GSICS GRWG and CEOS WGCV Update, Interactions, UV Subgroup

L. Flynn, Director GSICS Coordination Center (GCC)

October 1, 2014

[with material from GSICS presentations by
T. Hewison (EUMETSAT) and M. Bali and F-F Yu (NOAA)]

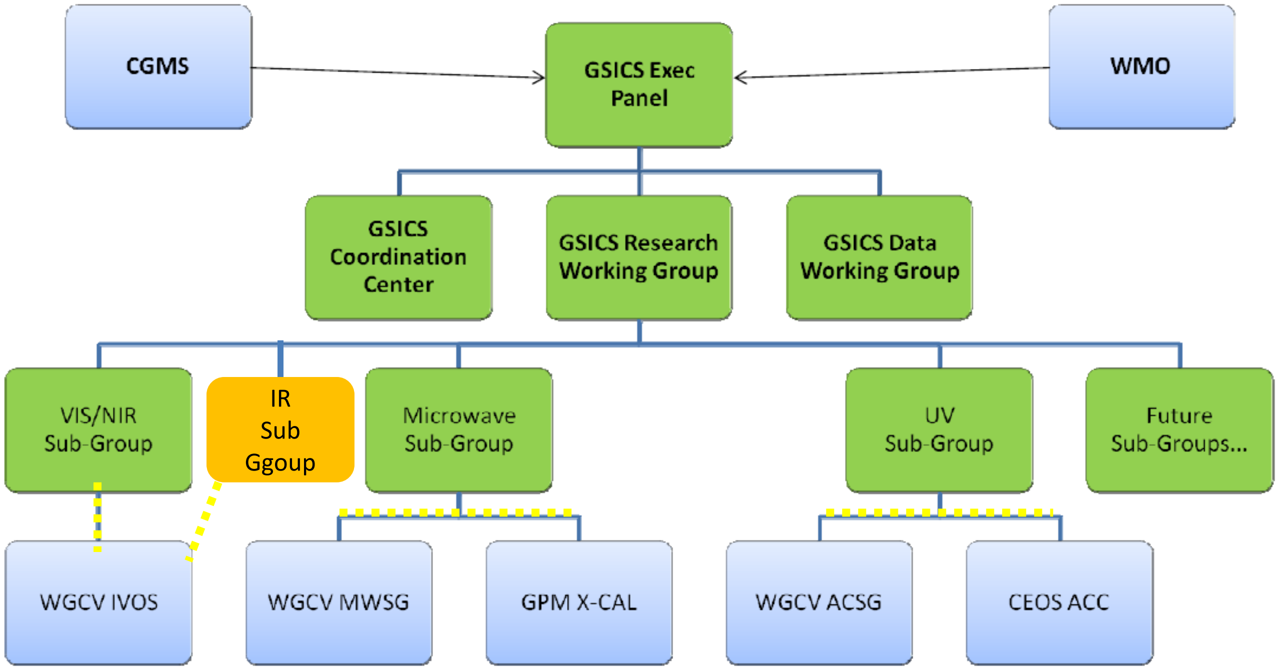
Outline

- Introduction to GSICS
  - www.star.nesdis.noaa.gov/smcd/GCC/
  - gsics.nesdis.noaa.gov/wiki/GPRC/LeoLeo
  - gsics.nesdis.noaa.gov/wiki/Development/20140324
- Interactions (discussion later)
- Research Working Group Short Summaries
- Quarterly Newsletter
- Summaries of four UV Projects
- Future
- Request for contacts and information

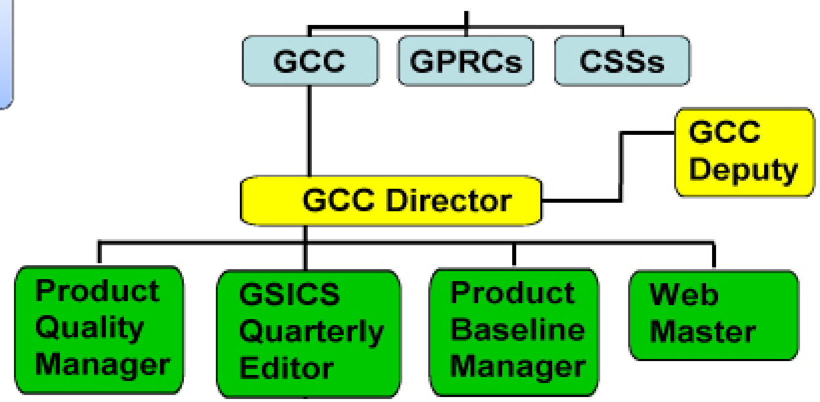
Global Space-based Inter-Calibration System (GSICS) Mission

- Assure high-quality, inter-calibrated measurements from the international constellation of operational satellites to support the GEOSS goal of increasing the accuracy and interoperability of environmental products and applications for societal benefit. http://gsics.wmo.int/

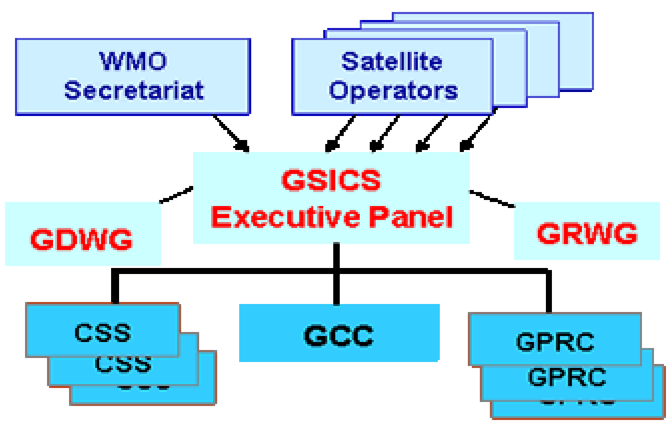
GSICS Organization Charts



- GSICS Processing and Research Centres (GPRC) operated by each satellite operator, and Calibration Support Segments (CSS) such as field sites and laboratories. Activities are overseen by a GSICS Executive Panel assisted by a Research Working Group (GRWG) and a Data management Working Group (GDWG).



www.star.nesdis.noaa.gov/smcd/GCC/ProductCatalog.php



GSICS Global Space-based Inter-Calibration System

- **Executive Panel**, consisting of representatives of the participating agencies, sets strategic priorities and monitors and evaluates GSICS evolution and operations.
- **GRWG and GDWG** advise the Executive Panel and assist in the planning and implementation of GSICS research and data management activities respectively. The GRWG consists of scientists, and the GDWG of data management experts, representing the participating agencies.

- **GCC**, located at the NESDIS, supports technical coordination among GPRC and CSS entities and is monitoring GSICS progress and milestones. It also maintains an important Internet hub of information and data exchange between GSICS members and data users and is responsible for publishing the GSICS Quarterly newsletter.
- **GPRCs**, one at each operational satellite agency, are responsible for pre-launch calibration, inter-calibration of their own agency's sensors with other satellite sensors, and supporting research activities.

- **CSSs** are participating satellite agencies, national standards laboratories, major NWP centers, national research laboratories, and university collaborators. CSS activities include:
  - Providing in-situ observations of Earth reference targets (e.g., stable desert and perpetual snow areas), long-term specially equipped ground sites, and special aircraft and field campaigns
  - Observing stable extra-terrestrial calibration sources, such as the Sun, Moon, and stars
  - Comparing radiances computed from NWP analyses of atmospheric conditions with those observed by satellite instruments
  - Championing and supporting benchmark missions of the highest accuracy to serve as calibration standards in space
  - Developing calibration “best-practices” procedures
  - Supporting efforts to make satellite instruments SI-traceable.

GSICS & CEOS/WGCV

- The initial concept of GSICS was brought forward by people involved in calibration activities, therefore with some links with WGCV. Since the beginning (EP-2 in 2007) the Panel welcomed interaction with CEOS/WGCV, to keep each other informed. Since then, collaboration with CEOS/WGCV is a standing agenda item for GSICS EP and the WGCV Chair or his representative is invited as observer. (Greg Stensaas attended EP-12, Albrecht von Bargen contributed remotely to EP-15).

Possible Future GSICS-WGCV Cooperation from GSICS Presentation at WGCV-37

- Best Practice Guidelines
  - e.g. Traceability,
  - Calibration Uncertainty
- Glossary of calibration terminology
- Definition of Standards
- Specific interactions with WGCV Sub-Groups: IVOS, MWSG, ACC
  - Need for coordination
- Geolocation/navigation/rectification methodology & metrics
- Inter-comparison Campaigns – aircraft, ground-based support, etc.
  - Data exchange/analysis,
  - Offer to review campaign plans
- Intra-System Comparisons

GSICS Global Space-based Inter-Calibration System

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

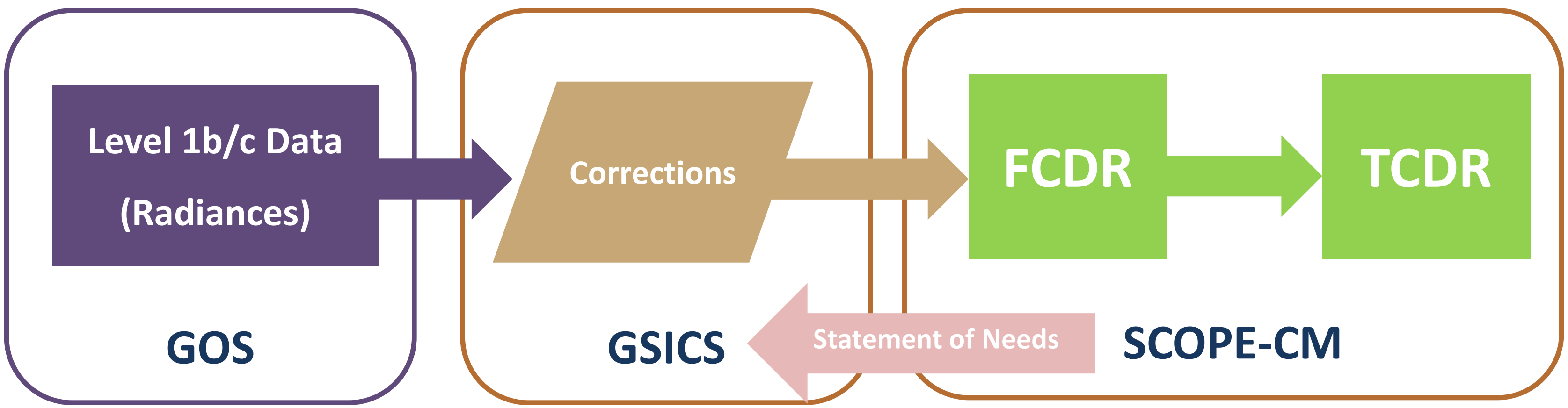
Who are the targeted users?

Any activity requiring well calibrated Level 1 data acquired by the satellites covered by GSICS

- **Level 2 products (geophysical parameters)**
- **Climate applications**

Example of user = the SCOPE-CM initiative (Sustained Coordinated Processing of Environmental Satellite Data for Climate Monitoring)

Scope ➔ generate multi-mission and global satellite climate data records (Fundamental CDRs & Thematic CDRs)



➔ The way toward operational production of high quality ECVs on a global scale

GSICS User Community

- Satellite Application Community
  - CDR generation for climate monitoring
    "SCOPE-CM" framework, national/international programs
    WCRP/GEWEX/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
    to generate stable (composite) L2 quantitative products or imagery
- Satellite Operators
  - Prelaunch instrument characterization guidelines
  - Cal/Val Plans
  - Best practices for instrument monitoring and improved calibration

Partner programmes

- Other calibration initiatives
  - CEOS WGCV, in particular IVOS
  - GPM X-cal
  - GRUAN
- Thematic application expert groups
  - GHRSST
  - IPWG ? ITWG ?

Some Key GSICS Methods for IR/Vis/MW

- Simultaneous Nadir Overpass
  - https://gsics.nesdis.noaa.gov/wiki/GPRC/LeoLeo
- Double Differences (Transfer Standards)
  - RT Forward Models with forecasts as inputs
  - LEO under-flights of GEO
- Targets (and distributional analysis)
  - Deserts
  - Ice
  - Moon
  - Deep Convective Clouds

GSICS Global Space-based Inter-Calibration System

Development of Infrared Products

- Progress with GSICS Corrections for GEO-LEO IR: – Some expected to be ready to enter demonstration mode at 3 agencies this year (ISRO, CMA and KMA) – and others to become the first operational GSICS products in 2014 (from NOAA, EUMETSAT and JMA
- netCDF format agreed for delta corrections in GSICS Corrections – to allow users to transfer from one reference to another
- Long-term: Aim to develop community consensus reference, – based on a blend of best quality instruments available. – Robust system from which to derive FCDRs. – Encouraging results were presented for AIRS, IASI and CrIS, as well as MODIS, VIIRS and MERSI, in this regard.

Development of VIS/NIR Products

- Chaired by Dave Doelling (Sub-Group Chair)
- Continued to develop GEO-LEO VIS based on Deep Convective Clouds (DCCs) – Soon sufficiently mature to generate demonstration products suitable for study by beta-testers.
- Lunar calibration session – highlighted the potential for sub 1% accuracy level – Discussion of issues faced by implementing ROLO – EUMETSAT suggested hosting Lunar Calibration Workshop
- What next? – Survey of members priorities/interests – Summer 2014

Lunar Calibration Workshop

- EUMETSAT implementation of ROLO model – Validated against USGS version by Tom Stone – EUMETSAT will provide code to apply ROLO model – Participants will provide Moon observations – Standard I/O formats to be defined
- Results from different sensors will be compared – Form consensus on absolute calibration – To investigate dependences – To develop inter-calibration GSICS demo products
- Further development of ROLO model (by USGS) – propagation of updates to EUMETSAT distribution is anticipated

Microwave and Ultraviolet Subgroups

Microwave Subgroup

- Interactions with counterparts in CEOS WGCV
- Reviewing different interpretations of root cause of bias patterns found in inter-calibration of microwave sounders’ window channels.

Ultraviolet Subgroup

- Continued to develop four projects on challenges for ultraviolet instruments.
- Rosemary Munro (EUMETSAT) accepted chair.

GSICS Quarterly Newsletter

- Request for articles for the next newsletter
  - www.star.nesdis.noaa.gov/smcd/GCC/newsletters.php
  - Send articles to Manik.Bali@noaa.gov
- Special Topic Issues for the past year include Microwave, Lunar and Ultraviolet.
- Summaries and articles related to UV projects are in the latest GSICS Quarterly (v8_no2_2014.pdf):
  - Send new proposals for new UV projects to Rosemary.Munro@eumetsat.int

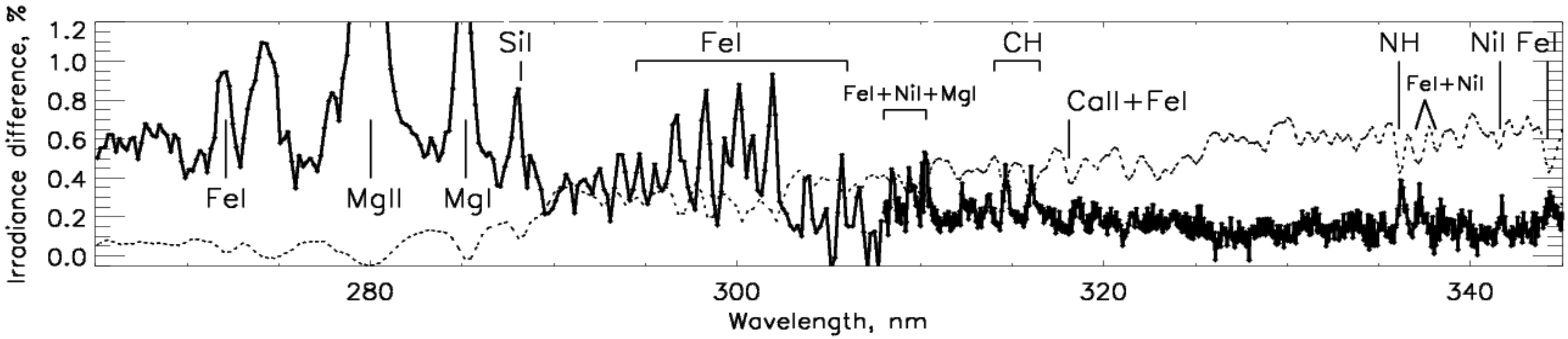
Ultraviolet Subgroup of the GSICS Research Working Group

- The group has four initial projects working with backscatter solar ultraviolet (BUV) measurements from instruments on polar-orbiting platforms. **GSICS members are asked to designate participants for the UV subgroup and identify contacts for each of the four projects. Information can be sent to the chair Rosemary.Munro at eumetsat.int .**
- **1. Solar UV Measurement Project.** This project's goal is to create quantitative comparisons among the solar spectra measured in the UV by the different instruments.
- **2. Best practices for BUV on-ground and in-flight calibration and characterization.** This project seeks to build on the lessons learned from past instruments to identify the key areas of calibration that will most benefit the mission goals. It is also recognized that sharing calibration assets across missions is efficient and beneficial.
- **3. Calibration of Reflectivity and Aerosol Channels.** This project's goals are to develop vicarious calibration methods and provide comparisons for monitoring the BUV measurements (radiance/irradiance ratios) for channels with little trace gas absorption, primarily from 340 nm to 405 nm.
- **4. Calibration comparisons for 240 nm to 300 nm.** Seeks to develop comparisons of radiance/irradiance ratios from 240 nm to 300 nm. The basic idea is to use a model atmosphere (from climatology, assimilation or other sources) with a radiative transfer (RT) forward model to predict the radiance/irradiance ratios for two instruments viewing the same region. The results of the RT model results are used as a transfer to compare the measurements.

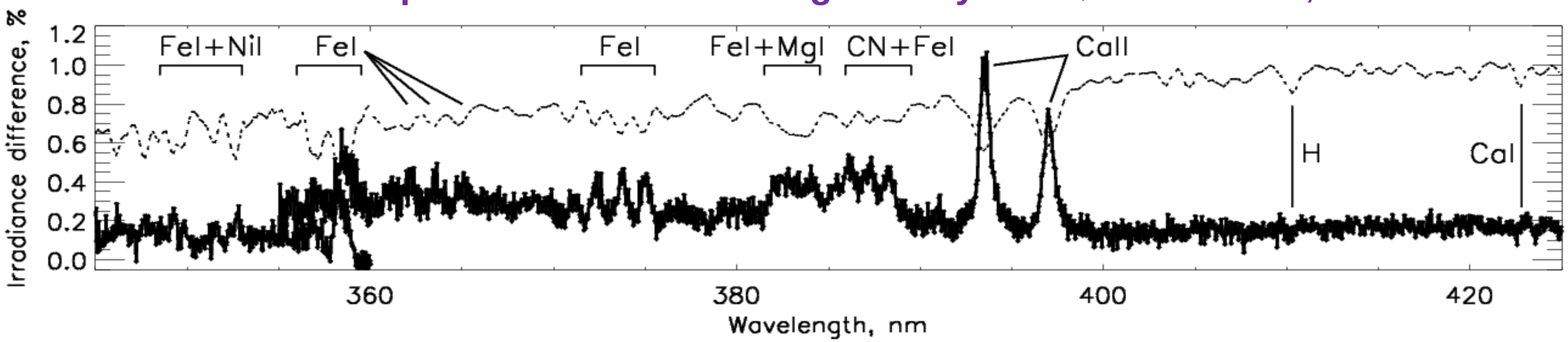
Solar UV Measurement Project

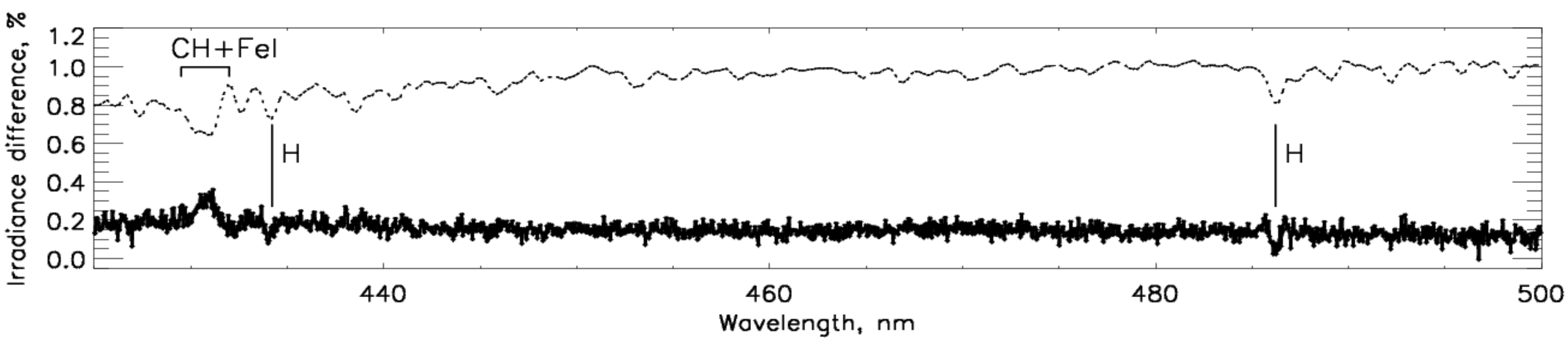
- High resolution solar reference spectra
  - Reference high resolution solar Spectra (SOLSTICE, SIM, Kitt Peak, etc. – Everybody has a favorite. How do they compare? Can we create a standard?)
  - Mg II Index time series, Scale factors at high resolution
- Instrument data bases
  - Bandpasses, wavelength scales (Shift & Squeeze codes)
  - Day 1 solar, time series with error bars (new OMI product) (Formats, Doppler shifts, 1 AU adjustments)
  - Mg II Indices and scale factors at instrument resolution
  - Reference calibration and validation papers
- Using the information from above we can compare spectra from different instruments and times.

Recent Result from EOS Aura OMI



Sun as a star Aura OMI: spectral irradiance changes in Cycle 24, **S. Marchenko, M. DeLand**





Best practices for UVN on-ground and in-flight calibration and characterization
R. Lang – Starting point for discussions on lessons learned and best pracitices:

- On-ground calibration efforts need to be improved at all levels: *time, documentation, availability, and accuracy of data and the related error budgets.*
- Vicarious calibration can complement these efforts but so far accuracy levels below 1% can not be achieved.
- Below 1% radiometric accuracy levels are difficult to achieve if achievable at all through on-ground calibration alone. On-board calibration and vicarious calibration methods need to be added.
- Huge amount of effort has been invested to compensate for avoidable deficiencies in on-ground characterisation for past or currently flying UVN instrumentation.
- Some proposals are on the table to significantly (fundamentally) improve our capabilities for accurate on-ground characterisation (e.g. Fox et al.)
- 1st EO lessons learned meeting in ESRIN, June 2013 called for detail recommendation on "best practices" for on-ground calibration in-line and supported by the CEOS activities of best-practices for calibration.

Shall and can we support these activities with UVN GSICS activities?

Recommendations for On-Ground Characterization

Considerations for On-Ground Characterisation Campaign (I)

Time … Time … Time

- Characterisation campaigns should be long enough to allow for measurements to be repeated for *consistency checking*
- Assess impact of *lamp position & alignment* errors
- Allow sufficient time for *stabilisation*

Environment

- Essential that all characterisation measurements are carried out in thermal vacuum and that the thermal environment including gradients is representative of the in-orbit situation
- Scan-angle dependencies should also be characterized in vacuum

Recommendations for On-Ground Characterization

Procedures I

- Alignment procedures should be *documented and reproducible* with photo/video documentation
- Ensure *reproducibility* of distance measurements
- Close attention should be paid to frames of reference, coordinate systems & angles (e.g. GOME-2 flip of elevation angles diagnosed in orbit)
- All *sources* should be well commissioned prior to the start of measurement
- Radiometric calibration must be *connected to standards* e.g. NIST
- All measurements and procedures must be *traceable & under configuration control* including software versions and documentation of which precise measurement is used in the generation of key data
- Data processing should be *automated* as far as possible

Procedures II

- Check *temperature sensitivity* in case thermal stability is not as expected
- Ensure sufficient *angular discretisation* for characterisation of diffuser BSDF
- For slit function characterisation need *requirements from the data analysis* activity (signal:noise, spectral coverage and sampling, source commissioning requirements etc) before planning the measurements
- Ensure that all required *supplementary calibration measurements* (e.g. dark signal etc) are taken close to the time of each measurement (GOME-2 monitoring block)
- Ensure sufficient sampling points for straylight characterisation
- Ensure that the slit is overfilled

Future for UV GRWG UVSG

- BUV is coming to L1 with DSCOVR
  - EPIC (NASA/NOAA 2015) (Global NRT down link?)
- BUV is coming to GEO with
  - TEMPO (NASA 2018)
  - GEMS (KARI 2018)
  - UVN (ESA 2019)
- How do limb instruments fit in?
  - SciSAT ACE/MAESTRO, EOS AURA MLS, SAGE III ISS (NASA 2015)
- How can we use the 4 billion year-old lunar diffuser in the UV?

Instrument and Project Subject Matter Experts

Instrument	Main Contact	Reflectivity/ Aerosols	Solar Spectra	Ozone Profiles	Calibration
ACE/MAESTRO	C.T. McElroy, York U.				
EPIC 2015	J. Herman				
GEMS 2018	J. Kim, Yonsei U				
GOME					
GOME-2	R. Lang EuMetSat	M. Krijger			R. Lang
GOMOS					
MLS					
OMI		O. Torres	M. DeLand		
OMPS Nadir	L. Flynn NOAA			L. Flynn	S. Janz?
OMPS Limb	G. Jaross NASA				
OMS					
OSIRIS					
SAGE III	D. Flittner NASA				
SBUS	F-X. Huang CMA			F-X. Huang	
SBUV/2	L. Flynn NOAA		M. DeLand	L. Flynn	
SCIAMACHY	M. Weber Bremen		M. Weber		
TEMPO	K. Chance SAO				
TOMS					
TOU	W-H. Wang CMA				
TropOMI	P. Levelt, KNMI				
UVN	B. Veihelmann, ESTEC				M. Dobber/B. Ahlers

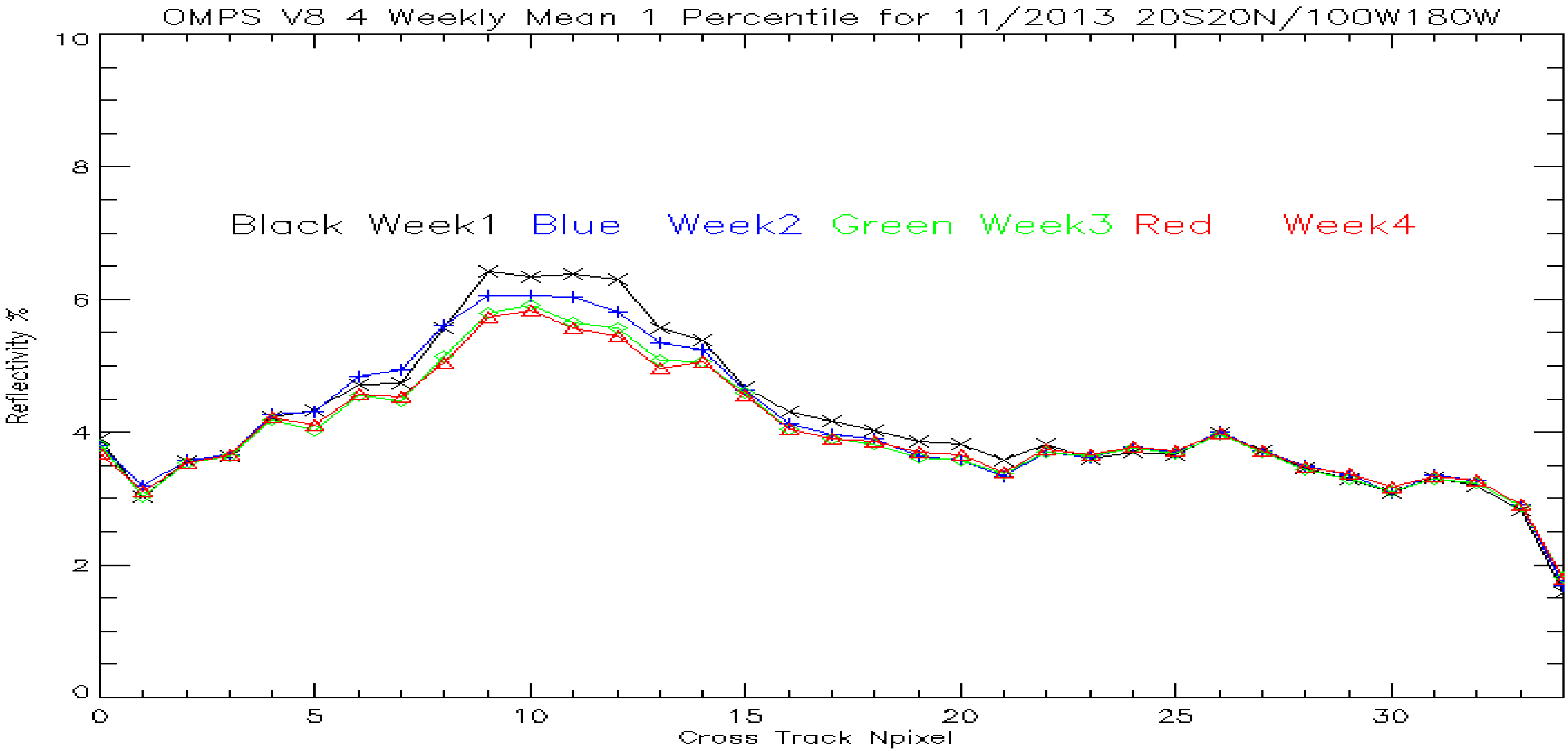
Background material

UV Project 3. Reflectivity and Aerosol Channels 340 nm to 400 nm

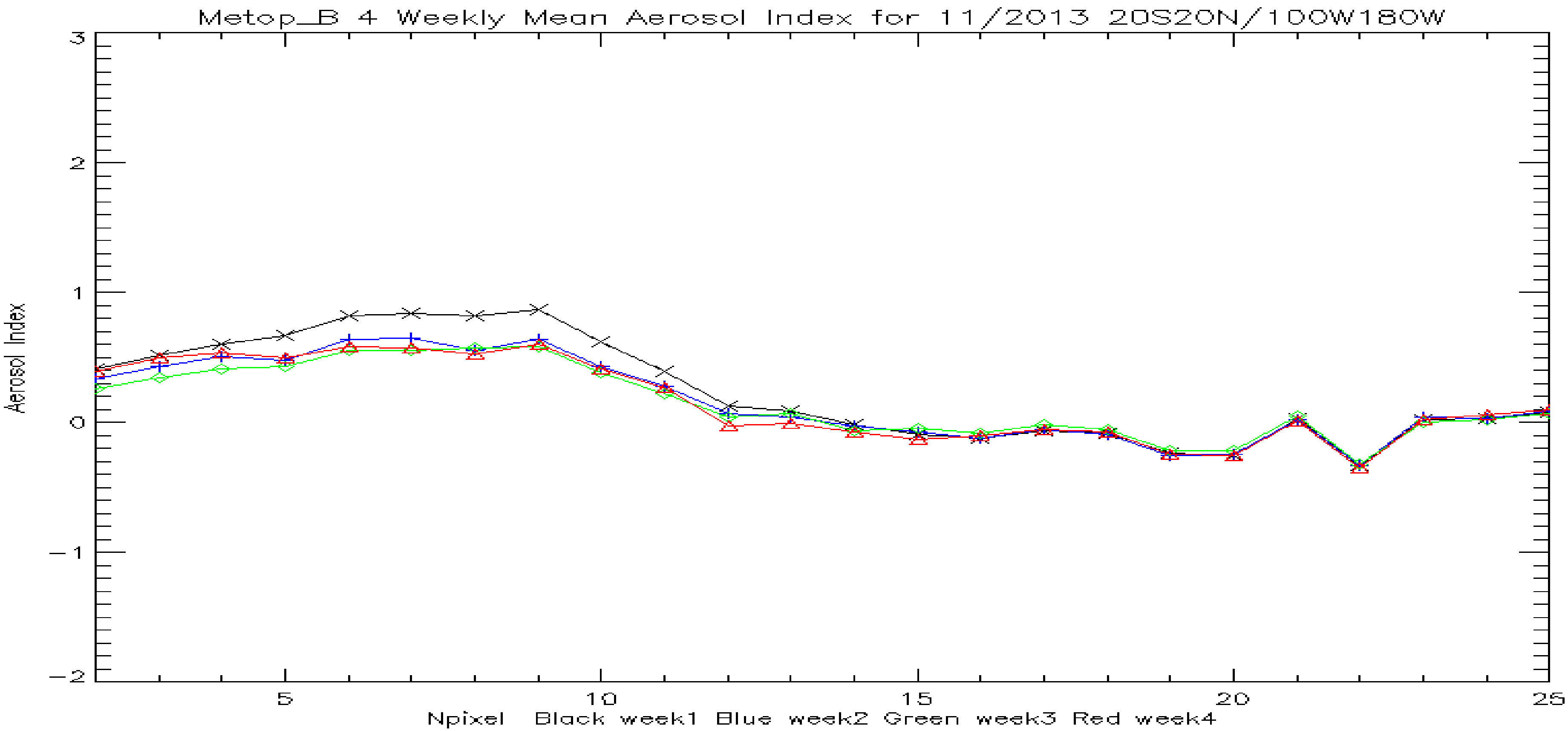
- Effective Reflectivity and Aerosol Indices are already in use to track calibration stability for GOME-2, OMI and OMPS (LEO to LEO, Rayleigh Scattering over targets)

e.g., www.star.nesdis.noaa.gov/icvs/prodDemos/proOMPSbeta.php

- Absolute Radiance/Irradiance check
- Ice, desert and open ocean targets
- reflectivity range/distribution, 1-percentile open ocean values
- Wavelength Dependence – Aerosol Indices
- Complications
  - Surface pressure
  - Partially Cloudy scenes
  - Viewing and Solar angle considerations
  - Sun Glint
  - Ring Effect
  - Polarisation
  - Stray Light



The lines show the S-NPP OMPS weekly, one-percentile effective reflectivity values for the Version 8 algorithm (331-nm channels) for November 2013 for all the data in a latitude/ longitude box in the Equatorial Pacific versus cross-track view position. (17 is the nadir position and 0 and 34 are the extreme viewing angles.) We expect the one-percentile effective reflectivity values to be approximately 4% for this region of the globe from climatological measurements made by other instruments. The cross-track variations for positions 5 to 15 are related to sun glint effects. Consistent deviations by position are from imperfections in calibration coefficients across the CCD array and intra-orbit wavelength scale shifts.



The lines show the MetOP-B GOME-2 weekly aerosol index values for the Multiple Triplet algorithm (measurement residuals for wavelengths in the 360-nm range using effective reflectivity calculated for the 331-nm range) for November 2013 for all the data in a latitude/ longitude box in the Equatorial Pacific versus cross-track view position. (12/13 are the nadir position and 2 and 25 are the extreme viewing angles.) We expect the aerosol index values to be approximately zero N-values for this region of the globe. The cross-track variations for positions 4 to 10 are related to sun glint effects. Consistent deviations by position are probably from calibration imperfections but are surprising given the scanning nature of GOME-2.

UV Project 4: Outline of an Approach for Comparisons of radiance/irradiance ratios from 240 nm to 300 nm

Compute the measurement residuals using a forward model with the effective scene reflectivity of the clouds and surface determined from longer channel measurements, and the ozone profile prescribed by the Version 8 *a priori* climatology. Viewing geometries and bandpasses are as reported for each instrument.

Compare residuals for channels λ1 and λ2 where $S1*\alpha1 = S2*\alpha2$, where S values give the path lengths and α values give the ozone absorption cross sections. That is, works with pairs of wavelengths where the measurement contribution functions are similar.

Perform comparisons (statistical trade off in quantity of matchups vs. quality)

- Simultaneous nadir overpass matchups
- Zonal means (and No-local-time differences zonal means)
- Opportunistic Formation Flying / Chasing orbits
- Benign geographic regions (e.g., Equatorial Pacific Box)
- Ascending/descending zonal means (In the Summer hemisphere, the same latitude is observed twice so one can obtain a set of internal comparisons.)

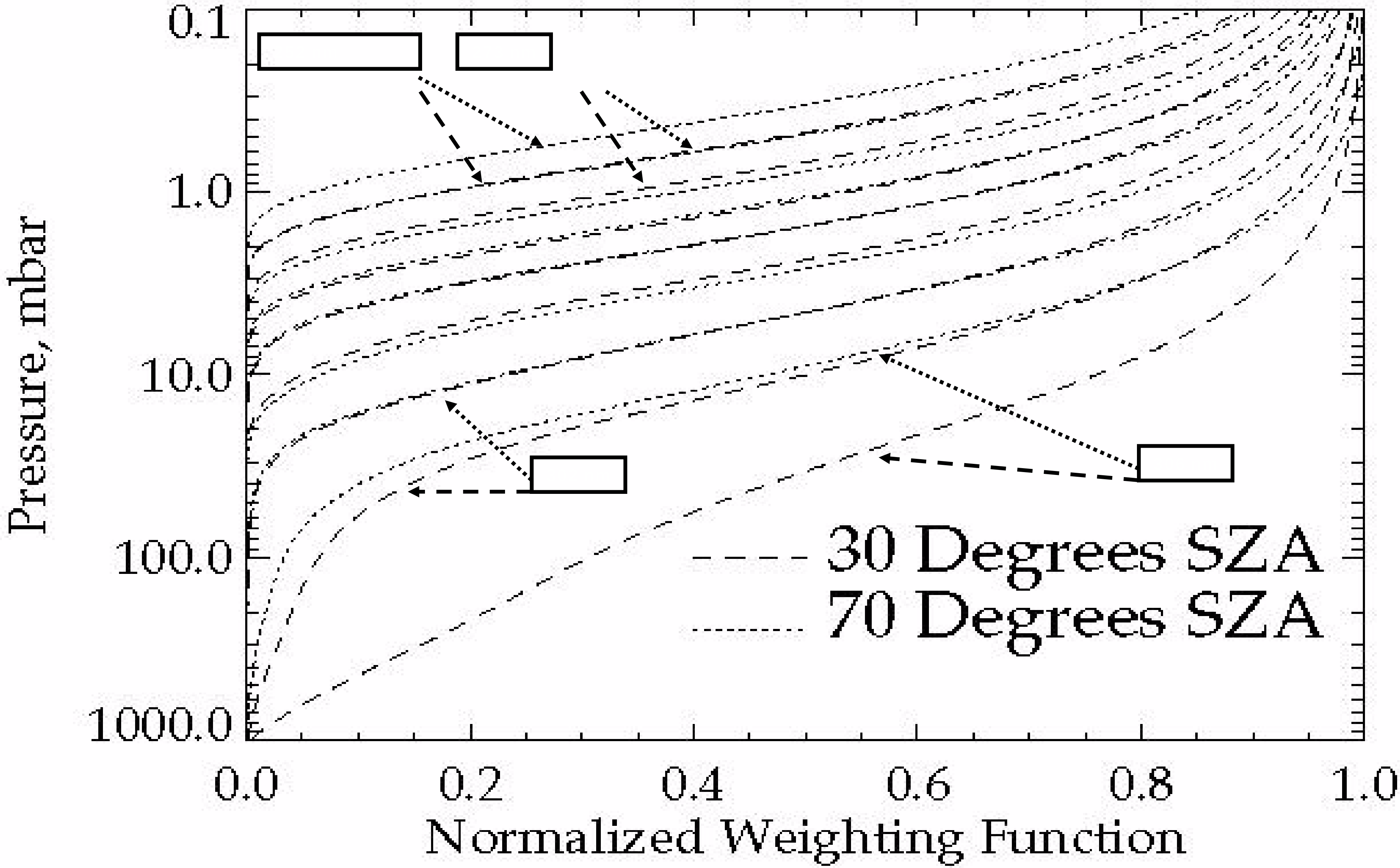
Forward model and measurements

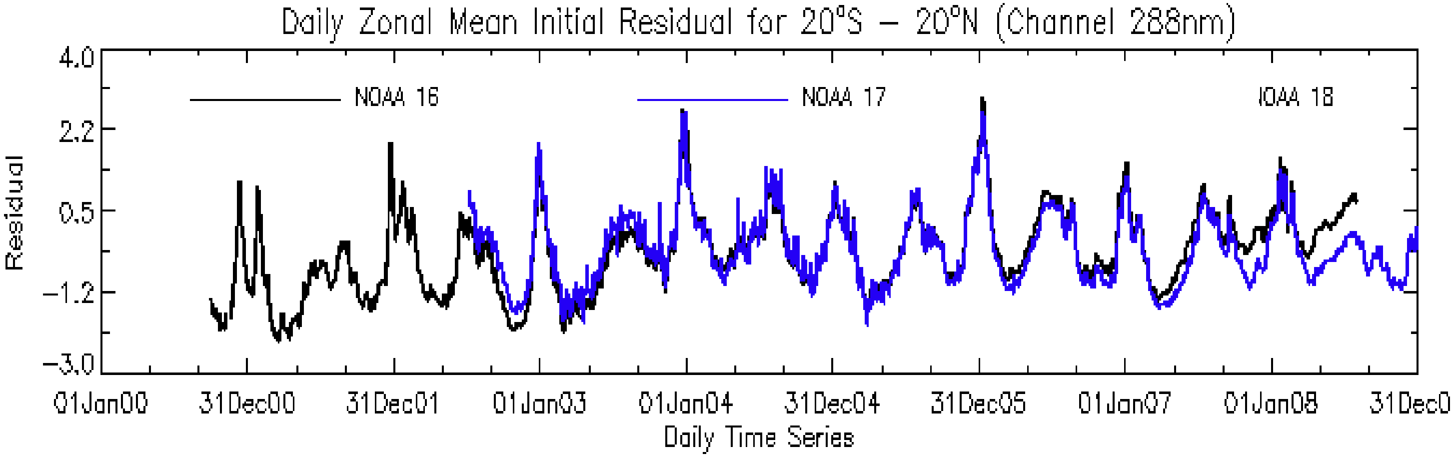
- V8 SBUV/2 forward model and *A Priori* as transfer for Viewing conditions

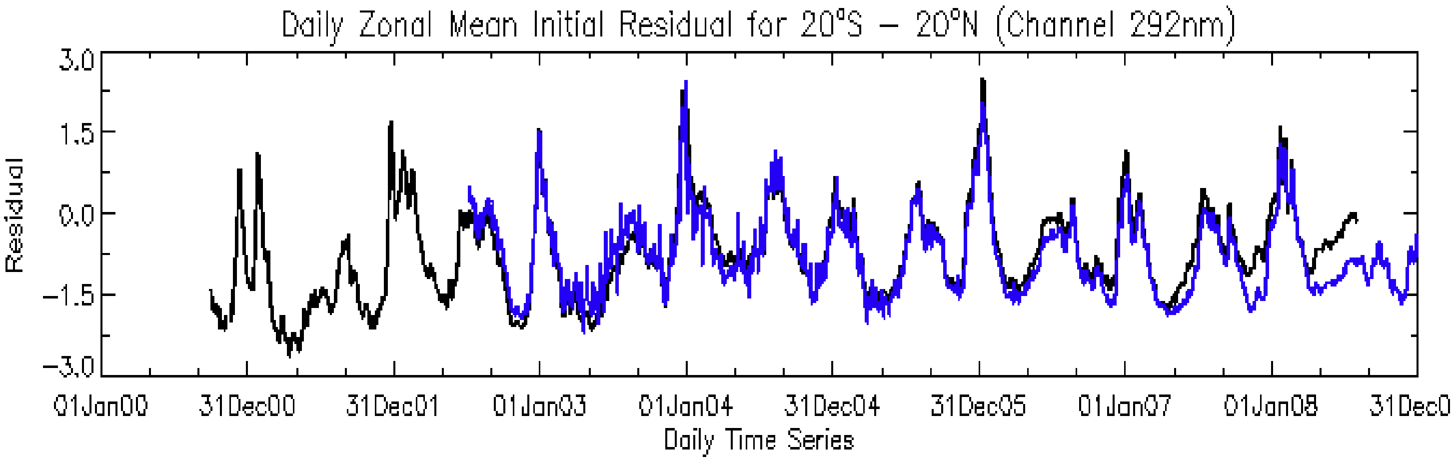
Complications from real diurnal variations in the ozone profiles.

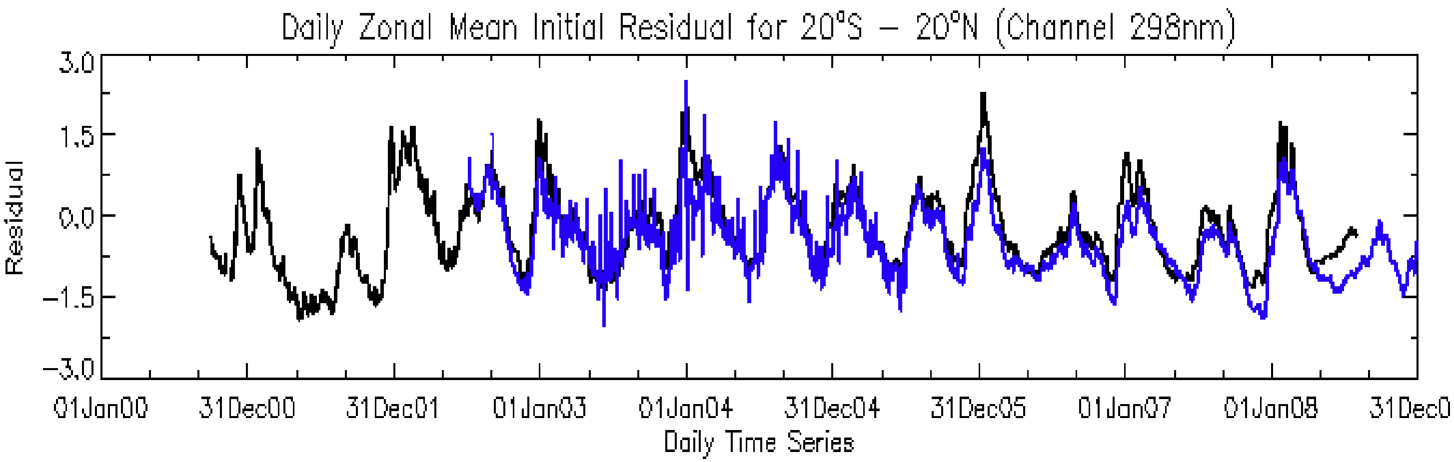
Total ozone or reflectivity uncertainties will affect longer profiling wavelengths.

Measurement residuals' correlation with scene reflectivity can disclose stray light contamination.


Pressure, mbar
0.1
1.0
10.0
100.0
1000.0
0.0
0.2
0.4
0.6
0.8
1.0
Normalized Weighting Function
30 Degrees SZA
70 Degrees SZA







The figures show the initial measurement residuals for three profile wavelengths (Top 288 nm, Middle 292 nm, and Bottom 298 nm) for the V8PRO product for the equatorial daily zonal means (20N to 20S). The two sets of data are for the NOAA-16 SBUV/2 and the NOAA-17 SBUV/2. The units are N-values (~2.3%). The Version 8 algorithm a priori ozone profiles and forward model have been used to allow direct comparison of the radiance/irradiance ratios for the two instruments. NOAA-16 was an afternoon satellite and NOAA-17 was a morning satellite during this period. By the end of the record, the NOAA-16 satellite was in a late afternoon orbit.

Possible Goals/Topics for a UV Subgroup

1. Exchanges and traceability of standards
   - NIST and SIRCUS
   - Integrating Spheres, diffusers, lamps, lasers, etc.
2. Establish a library of solar measurements
   - Reference high resolution solar (SOLSTICE, SIM, Kitt Peak, etc.)
   - Mg II Index time series, Scale factors at resolution
3. Establish a library of instrument data bases
   - Bandpasses, calibration constants, WL scales
   - Day 1 solar, time series with error bars
   - Mg II Indices and scale factors
   - FOVs, Polarization sensitivity,
   - Reference papers, ATBDs, validation, Shift & Squeeze,
4. Establish a library Absorption data bases
   - O3 in the UV with wavelength and temperature dependence
     - at instrument resolution -- DOAS
   - UV compared to Visible and IR
   - other species -- SO2, NO2, etc.
5. Standard climatologies; vicarious calibration & residuals
   - Ozone and temperature profiles, covariances
   - Neural net, with tropopause information
   - Averaging kernels or efficiency factors, measurement contribution functions, and Jacobians
6. Analysis of on-board systems
   - Diffusers, stable orbits
   - White lights, spectral lamps, LEDs
   - Moon views

Stray light, linearity, gains, offsets, mirrors, polarisation, λ-scale, bandpass

7. Considerations for comparisons
   - Complications from diurnal variations, SZA, SVA, RAA
   - Zonal means
   - Simultaneous nadir overpass (Rad/Irrad or products)
   - Formation flying / Chasing orbits
   - No-local-time differences
   - Snow/Ice, desert and open ocean targets
   - Pacific Box
   - LEO to GEO to L1
8. Internal consistency techniques
   - Ascending/descending -- Langley methods
   - Pair justification
   - DOAS (and EOF analysis) (Closure polynomials)
   - Stray light correlation
   - Wavelength scale, shift and squeeze, etc.
   - Measurement Residuals, reflectivity range/distribution
9. Forward model and measurements
   - Rayleigh
   - Absorption
   - Spherical geometry
   - Inelastic scattering (Ring Effect), Stray light, solar activity
   - Aerosols
   - Polarization
   - TOMRAD, VLIDORT, SCIATrans, CRTM, etc.
   - V8 SBUV/2 and *A Priori* as transfer for Viewing conditions…
10. Reflectivity
    - Surface (database and snow/ice forecasts), Variations in surface reflectivity with season, sza and sva.
    - Surface pressure
    - Clouds (Cloud top pressure)
    - Cloud-optical-centroids (Ring Effect, 02-02, O2 A band)
11. Aerosols
    - Climatology/Type, height
    - Wavelength or polarization dependence (Aerosol Indices)

12. Nadir Instruments LEO
- TropOMI, GOME(-2), OMPS, TOU/SBUS, OMS,
- SCIAMACHY, OMI, TOMS, SBUV(/2)

12. Nadir Instruments GEO or L1
- TEMPO, GEMS, UVN and EPIC

13. Limb instruments
- SAGE III, ACE/MAESTRO, OSIRIS, MLS, GOMOS, SCIAMACHY, OMPS-LP

14. Ground-based
- WOUDC, Dobson, Brewer, Lidar, MW and Ozonesondes

Presentation at WGCV-37 included for Reference

GSICS
Global Space-based
Inter-Calibration System

Introducing GSICS
and interactions with WGCV
Presented at WGCV-37

Tim Hewison[1] and Jerome Lafeuille[2]

(1) EUMETSAT - Chair of GSICS Research Working Group
(2) WMO – Secretariat of GSICS Executive Panel

Outline

- Introduction to GSICS
  - emphasis on systematic generation of inter-calibration products
  - Members, Aims, Principles
- GSICS Products
  - Product Catalog, Examples
- GSICS structure
  - GCC + User Workshops
  - GDWG + servers, etc
  - GRWG + Sub-groups
- Interaction with WGCV
  - Past examples
  - Future Possibilities

GSICS and CGMS

- The main goal of CGMS is technical coordination among satellite operators supporting WMO programmes
- GSICS addresses one key aspect of this coordination:
  best practices to maximize mission usability and interoperability
- GSICS was jointly established by CGMS and WMO
  as an outcome of CGMS Working Group on satellite products
- GSICS members are CGMS member agencies (operational or R&D)
- GSICS reports annually to the CGMS plenary

Global Space-based Inter-Calibration System

- What is GSICS?
  - Global Space-based Inter-Calibration System
  - 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 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

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
- 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

TRACEABILITY / UNBROKEN CHAINS OF COMPARISONS

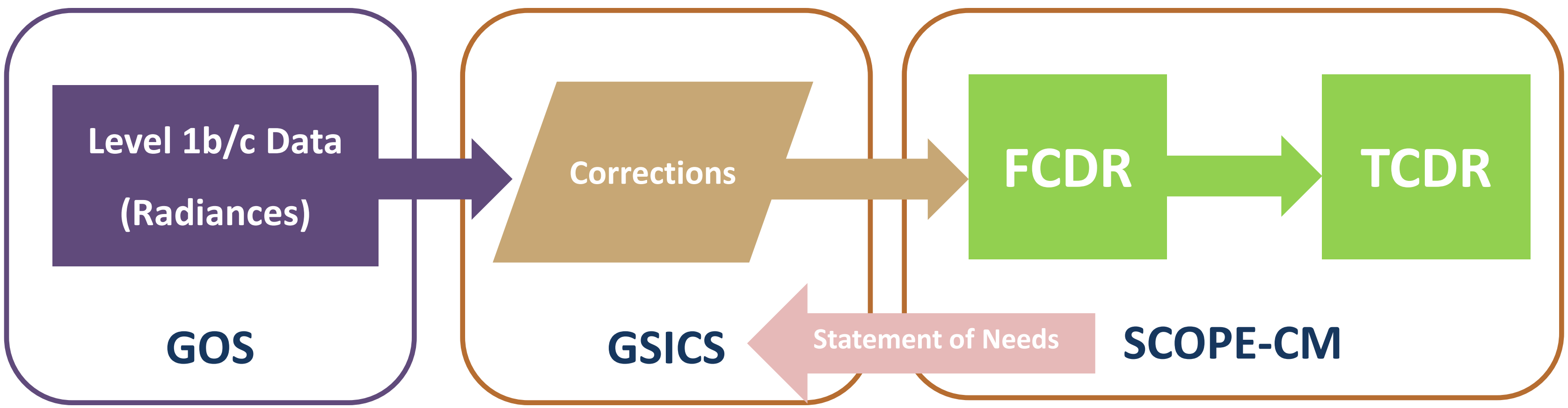
Who are the targeted users?

Any activity requiring well calibrated Level 1 data acquired by the satellites covered by GSICS

- **Level 2 products (geophysical parameters)**
- **Climate applications**

Example of user = the SCOPE-CM initiative (Sustained Coordinated Processing of Environmental Satellite Data for Climate Monitoring)

Scope ➔ generate multi-mission and global satellite climate data records (Fundamental CDRs & Thematic CDRs)



➔ The way toward operational production of high quality ECVs on a global scale

GSICS User Community

- Satellite Application Community
  - CDR generation for climate monitoring
    "SCOPE-CM" framework, national/international programs
    WCRP/GEWEX/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
    to generate stable (composite) L2 quantitative products or imagery
- Satellite Operators
  - Prelaunch instrument characterization guidelines
  - Cal/Val Plans
  - Best practices for instrument monitoring and improved calibration

Partner programmes

- Other calibration initiatives
  - CEOS WGCV, in particular IVOS
  - GPM X-cal
  - GRUAN
- Thematic application expert groups
  - GHRSST
  - IPWG ? ITWG ?

GSICS Products

- **GSICS Bias Monitoring**
  - Routine comparisons of satellite radiances against reference
- **GSICS Correction**
  - Function to correct issued radiances
  - For consistent calibration with reference
- **GSICS Reports & Guidelines**
  - Recommendations to modify practices
  - Design and Operation of future satellite instruments
- **For Operational Environmental Satellites**
  - ✓ Infra-red recalibration (GEO and LEO)
    (current operational satellites)
  - ✓ Visible and near-infrared recalibration (GEO and LEO)
  - ✓ Microwave – Conical & Cross-track Scanners (LEO)
  - ✓ Historic Instruments
  - ✓ Pre-Operational & Demo status
  - ✓ Near real-time and re-analysis
  - ✓ In development within GSICS
  - ✓ In development with GPM XCAL
  - ✓ In development at EUMETSAT…

GSICS Global Space-based Inter-Calibration System

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

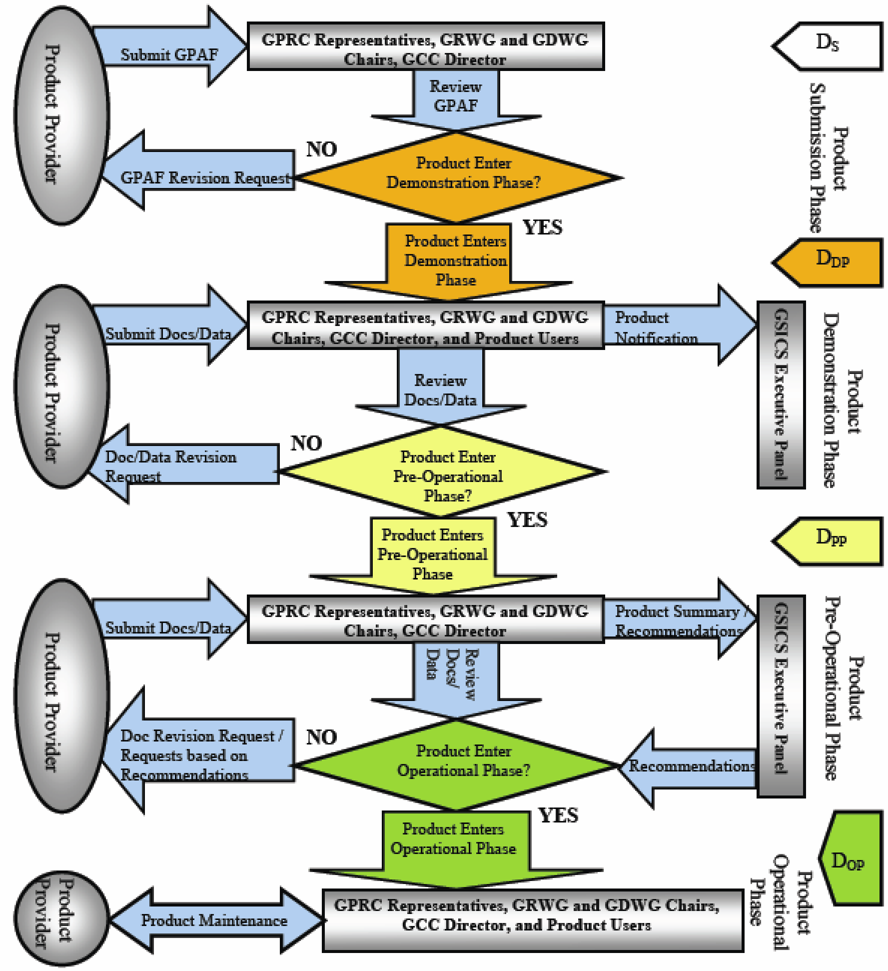


Figure 1: From top to bottom, the GSICS Procedure for Product Acceptance is described by four phases - Product Submission Phase, Demonstration Phase (DP), Pre-operational Phase (PP), and Operational Phase (OP) – and their review and revision cycles. The time markers at the far right, and their defined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

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*

GSICS Product Status 2014-02

GPRC	Monitored Instrument	Reference Instrument	GSICS NRT Correction	GSICS Re-Analysis Correction	GSICS Bias Monitoring
EUMETSAT	Meteosat-8 – 10 } Meteosat-7	Metop-A/IASI	Pre-operational	Pre-operational	Prototype
JMA	MTSAT-1R } MTSAT-2 }	IASI (+ AIRS)	Demonstration	Demonstration	Prototype
NOAA	GOES-13 & -15 Imager GOES-11 & -12 Imager	IASI (+ AIRS)	Pre-operational	Pre-operational Demonstration	Prototype
	GOES Sounder	IASI (+ AIRS)	In development	In development	In development
CMA	FY2C – E	IASI (+ AIRS)	In development	In development	Prototype
NOAA	AMSU/MSU	NOAA14/AMSU	In development	Pre-Operational	In development
NOAA Patmos-X	TIROS-N – NOAA – Metop /AVHRR	Aqua/MODIS	-	Demonstration	-

Full GSICS Product Catalog available at http://www.star.nesdis.noaa.gov/smcd/GCC/ProductCatalog.php

Comparison of Collocated Radiances

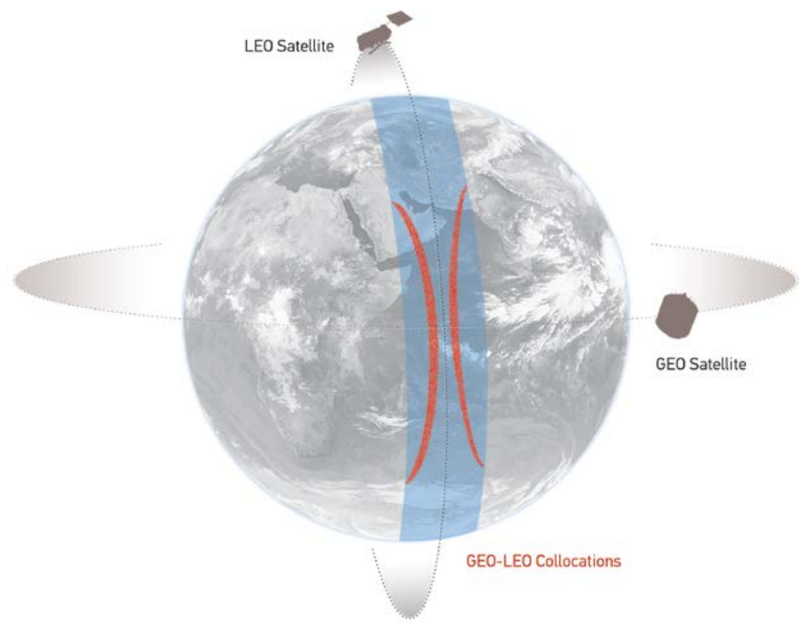
Simultaneous near-Nadir Overpass of GEO imager and LEO sounder

- Collocation Criteria:
- ΔLat<35° ΔLon<35°
- Δt < 5 mins
- Δsecθ < 0.01 (Atmospheric path diff.)

- Concentrated in tropics

~1000 collocations/orbit

~1 orbit/night

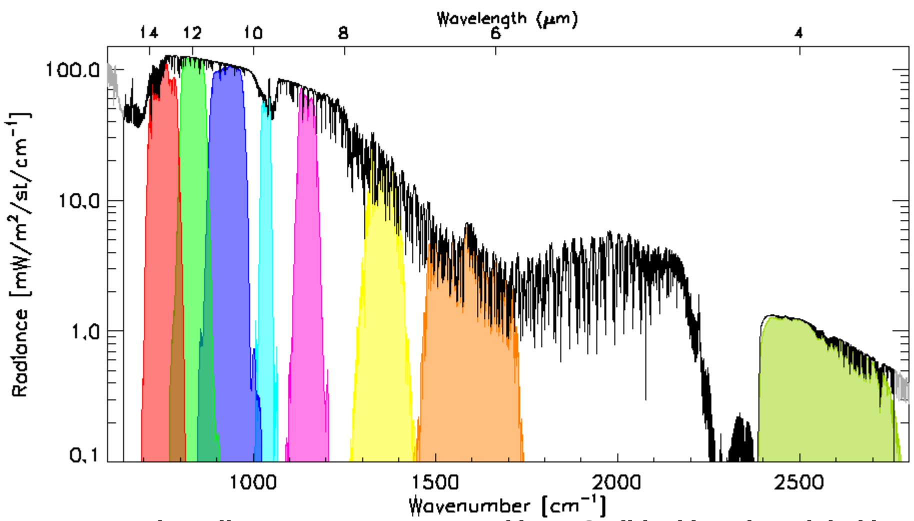


Schematic illustration of the geostationary orbit (GEO) and polar low Earth orbit (LEO) satellites and distribution of their collocated observations.

Data Transformations
(Spectral and Spatial)

•Spectral Convolution:

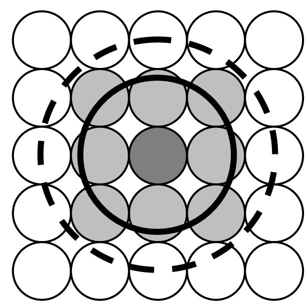
- Convolve LEO Radiance Spectra with GEO Spectral Response Functions
- to synthesise radiance in GEO channels



Example radiance spectra measured by IASI (black) and modeled by LBLRTM (grey), convolved with the Spectral Response Functions of SEVIRI channels 3-11 from right to left (colored shaded areas).
n.b. The IASI observations (645 – 2760 cm^{-1}) do not quite cover the full spectrum observed by SEVIRI.

•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



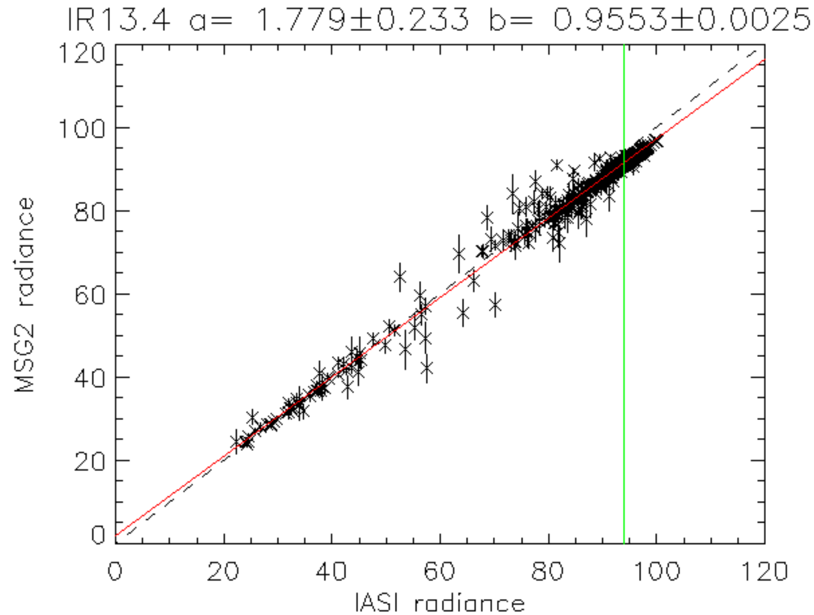
LEO FoV~10km

~ 3x3 GEO pixels

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 *n*x*m*=3x3 and SEVIRI-IASI, where *n*x*m*=5x5.

Comparison by Regression

- Compare collocated obs:
- GEO radiance
  - Spatially averaged
- Regressed against
- LEO radiance spectra,
  - convolved with GEO SRF
- Using Variance of GEO radiances + Noise
  - to estimate uncertainty on each collocation



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

Example of GSICS Bias Monitoring

From EUMETSAT: Time Series of Meteosat10-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 (PDF, 980 KB)** can also be downloaded as ▸ **GSICS Correction Coefficients (PDF, 79 KB)** in ▸ **netCDF format (PDF, 66 KB)** 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: Meteosat-10 SEVIRI

Channel: IR13.4

Date: Year 2013 Month 03 Day 17

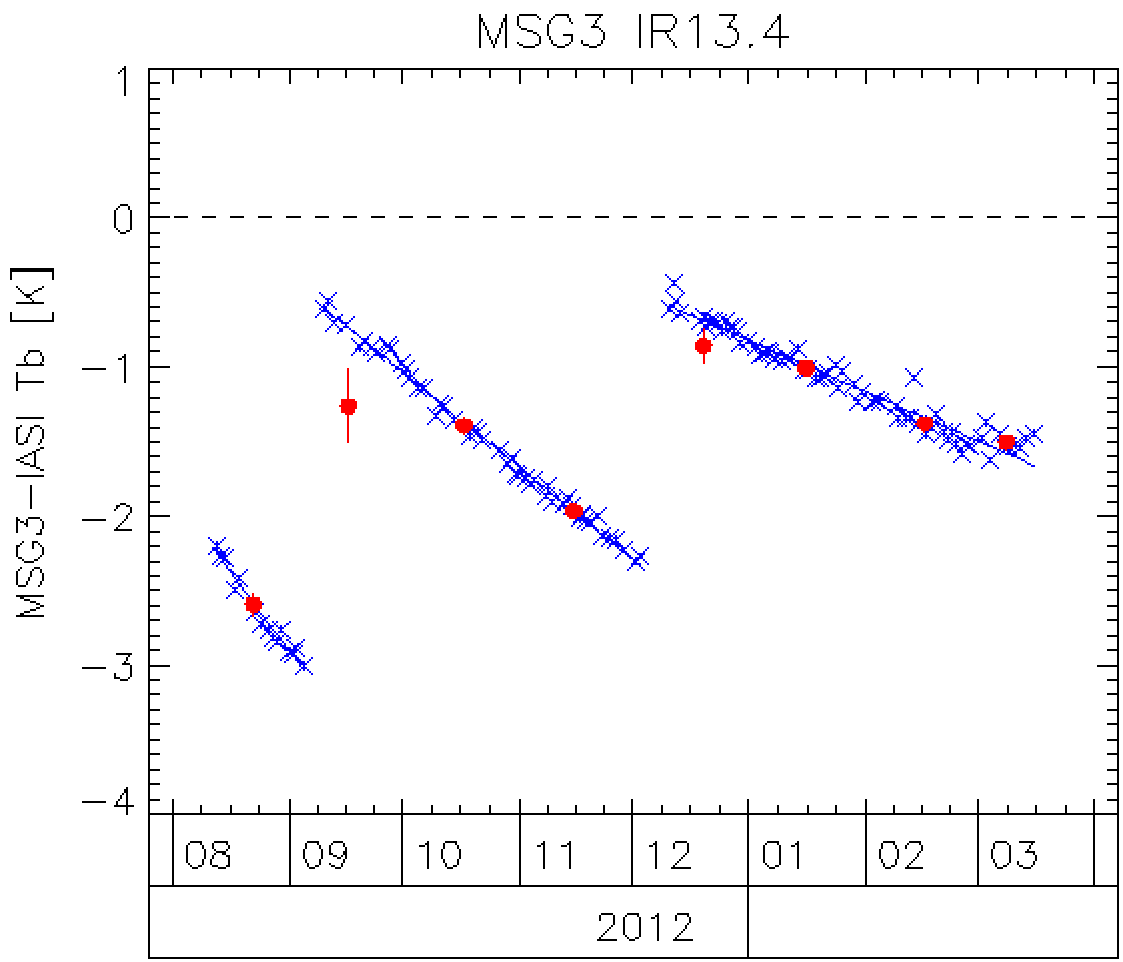
Time: 2215

Display: Time Series Plot

Legend

- Bias fitted at T_{bref} from 1 night-time overpass
- Bias fitted at T_{bref} from 1 day-time overpass
- Monthly mean Bias from all night-time data
- Trend in night-time data

Error bars: 1-σ uncertainty

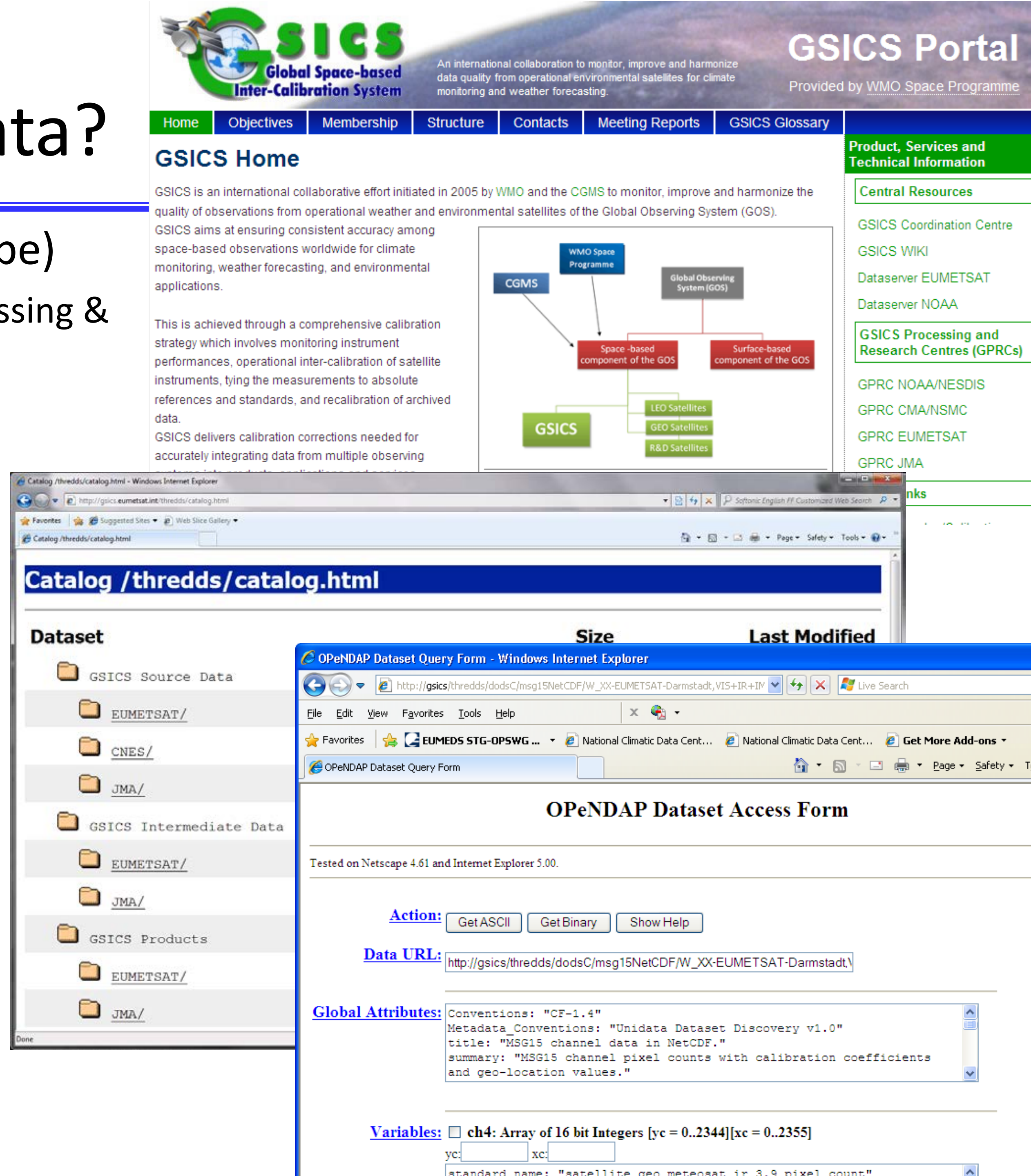


Where to get the data?

- 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



GTS = Global Telecommunication System
CF = Climate and Forecast

Cooperation with GSICS

Previous Examples

- NIST+NASA: Best Practice Guideline for Pre-launch Characterisation
- IVOS: Special Issue of TGARS
- IVOS: Cooperative development of vicarious methods/model val
- QA4EO: Design of GSICS Procedure for Product Acceptance

Future Possibilities

First GSICS Guideline document

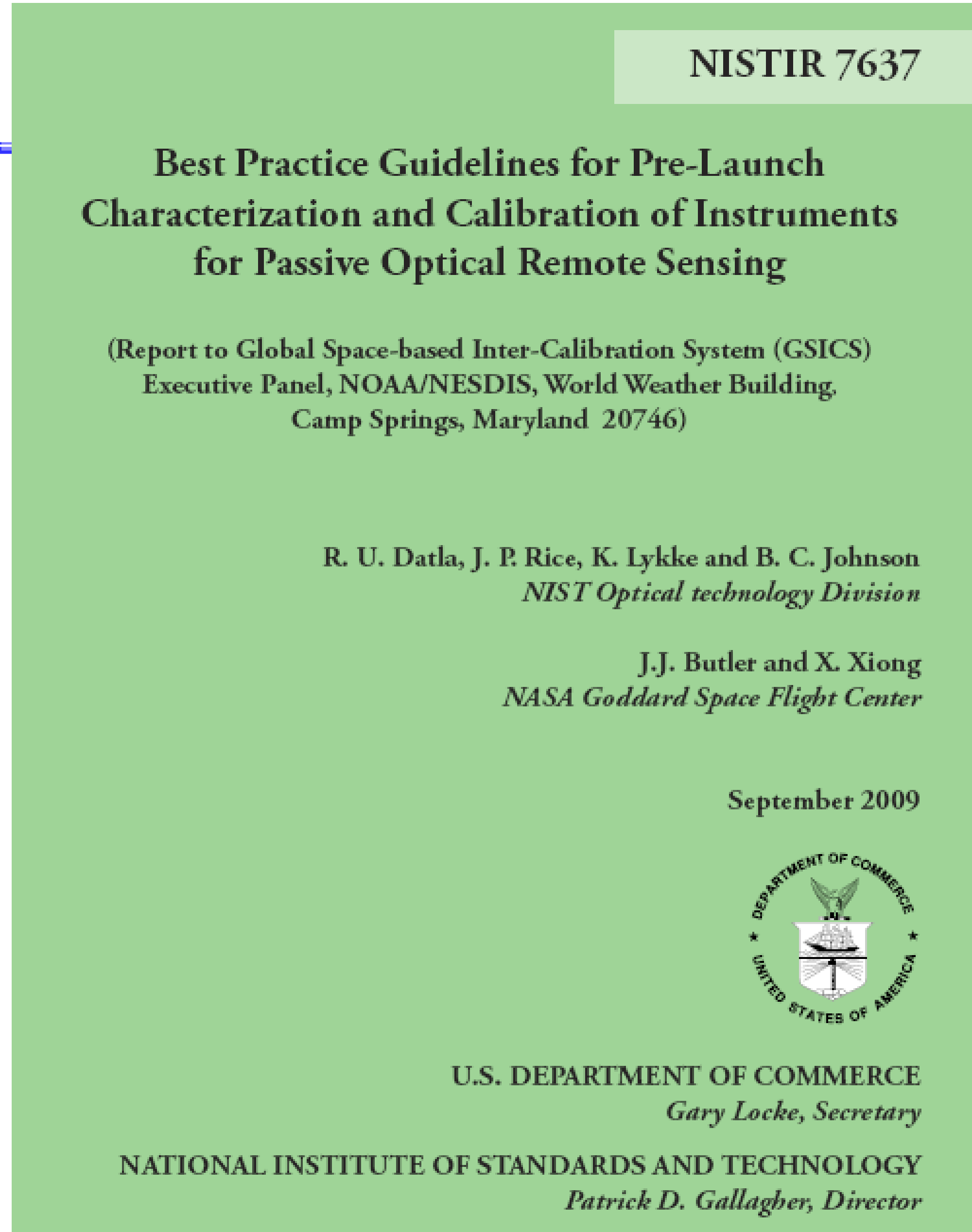
Best Practice Guidelines for Pre-Launch Characterization and Calibration of Instruments for Passive Optical Remote Sensing

Report to GSICS Executive Panel

R.U. Datla, J.P. Rice, K. Lykke and B.C. Johnson (NIST)

J.J. Butler and X. Xiong (NASA)

September 2009



NISTIR 7637

Best Practice Guidelines for Pre-Launch Characterization and Calibration of Instruments for Passive Optical Remote Sensing

(Report to Global Space-based Inter-Calibration System (GSICS) Executive Panel, NOAA/NESDIS, World Weather Building, Camp Springs, Maryland 20746)

R. U. Datla, J. P. Rice, K. Lykke and B. C. Johnson
NIST Optical technology Division

J.J. Butler and X. Xiong
NASA Goddard Space Flight Center

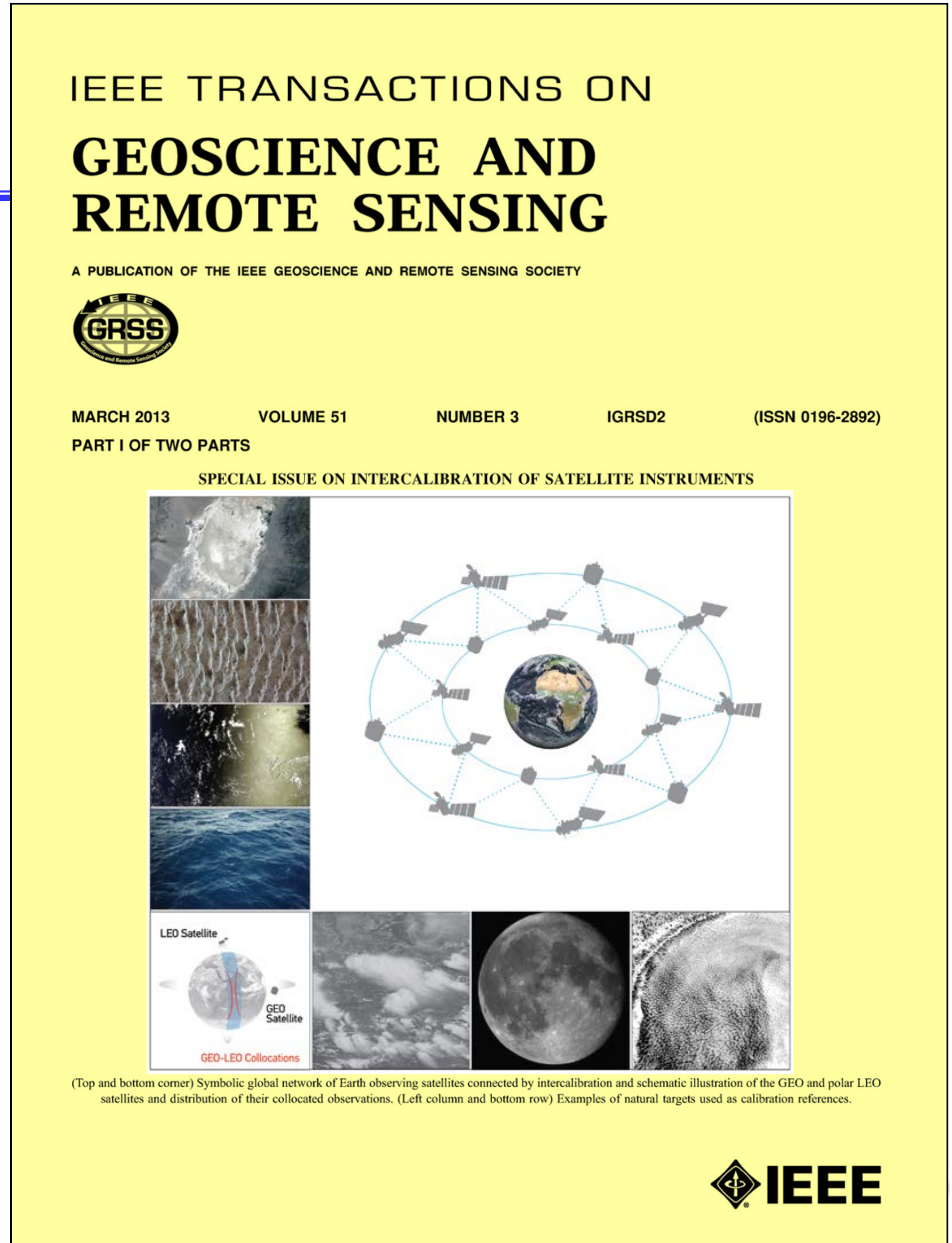
September 2009

U.S. DEPARTMENT OF COMMERCE
Gary Locke, Secretary

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
Patrick D. Gallagher, Director

Special Issue on Satellite Inter-Calibration

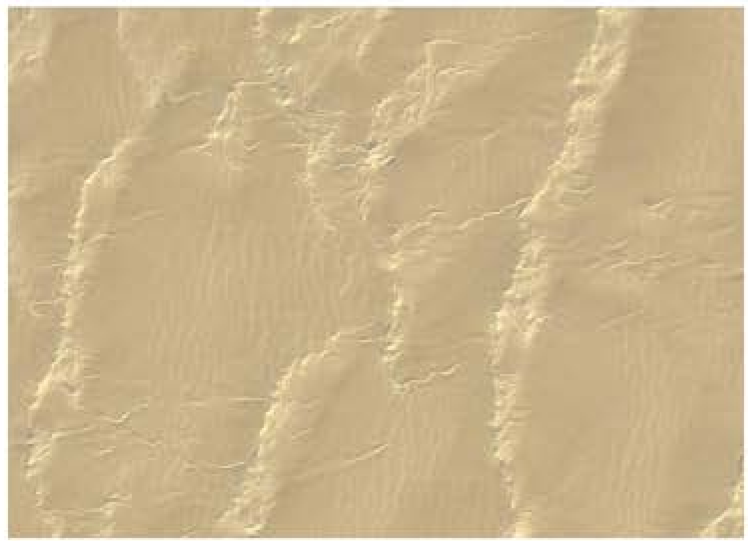
- IEEE Transactions on Geoscience and Remote Sensing
- On inter-calibration of satellite instruments
- 5 Guest GSICS/IVOS Editors
- 40 papers – incl. 13 Open Access
  - From CAS, CMA, CNES, ESA, EUMETSAT, ISRO, JAXA, KMA, JMA, MIT, NASA, NOAA, SDSU, USGS, etc.
  - Covering AVHRR, AMSU, (A)ATSR, CLARREO, ETM+, FY-2 & -3B, GOES, HIRS, Hyperion, IASI, Jason-2/OSTM, MODIS, PROBA, SCAIMACHY, Sentinel-2, etc.
- Published [March 2013]



Infrared and Visible Optical Sensors Subgroup

CEOS-IVOS Libya-4 Workshop

Paris, France. 4-5 October 2012



Background

In the context of CEOS IVOS, the pseudo-invariant Libya-4 desert site is commonly used by several teams. A special workshop fully dedicated to the use of Libya-4 site for calibration purposes was organised by CNES in Paris on 4th and 5th October 2012.

The main topics were studies on "site characterization" (morphology, homogeneity, spectral behaviour, stability, BRDF) and on "calibration results" (inter-calibration, calibration monitoring....)

CEOS WGCV

ACSG

IVOS

- IVOS 25
- IVOS 24
- IVOS 23
- **IVOS Lybia 4 Workshop 2012**
- IVOS Workshop 2010

GSICS Quality Assurance

GCC GSICS Coordination Center

Establishing product quality assurance, charting progress, and communicating accomplishments across the GSICS program and beyond

Hosted for GSICS at the NOAA/NESDIS Center for Satellite Applications and Research

GSICS Global Space-based Inter-Calibration System

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- » GSICS Quality Assurance >>
  - Product Acceptance Procedure
  - Standards and Best Practices
- » Baseline Analyses
- » Instrument Info Kiosk

GSICS Quality Assurance

As earnest work began to create the first GSICS product, the question arose of a GSICS product "stamp of approval."

This led the GSICS Coordination Center to draft a GSICS Procedure for Product Acceptance (GPPA), the role of which is to define and document product:

- Scope within the GSICS product portfolio;
- Theoretical basis, and implementation, distribution, and archive strategy; and
- Quality (uncertainty, quality indicators, etc).

The GSICS quality assurance program has been developed in conjunction with the Quality Assurance Framework for Earth Observations (QA4EO). The QA4EO is being established for the Group on Earth Observations (GEO) by the CEOS Working Group on Calibration/Validation as a general set of data quality assurance guidelines that can be applied throughout the earth observation community. At GSICS these guidelines have been tailored to meet the needs of GSICS quality assurance programs.

GSICS Global Space-based Inter-Calibration System

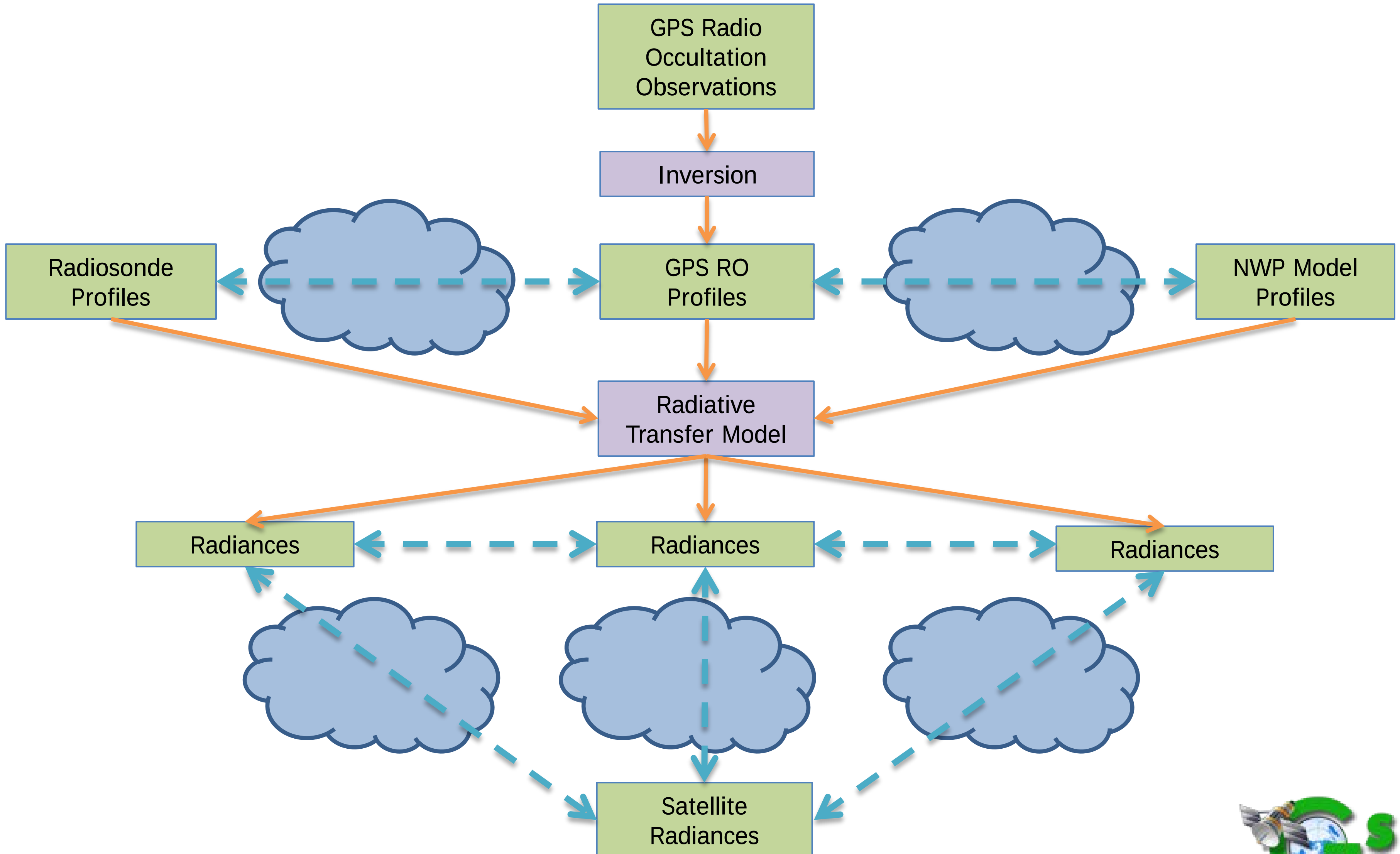
Possible Future GSICS-WGCV Cooperation

- Best Practice Guidelines
  - e.g. Traceability,
  - Calibration Uncertainty
- Glossary of calibration terminology
- Definition of Standards
- Specific interactions with WGCV Sub-Groups: IVOS, MWSG, ACC
  - Need for coordination
- Geolocation/navigation/rectification methodology & metrics
- Inter-comparison Campaigns – aircraft, ground-based support, etc.
  - Data exchange/analysis,
  - Offer to review campaign plans
- Intra-System Comparisons

Cross-cutting activities

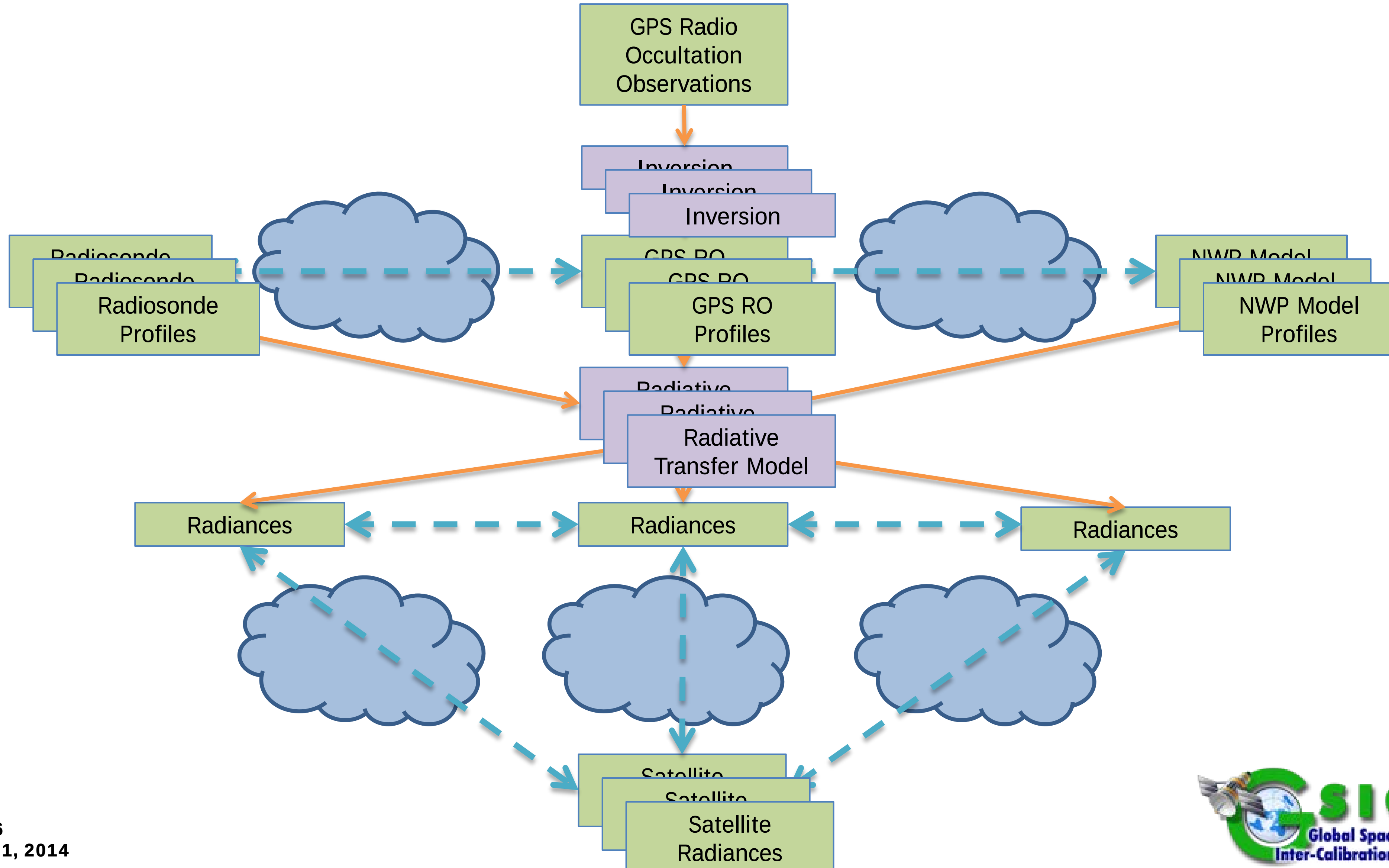
EP-12.18	ESA (Bojan Bojkov) to report at GRWG on its survey on the state of the art for geolocation issues, and on ESA activity on this subject	Main.ESA(Bojkov)	01 Mar 2013

GRUAN-GSICS-GPSRO-NWP Interaction Concept



GSICS Global Space-based Inter-Calibration System

GRUAN-GSICS-GPSRO-NWP Interaction Concept



GRUAN-GSICS-GPSRO-NWP Interaction Concept