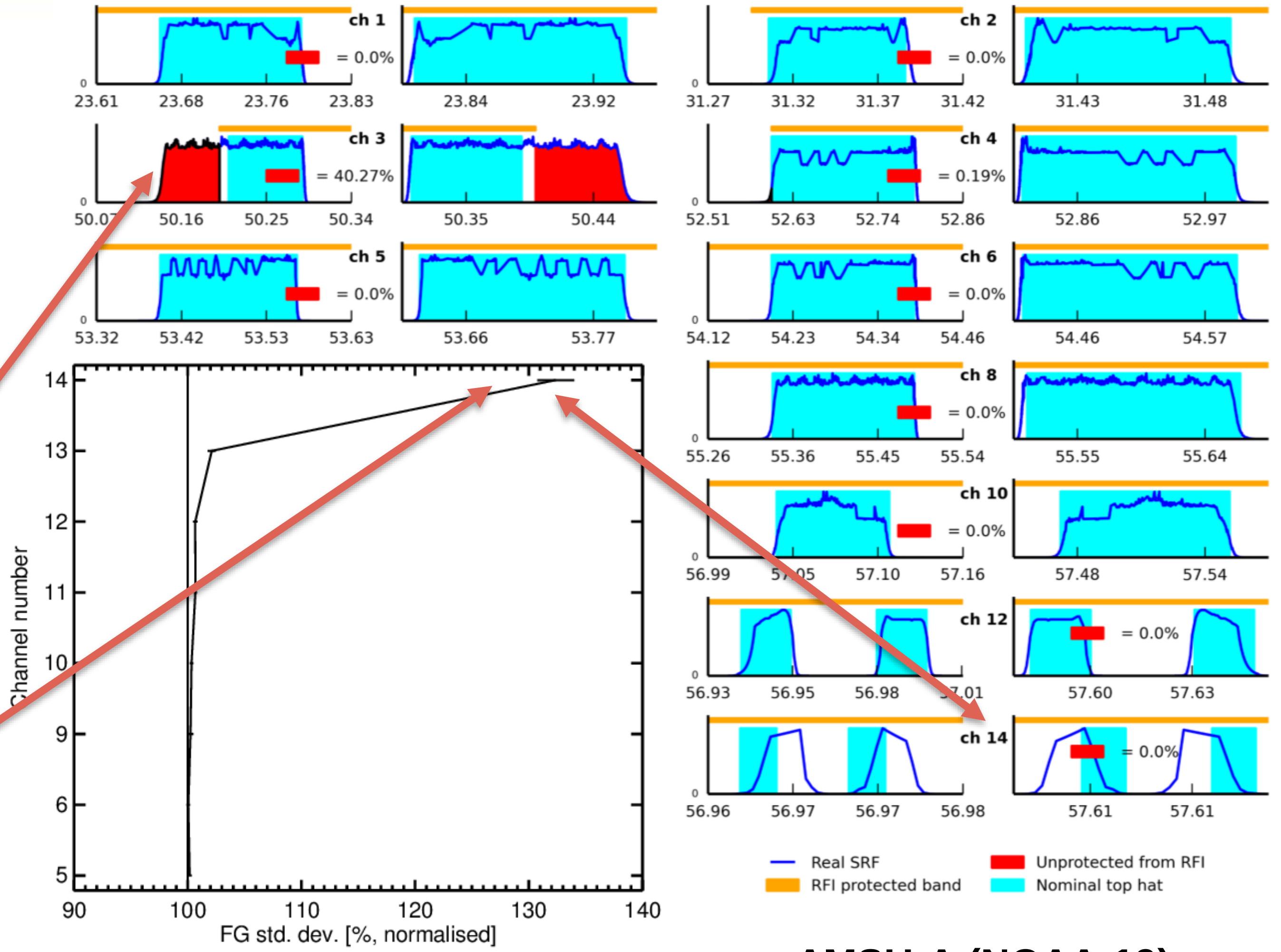
Importance of Accurate SRFs

- SRFs are often approximated as *top-hats*
  - (shaded cyan areas)
- Real SRFs often differ significantly
  - (Blue outlines)
- Sometimes extent beyond protected microwave bands
  - Expose channels to Radio Frequency Interference
- Top hat approx. and inaccurate SRFs
  - can introduce large biases in RTM
  - Illustrated by this trial
  - Shows a significant impact in First Guess
  - (from David Duncan, ECMWF)



NOAA-19 measuredSRF -Control

Fig. courtesy of David Duncan (ECMWF)

AMSU-A (NOAA-19)

Fig. courtesy of Emma Turner (Met Office)

CGMS action on Provision of Accurate SRFs

- *CGMS-48-WMO-WP-04* paper
  - by S. English:
- Provision of precise spectral response functions (SRFs) for microwave and infrared instruments has been a CGMS Best Practice since CGMS-44
- Accurate SRFs are increasingly vital in the realm of spectrum management for microwave sensors
- New research shows potential benefits for NWP when accounting for measured SRFs on microwave sensors
- The paper reaffirms the worth of sharing SRF information and encourages agencies to follow the CGMS best practice

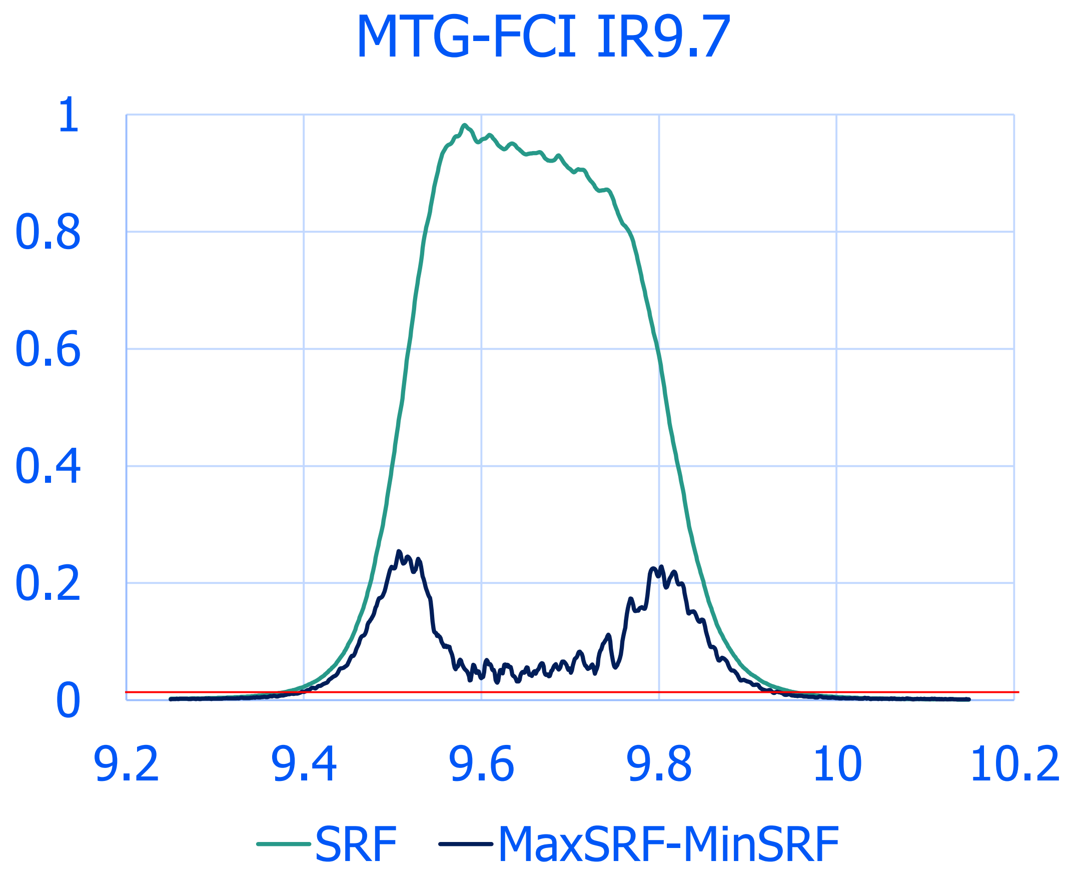
- *Actions proposed:*
- CGMS Members to endeavour that ***accurate Spectral Response Functions*** (SRFs) for all microwave and infrared instruments are measured and made available as described in CGMS Best Practice
- CGMS Members can also *make available* validated SRFs together with ***uncertainty*** information on their instrument calibration landing pages. Additionally, a document summarizing currently available SRFs and their status/accuracy as well as identifying any missing information can be provided
- WMO could establish links to this information through the relevant instrument entries in the ***OSCAR/Space*** database

SRF Uncertainties

- CLARREO studies showed inter-calibration uncertainty can be dominated by SRF uncertainties

- SRF Uncertainties may include:
  - Uncertainty in characterization
    - Estimated from error budgets
    - Typically assumed constant with λ
  - Dispersion among detectors
    - For instruments with multiple detectors
    - Varies with λ
    - Vector (- or matrix – to include correlations?)

- For MTG-FCI: EUM aim to provide SRF uncertainties
  - to analyse sensitivity to these uncertainties
    - e.g. on simulated radiances or L2 products
  - How to propagate into radiance space?
  - feedback required to ascertain whether SRF uncertainty information is sufficient
- For EPS-SG: MWI, ICI, MWS
  - Planning to provide SRF uncertainties – TBD



Example Spectral Response Function for Meteosat Third Generation -Flexible Combined Imager 9.7µm channel – showing average SRF (green), uncertainty in its characterization (red) and dispersion of full range of SRFs over detector array (black). From Wu & Fu 2013, 10.1109/TGRS.2012.2236100

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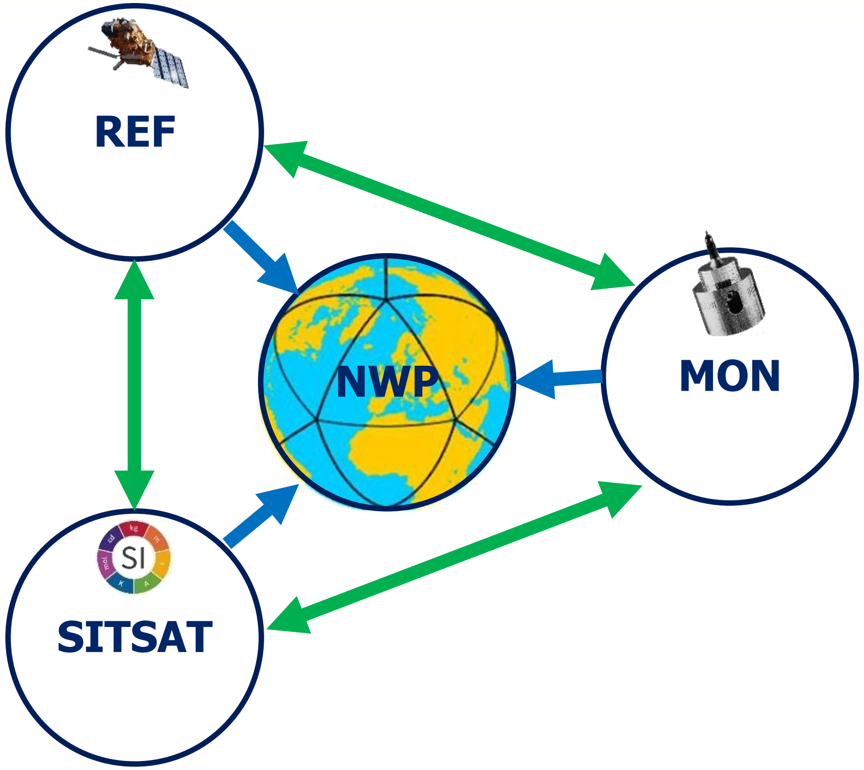
Benefits of SI-traceable Satellite Instruments

- SI-traceable Satellite Instruments
  - Such as CLARREO/TRUTHS
  - offer key advantages for NWP & Climate:
  - Provision of an irrefutable reference
  - Demonstrable traceability on-orbit calibration to SI
- Can be inter-compared with GSICS sensors
  - Tie GSICS products to an absolute scale
  - Diagnose reference instruments' sensitivity
- Can be assimilated without bias correction
  - To diagnose NWP and RT model errors
  - independent of instrument errors
  - As GNSSRO – traceable to SI second



Use of an SI-Traceable Satellite instrument (SITSAT):

To tie GSICS inter-calibration products for a Monitored instrument (MON), based on comparisons a Reference Instrument (REF) to an absolute scale (green arrows)

Compare with other instrument's biases in NWP assimilation (blue arrows)

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Conclusions

- GSICS monitor biases by inter-comparisons with reference sensors
  - This inter-calibration will become increasingly important for small sat missions
  - Which often have limited on-board calibration capabilities

- GSICS and NWP can provide information on satellite instruments' biases
  - Radiometric – or Spectral
  - Important to provide accurate SRF information
    - and associated uncertainty information

- Comparing GSICS and NWP results can help understand biases causes
  - and ultimately improve them at source

- Cooperative framework between GSICS and the NWP community
  - to exchange information on satellite instrument biases