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The Lunar Extended Spectral Simulation Reflectance model, a new model for lunar calibration

By J.M. Krijger, Earth Space Solutions, and Sebastien Wagner, EUMETSAT

The exceptional temporal stability of the lunar surface reflectance makes the Moon a very powerful target for assessing and monitoring the radiometric performances of instruments that can regularly acquire lunar observations in the reflective part of the solar spectrum (typically between 350 and 2500nm). While other vicarious calibration targets such as deserts, deep convective clouds or oceans (with Rayleigh scattering) can be used only over specific wavelengths of the solar spectrum, the Moon can be used over the full wavelength range with an accuracy that is solely limited by the uncertainties of the models predicting the lunar reflectance.

Lunar models such as **GIRO** (GSICS Implementation of the ROLO model, Wagner, 2015), and **LIME** (Lunar Irradiance Model ESA, C. Toledano et al, 2024) have similar mathematical formulation to the **ROLO** model (Kieffer et al., 2005). While these models serve as established standards, they pose mathematical challenges for fitting applications and were developed from a single terrestrial observation dataset Since 2014 and the development of the GIRO, EUMETSAT undertook a series of projects to develop further its capabilities in the field of lunar calibration to monitor the radiometric performances of geostationary and low-Earth-orbit missions operated by the agency and that acquire the Moon regularly. Thus, EUMETSAT initiated a series of projects to exploit lunar measurements done by the SCIAMACHY instrument on-board ENVISAT and the GOME-2 series on-board EUMETSAT Metop polar satellite series, which led in several stages to the development of a new lunar model, the **LESSR** (Lunar Extended Spectral Simulation Reflectance) model. While the primary mission of the SCanning Imaging Absorption Spectrometer for Atmospheric CHartographY (SCIAMACHY) aboard ESA's ENVISAT satellite was to capture global atmospheric data across a broad spectral range, from ultraviolet (214 nm) to near-infrared (2386 nm) (Bovensmann et al., 1999), the mission conducted extensive lunar observations during its lifetime, between 2002 and 2012. Although its slit instantaneous field of view (IFOV) (0.045 × 1.8) covered only a small portion of the lunar disk in the across-track direction, its two-mirror scanning system enabled lunar tracking and repeated scans across the whole disc. This sequential scanning approach significantly reduced measurement uncertainty.

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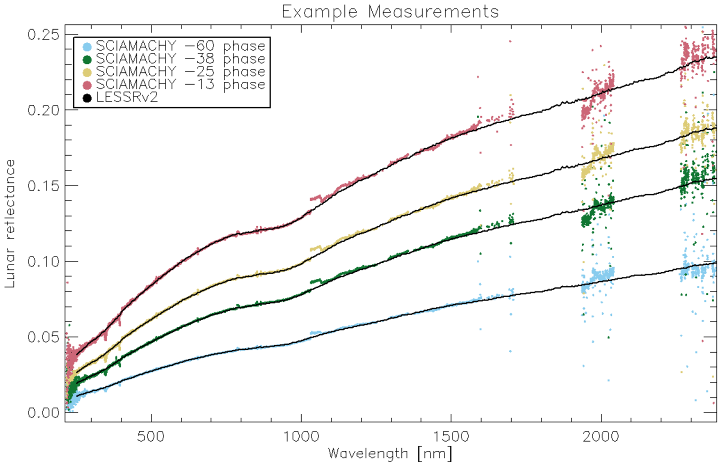

Figure 1. Example of SCIAMACHY measurement spectra. Colors indicate different lunar phase. In black: the model simulation for that measurement. Note the wavelength gaps and noise for the SCIAMACHY measurements.

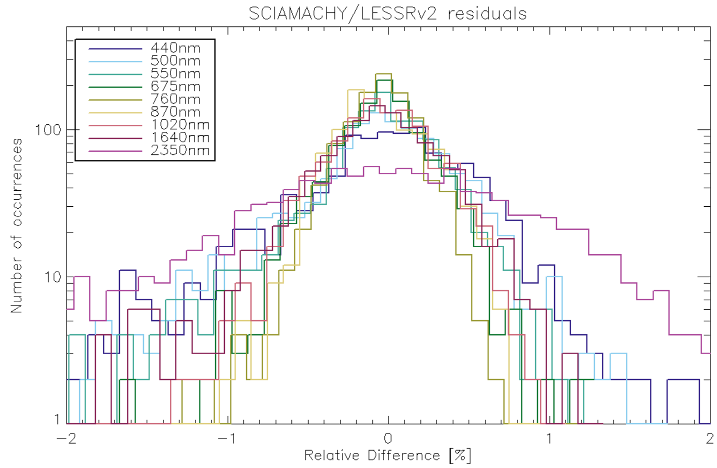

Figure 2. Histogram of the residuals for LESSRv2 model simulations for a few selected wavelengths, over a total of 1106 spectra. The residuals are roughly normally distributed with a standard deviation of 0.5%.

Aggregated observations produced lunar full-disk irradiance spectra, a process repeated over a thousand times throughout SCIAMACHY's operational lifetime. The resulting dataset provides an extensive sampling of lunar phase and libration geometries, with phase sampling constrained to -80° to 20° due to orbital mechanics (Krijger, 2017, 2021).

SCIAMACHY also measured solar irradiance, allowing direct conversion of lunar irradiance into lunar reflectance without the need for external solar reference spectra. This approach effectively mitigated instrumental influences, improving precision across wavelengths. The resulting lunar reflectance data exhibited high precision, with uncertainties ranging from 0.2% in the visible spectrum to approximately 1% in the ultraviolet (UV) and shortwave infrared (SWIR). Absolute accuracy was on the order of a few percent. The SCIAMACHY lunar data have been recently reprocessed and consolidated within the context of the ESA FDR4ATMOS project and will be publicly available (DOI: 10.57780/en1d549f05). This dataset was made available by ESA to EUMETSAT to improve the first version of LESSR. Additional empirical corrections were applied to those SCIAMACHY lunar spectra to remove residual instrumental artifacts – including polarization (Krijger, 2021) effects, and thus optimize further lunar full-disk reflectance data for modeling applications. These reflectance spectra were then refined using a fit to a combination of laboratory reflectance measurements of various lunar soil samples (RELAB), thus mitigating wavelength gaps and residual noise (see Figure 1), ultimately yielding a spectral resolution of 5 nm.

LESSR v1 (Krijger, 2019) was originally fitted to a formulation like ROLO, which depends on the lunar phase, the solar and viewing geometry**.** However, the exceptional precision of SCIAMACHY data (0.3% uncertainty in the visible spectrum) enabled a robust investigation into alternative modeling approaches and base functions for the parametrization of the lunar reflectance. An iterative process allowed the

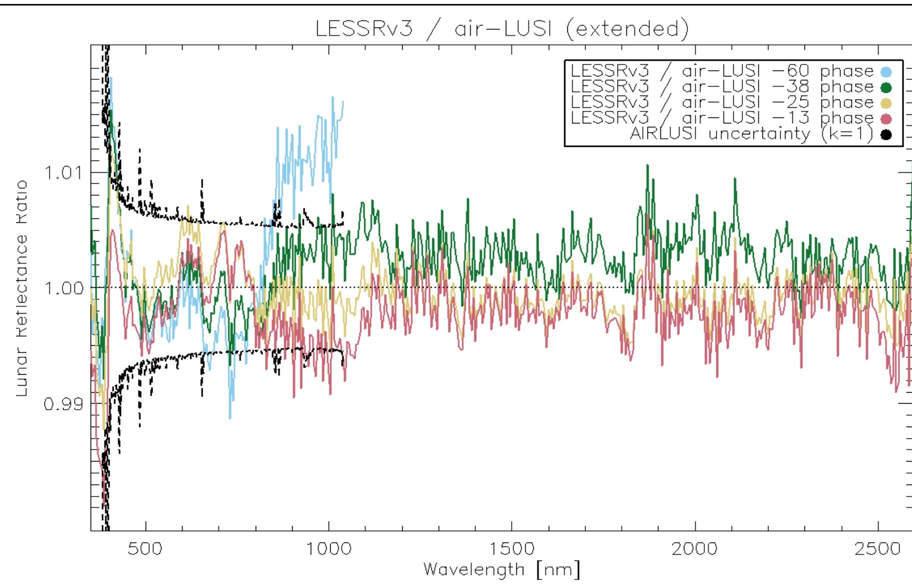

Figure 3. Ratio between the four air-LUSI measurements (below 1040nm) / RELAB extension (beyond 1040nm) and LESSRv3 simulations. Phases are indicated by colors. In black the reported k=1 uncertainty range of air-LUSI. The extension of the air-LUSI measurement with RELAB for -60° lunar phase is still under investigation and is not shown here.

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elimination of components with low Bayesian information content or parameters introducing excessive noise (SNR < 1), to keep only a validated set of base functions, each fitted independently across wavelengths. The final model, **LESSR v2** (Krijger, 2024)**,** achieves relative uncertainty below 0.5% in the visible spectrum, with slightly higher deviations in the UV and SWIR regions (see Figure 2). It predicts lunar reflectance between 280 nm and 2600 nm at 5 nm resolution, covering all librations and phase angles from -80° to 20°, except for the narrow exclusion range of -5° to 5°. Validation results indicate that LESSR v2 successfully mitigates the phase-dependent artifacts observed in the SWIR region of the GIRO model, which is essential for instrument detrending and intercalibration applications.

Despite SCIAMACHY's high-precision measurements, absolute uncertainties in the order of several percent remained due to diffuser calibration limitations. A recalibration was performed using the highly accurate (<0.6%) air-LUSI dataset (Woodward et al, 2022) to improve the absolute accuracy of LESSR. Before they could be used for anchoring LESSR, the original air-LUSI data were further refined using RELAB data to extend the original spectral coverage up to 2600 nm, and to eliminate instrumental spectral artifacts, ensuring spectral smoothness. The resulting recalibration process reduced the absolute uncertainty of the newly developed **LESSR v3** model to 0.6% (see Figure 3).

LESSR is shown to be a reliable new lunar calibration model to support Earth observing missions that can regularly observe the Moon. By construction, LESSR already allows the inter-calibration of the GOME-2 series with SCIAMACHY, opening the path for inter-calibration with similar hyperspectral sensors that could acquire lunar measurements. However, further investigations are needed to reduce the uncertainties for lunar phase angles beyond 20 degrees.
Future plans include integrating the LESSR model into the GSICS software framework, called LSICS which is currently being developed, facilitating streamlined lunar calibration for both existing and upcoming spaceborne missions. In addition, a machine-learning model, using the most recent tools and lessons learned, **LESSAIR** is in development and already showing promising results.

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Highlights of the Recent Development of the Global Navigation Satellite System Radio Occultation Processing and Science in NOAA/STAR

By Shu-peng Ho, NOAA

With Global Navigation Satellite System (GNSS) Radio Occultation (RO) receivers onboard satellites in the Low Earth Orbit (LEO), we can detect the delay of the occulted signal's phase (at L-band frequencies for 1575.42 MHz (L1) and 1227.6 MHz (L2)) across the atmosphere and the ionosphere, which is a function of temperature, water vapor, pressure in the neutral atmosphere, and electric density profile in the ionosphere (Ho et al., 2020). Recently, we have entered a new Era of GNSS RO technology (Ho et al., 2022a). In the past decade, we have had many newly launched RO missions (i.e., Taiwan/US Formosat-7/Constellation Observing System for Meteorology, Ionosphere, and Climate-2 (COSMIC-2), the ESA/EUMETSAT/US Sentinel-6, and missions from NOAA partners (i.e., MetOp-A, -B, -C, KOMSAT-5, TerraSAR-X, PAZ). To obtain more GNSS RO data, NOAA purchased RO data from commercial vendors, including GeoOptics, Spire, and PlanetiQ Inc. (see Ho et al., 2023). NOAA had included GNSS RO observations as one of their core observables for numerical weather prediction (NWP) and atmospheric studies (Ho et al., 2020, 2022a). Currently, we include approximately 12,000 RO profiles per day in the NOAA NWP system. Based on a forecast sensitivity to observation impact (FSOI) by all the observing systems used by the ECMWF in June 2011, Cardinali and Healy (2014) reported that GNSS RO data ranks as the 4th most impactful dataset for reducing forecast errors (also see Ho et al., 2020). Figure 1 shows that if we double the current RO profiles (12,000 profiles per day) to 25,000 RO profiles per day (under the efforts of the Radio Occultation Modeling Experiment (ROMEX), Lovitz et al., 2025) GNSS RO data ranks first among all data from satellites, in situ, and aircraft for reducing global NWP forecast errors.

The Center for Satellite Applications and Research (STAR) is NOAA's dedicated RO monitoring and reprocessing, as well as the science center (the STAR GNSS RO website is under internal evaluation, here we provide a mirror site at https://gpsmet.umd.edu/gnssro/index.php). The role of the STAR GNSS RO program is to support NOAA/NESDIS offices to fulfill the following functions:

- In-house RO data processing for the current RO missions
- Development of the enterprise GNSS RO algorithms, including software engineering, for the current and future RO missions
- Data maintenance and delivery (both in real-time mode and post-processed mode)
- Calibration and validation of each processing step from raw data to L1, L2, and L3 data products
- RO data validation, monitoring, and data maintenance and delivery (both in a real-time mode and post-processed mode)
- Product portfolio management and cloud framework
- Optimization of data for NWP and other operational applications
- RO research and science within NOAA and in the international RO community

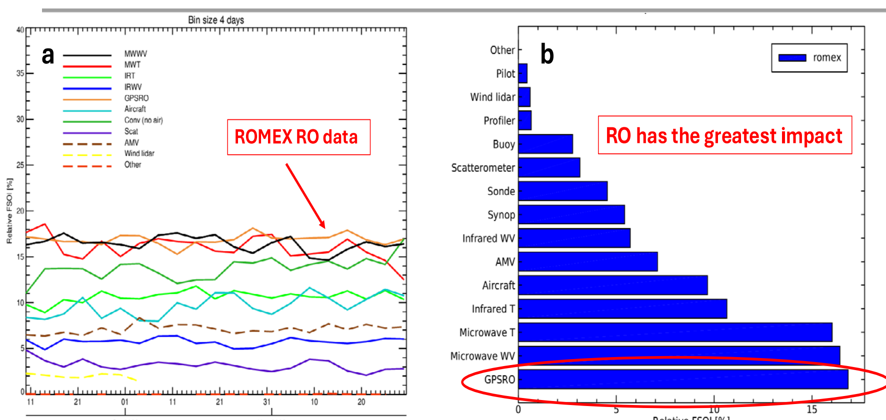

Figure 1. (a) the reduction of forecast error using various observations and (b) the relative FSOI (%). RO has the most significant impact on reducing forecast errors among all data.

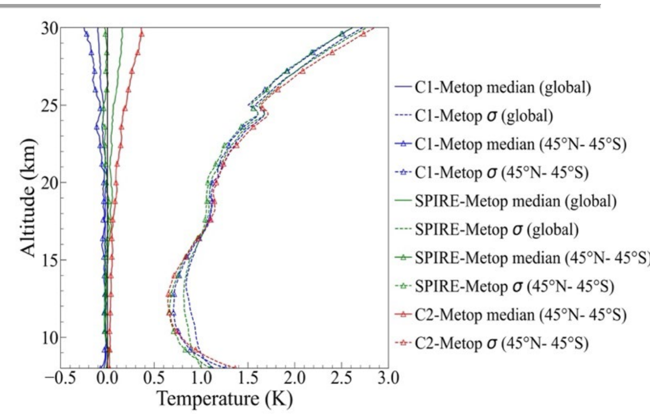

Figure 2. Measures of consistency between collocated COSMIC-1 and MetOp (blue), Spire and MetOp (green), and COSMIC-2 and MetOp pairs (red) as a function of height for the entire globe and 45°N-45°S region.

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Since initiating the STAR GNSS RO program in 2018, we have published over 40 journal papers that document our GNSS RO processing algorithms, data product validation, and science applications). STAR has demonstrated the capability to process multiple RO missions, from the time delay to the excess phase (Zhang et al., 2022), as well as bending angle and refractivity profiles (Adhikari et al., 2021). Ho et al. (2022b) documented the detailed process of inverting the COSMIC-2 refractivities to estimate the neutral atmosphere's temperature and water vapor profiles. The consistently processed STAR GNSS RO data for multiple RO missions (i.e., COSMIC-2, KOMPSAT-5, PAZ, GRAS Metop-B/-C, PlanetiQ, and Spire) from 2006 to the present are available to the public at https://gpsmet.umd.edu/gnssro/download.php. We also intensively validated these GNSS RO data products using measurements from NOAA microwave sounders (Shao et al., 2021a; Jing et al., 2023), collocated radiosondes (Shao et al., 2021b; Jing et al., 2023), and NOAA CrIS Infrared observations (Chen et al., 2022).

Zhou et al. (2025) detailed the construction of temperature time series using STAR-processed GNSS RO data from multiple missions. We first validated the long-term stability of RO data using RO-RO pairs. Figure 2 depicts COSMIC-1 and MetOp (blue), Spire and MetOp (green), and COSMIC-2 and MetOp pairs (red) temperature differences from 8 km to 30 km altitude.

We further identified that COSMIC-2 viewing geometry (with a 24-degree inclination angle) is the primary reason for their retrieval biases (not shown). Then, we utilized multiple RO missions (i.e., COSMIC-1, Metop-A, -B, and -C, and Spire) to construct the monthly mean temperature climatology (MMC) data record, excluding COSMIC-2 data. Figure 3 presents the vertical profiles of temperature trends, estimated at 0.2 km intervals, from the STAR-ROPP, ERA-5, JRA-55, and MERRA-2 datasets.

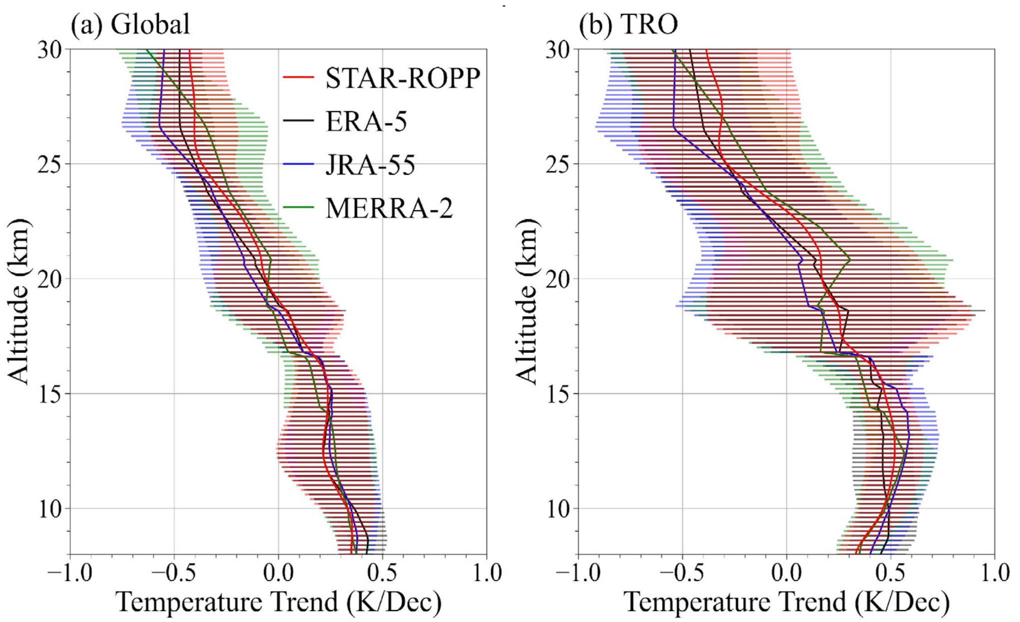

Figure 3. Vertically resolved temperature trends (September 2006 - July 2023) estimated from STAR-ROPP (red), ERA-5 (black), JRA-55 (blue), and MERRA-2 (green) for (a) global (90ºN-90ºS) and (b) the TRO (20ºN-20ºS) regions. Error bars represent the uncertainty in the trend at the 95% confidence level.

Conclusions

We highlight the recent developments in GNSS RO processing and science at NOAA/STAR since 2018. STAR GNSS RO program has developed independent RO processing packages, which are used to process multiple RO missions consistently. We documented the inversion algorithms, validation results, and procedures for constructing the RO temperature MMC, which is freely available to the public at https://gpsmet.umd.edu/gnssro/download_mmta.php. All STAR-processed RO data are freely available to the public (https://gpsmet.umd.edu/gnssro/downlad.php). Approximately 25,000 individual scientists and researchers visited our website, resulting in over 500,000 visits in 2024 (https://gpsmet.umd.edu/gnssro/Analysis.phps)

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Copernicus Sentinel-2 Collection-1 Radiometric Vicarious Validation over Desert-PICS targets

By Bahjat Alhammoud, Sebastien Clerc, Sonia Amaaouch, Florian Poustomis, Jerome Bruniquel, ACRI-ST, Silvia Enache, Bruno Lafrance, CS-Group, and Valentina Boccia, ESA

The Copernicus Sentinel-2 constellation is an Earth Observation optical mission developed and operated by the European Space Agency (ESA) in the frame of the Copernicus program of the European Commission. Since the launch of Sentinel-2A in 2015, followed by Sentinel-2B in 2017 and Sentinel-2C in 2024, the mission offers a unique insight into our planet providing high-resolution, multispectral imagery of the Earth's surface reflectance. The Sentinel-2 mission has been supporting a large range of Earth Observation applications and empowering policymakers, scientists, businesses, and communities worldwide. The radiometric calibration of the Sentinel-2 sensors is performed routinely each month. It includes a dark signal calibration as well as an absolute and relative gain calibration, and results in the update of the Ground Image Processing Parameters (GIPP) used by the processor to generate Level-1C products. However, major reprocessing effort on the Sentinel-2A and Sentinel-2B archive resulted in several improvements of the Level-1C (L1C; Top-Of-Atmosphere reflectance) and Level-2A (L2A; Surface Reflectance) products. This paper recalls the features of Collection-1 products and gives an overview of the L1C radiometric validation results over desert PICS targets.

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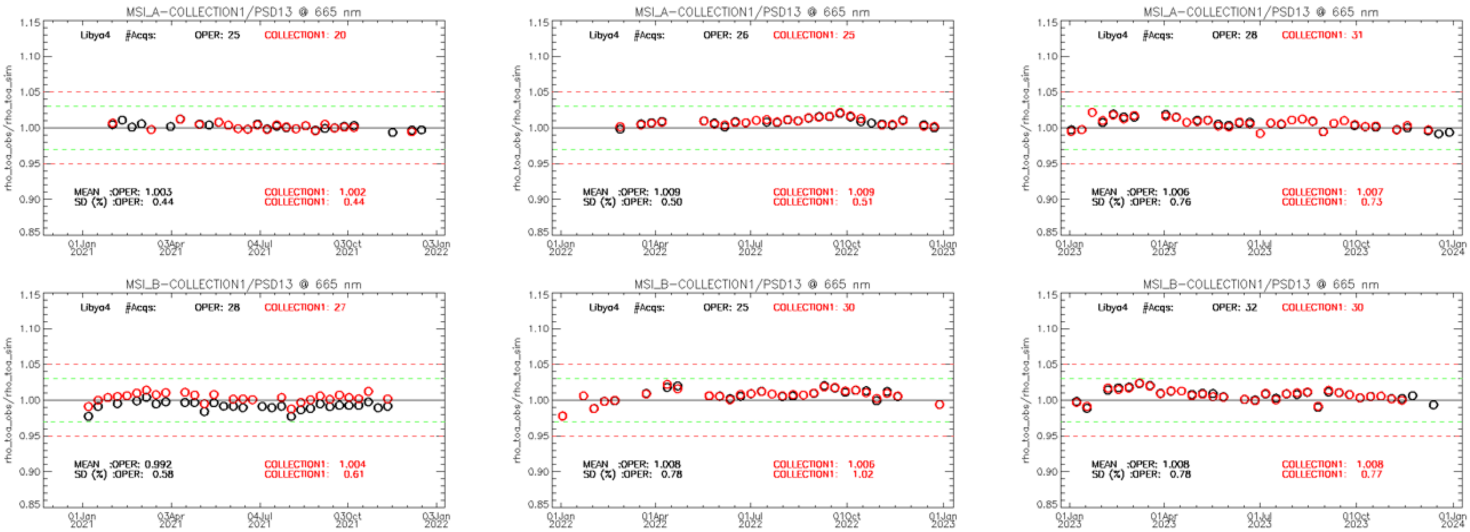

Figure 1: Time-series of gain coefficients as the ratio of observed TOA-reflectance to reference TOA-reflectance from (top row) MSI-A and (bottom row) MSI-B for band B04 (665 nm) from (black) Pre-Collection, and (red) Collection-1 dataset over Libya-4 site in 2021, 2022, and 2023 from left to right. Mean and Standard deviations are indicated in the figure legend. Orange and green dashed-lines indicate the 5% and 3% accuracy respectively.

1. Main improvement features of collection-1 products

The Collection-1 reprocessing aims on providing consistent Sentinel-2A and Sentinel-2B time series with a uniform processing baseline and optimized calibration

The main improvements that are carried out in Collection-1 are:

- The TOA reflectance alignment of Sentinel-2B VNIR bands with Sentinel-2A ones using vicarious adjustment factor of 1.1% [1],[2]The TOA reflectance alignment of Sentinel-2B VNIR bands with Sentinel-2A ones using vicarious adjustment factor of 1.1% [1],[2].
- The introduction of a radiometric offset in both Level-1C and Level-2A products allows us to avoid truncation of negative reflectance due to noise.
- The improvement of the radiometric calibration with an upgraded model of the on-board Sun diffuser
- Upgraded L1C quality masks using the latest raster format as well as introducing a coarse snow mask.
- Better tracking of the missing packets, radiometric saturation as well as partially corrected crosstalk effects at pixel level.
- The systematic use of geometric refining based on the Sentinel-2 Global Reference Image and the Copernicus Digital Elevation Model at 30 m resolution, which introduced a geometric uncertainty of Collection-1 products below 8 m (CE95) and the multi-temporal uncertainty below 5 m (CE95).

Several improvements have been made to Level-2A products, which are beyond the scope of this article

2. Materials and Methods

2.1. Sentinel-2 level-1C products:

The Sentinel-2/MSI L1C product consists of orthorectified TOA reflectance provided as 110 x 110 km2 tiles, based on the UTM/WGS84 reference frame with spatial resolution of 10m, 20m and 60m. We use six desert sites to perform an

Wavelength (nm)	MSI-A PC #420 Acq	MSI-A C1 #296 Acq	Difference MSI-A PC-C1	MSI-B PC #406 Acq	MSI-B C1 #297 Acq	Difference MSI-B PC-C1
443	0.991	0.993	-0.002	0.982	0.996	-0.015
490	0.993	0.992	0.001	0.987	1.000	-0.013
560	1.005	1.007	-0.002	1.004	1.017	-0.013
665	0.999	1.000	-0.001	0.991	1.003	-0.012
705	1.003	1.006	-0.002	0.986	1.004	-0.018
740	1.012	1.012	0.000	1.007	1.019	-0.012
784	1.007	1.009	-0.001	0.989	1.001	-0.012
842	0.993	0.995	-0.001	0.983	0.995	-0.012
865	1.000	1.001	-0.001	0.991	1.003	-0.012

Table 1. Average gain coefficients from both sensors for both pre-collection and Collection-1 dataset, as well the differences between both datasets over the VNIR spectral range.

intercomparison between the operational (pre-collection) and the Collection-1 products using the PICS method [1], [3]. The whole L1C-archive dataset until December 2023 is ingested into DIMITRI V3 database to be analyzed.

2.2. Desert PICS Vicarious method

The Desert PICS targets have been used extensively to monitor the in-orbit satellite sensors performance and its radiometric stability for decades as reported in [3] and [4] and references in there. The desert PICS method builds a reference reflectance model for the selected site using top-of-atmosphere (TOA) measurements from a reference sensor (MERIS in DIMITRI [5]) and a four-parameters bidirectional reflectance distribution function (BRDF) model for each spectral band. The TOA measurements are computed using the BRDF model and the observation geometry of the target sensor (here MSI-A & B). This method allows multi-temporal analysis performing, as well as comparison of multiple sensors or multiple processing baselines over the same site over the visible to near-infrared (VNIR) spectral range.

3. Vicarious validation results

The radiometric validation of the reprocessed products consists of two folds: 1) the verification of the correction-bias application over S2B products, and 2) the verification of the alignment of S2B with S2A TOA reflectance.

To achieve these objectives, the verification over desert-PICS test sites is performed over the available dataset from S2A and S2B Pre-collection and Collection-1 acquisitions over 2015-2023. The PICS methodology is applied, and the outputs are compared over the same acquisition period (comparing the gain coefficients as ratios of TOA-Reflectance). Figure 1 presents the yearly time-series of the gain coefficients from both S2A and S2B over Libya-4 CalVal site in 2021, 2022 and 2023. One observes that S2A gain coefficients from Pre-collection products match well those from Collection-1 data as expected. On the other hand, S2B gain coefficients from pre-collection products in 2021 show bias of about 1% wrt those from Collection-1, while they match well each other in 2022 and 2023. This is explained by the differences between the processing baseline (PB04.00) and its evolution applied Jan. 2022 onward.

Table 1 show the average of the gain coefficients from both sensors for pre-collection and Collection-1 dataset, as well the differences between both datasets in VNIR spectral range over Jan.2019 - Jan.2022. The overall gain coefficients (expressed as ratios) are within the 3% (mission target requirements), which provide evidence of the excellent radiometric performance of both S2A and S2B sensors. The gain coefficients differences from S2A are close to 0.0, while those from S2B are close to 0.01, which illustrates the successful reprocessing and attests that the bias correction is well considered for S2B radiometry alignment.

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Acknowledgements

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NEWS IN THIS QUARTER

Highlights on 2025 Annual GRWG/GDWG Meeting

By M. Bali (UMD), L. Flynn (NOAA), Mounir Lekouara (EUMETSAT), Paolo Castracane (ESA), Tim Hewison (EUMETSAT), Chengli Qi (CMA), T. Stone (USGS), D. Doelling (NASA), Tsutomu Nagatsuma (NICT), L. Wang (UMD) and Flavio Iturbide (NOAA)

This year's meeting of the GSICS Research and Data Working Groups (GRWG and GDWG) was hosted from 17-21 March 2025 jointly by Changchun Institute of Optics, Fine Mechanics and Physics (CIOMP) and CMA's National Satellite Meteorological Center. Members from CMA, CIOMP, CAS, CNES, ECMWF, EUMETSAT, ESA, ISRO, JAXA, JMA, KMA, LAS, NIST, NASA, NOAA, NSMC, NPL, UKMO, USGS, VITO and WMO attended the meeting.

Plenary

Xuejun Zhang from CIOMP welcomed the members after which the plenary agenda initially focused on the CMA, SITP and CIOMP missions [FY-4C status by Feng Lu (CMA), Absolute Measurement System for Terrestrial Reflected Spectral Radiance, Xin Ye (CIOMP), Research Progress on Infrared Benchmark Payloads, Lei Ding (SITP), and Early Performance of FY-3G/HAOC and Cross Calibration Test to other Sensors by, Lu Lee/Xiuqing Hu (CMA), and Radiometric calibration using artificial intelligence by Boyang Chen (CMA)]. This was followed by talks on EarthCARE Cal/Val activities by Paolo Castracane (ESA) and on MTG-I1 entry into operational phase and MTG-S status by Mounir Lekouara (EUMETSAT) and then by reports on the GDWG by Paolo Castracane (ESA) and on the GRWG by Mounir Lekouara (EUMETSAT).

VIS/NIR and Lunar Subgroups and Space Weather Breakout Session

The second half of the first day had two parallel sessions. The VIS/NIR breakout session was chaired by Mounir Lekouara with a subset of talks from the Lunar Calibration subgroup aligned with VIS/NIR chaired by Tom Stone (USGS). Tsutomu Nagatsuma (NICT) chaired the Space Weather breakout session.

The VIS/NIR subgroup covered topics on Global Pseudo-Invariant Pixels (GPIPs) Selection by Junwei Wang (CMA), FY-3F MERSI-III Reflective Solar Band On-orbit Calibration Methodology and Performance and provided status of KMA VIS/NIR Calibration and transition from MODIS to VIIRS for AHI vicarious calibration. Harmonization of SPOT-VGT1, SPOT-VGT2, and PROBA-V Time Series and Status of the FDR4VGT Project demonstrated the extensive exploitation of GSICS algorithms across a range of observing platforms in VIS/NIR.

Tom Stone welcomed members in the Lunar Subgroup, and talks covered three topics: lunar calibration of MTG-FCI, the LESSR V2.0 lunar model, and LSICS development.

Key Outcome: *The Lunar subgroup decided to work towards building a database of additional Lunar observations.*

Dave Doelling (NASA) chaired the VIS/NIR subgroup the next day with talks on calibration of lightning mapper, Deep Convective Cloud (DCC), Vicarious Desert Calibration and Ray Matching.

Key **Outcome:** VIS/NIR subgroup to discuss GSICS feasibility of Correction for lightening mappers

Participants in the GSICS Annual Meeting 2025, Changchun, China

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Tsutomu Nagatsuma (NICT) chaired a parallel session on Space Weather. It covered calibration of space weather instruments including GOES-19 MPS-HI, GOES 16-19 SGPS, Pre-launch of FY-3H/WAI-II, ADITYA-L1 ASPEX, and FY-3E X-EUVI. The reports about the multi-point GEO observations of Major 2024 Space Weather events, long-Term Variation of Cross-calibration results between Himawari8/SEDA and GOES16/MPS-HI, Cross-calibration of ESA Radiation Monitors helped take the discussion towards setting up new goals for the Space Weather subgroup.

Key Outcome: *The space weather subgroup is discussing sharing data in consistent and coherent manner and map data level definitions, and standardization of cross-calibration procedure.*

UVNS Spectrometer Sub-Group Session Summary

Eighteen talks were presented to over thirty attendees during two half-day sessions. They covered calibration and validation efforts for satellite instruments including TEMPO, OMPS (NOAA-20/21), OCO-2, OCO-3, GOSAT, FY-3F OMS-Nadir and Limb, GEMS, CO2M, GOME-2, OMI, TropoMI, GF-5 EMI, and FY-3E SSIM. Topics included time-dependent calibration updates, radiometric trending, and inter-sensor comparisons. Updates on plans and activities supporting future missions – Sentinel-4 UVN, Sentinel 5 UVNS and CO2M – were covered in talks by Eumetsat attendees. Talks on the status of LER and DLER databases from GOME-2 and TropoMI for use as ancillary information, and on the FDR4ATMOS project rounded out the session. These activities enhance Level 1 data accuracy, enable better inter-instrument harmonization, and improve the reliability of derived products for climate and greenhouse & trace gas monitoring.

Key Outcome: *Work towards the development of inter-comparisons using under-flights of GEMS, TEMPO, UVN and EPIC*

IR Sub-Group Session Summary

The session on infrared calibration and validation showcased a broad spectrum of advances across current and future missions. Key discussions included the future development of EUMETSAT GSICS IR products and an introduction to the Level-1 processing and prelaunch calibration of the FY-4C GIIRS instrument. Several presentations highlighted lunar calibration, including lunar geometry computation for CrIS, innovative IR lunar calibration techniques, and navigation and radiometric calibration for geostationary satellite lunar observations. Updates were provided on the validation of airborne HIRAS experiments and the development of an SI-traceable infrared radiation reference subsystem. The session also covered calibration monitoring of MTG-I1 FCI using GSICS algorithms, the status of AMI IR products, and calibration systems for the FY-3/MERSI instrument, including on-board calibration techniques. Further topics explored improved inter-calibration methods between CrIS and VIIRS, line-of-sight (LOS) vector-based collocation for AHI and LEO instruments, and relative spectral response function (SRF) retrievals applied to Metop IASI. These efforts collectively underscore global progress toward more accurate, traceable, and harmonized infrared observations from space.

Key Outcome: *Review GSICS product User requirements and build new GSICS products*

MW Subgroup Session

The session on microwave calibration and validation highlighted a range of ongoing and planned activities supporting GSICS objectives. Reports from GSICS focus groups detailed progress in pre-launch testing, post-launch characterization, lunar calibration techniques, and vicarious calibration for microwave radiometers. The last of these focus groups plans to consolidate proposal for a baseline SNO algorithm and uncertainty framework, which will address an open CGMS-51 WG-II action to establish a methodology to characterize microwave instruments for O2 absorption channels. Updates included advancements from the COSMIR-H aircraft and WH²yMSIE campaigns, as well as NASA-GSFC's developments in hyperspectral microwave sounding. China's FY-3H MWRI-II instrument and the broader status of FengYun microwave radiometers were reviewed, alongside AMSR3 updates and ESA's microwave initiatives. Additional talks introduced the EPS-Sterna inter-calibration study, FY-3 in-orbit monitoring using radiative transfer and NWP, the VICIRS radiosonde calibration tool, and PICS-based calibration site selection via lunar observations. Additional discussions included plans to work with WMO OSCAR and CGMS to detect, monitor and map Radio Frequency Interference, and potential partnership with the International Precipitation Working Group (IPWG), which was referred to the Executive Panel.

Outcome: *Subgroup decided to build a methodology to characterize microwave instruments for O2 absorption channels through the SNO and RTM modelling.*

GSICS Data Working Group (GDWG)

The GSICS Data Working Group breakout session was chaired by Paolo Castracane (ESA) and Manik Bali (UMD).

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The GDWG discussed many topics critical to supporting GSICS. Key topics that were discussed included

1. Replacing EUMETSAT's GSICS THREDDS server with the EUMETSAT Data Store
2. Review and update the GSICS documents on WMO website such as GSICS Terms of Reference, Glossary
3. Review the WMO GSICS webpage and restructure GSICS Wiki.
4. Updates from KMA on GPRC and design of LSICS data file by Masaya Takahashi at JMA and implementation of machine readability of KMA and JMA bias on their GPRC
5. RICH-CEOS Data site and GPRC websites by CMA.
6. Maintenance of the GSICS Wiki, THREDDS server, GSICS Product Alert system, GSICS product catalog, Action Tracker and application of Artificial Intelligence in data extraction of data on the GSICS by NOAA
7. ESA (Paolo Castracane) made major contribution towards Development of EVDC, Orbit Prediction and Overpass tool , API that allows users to get a DOI for data made available in the data center. Further ESA contributed towards Development of CEOS CAL/VAL portal and online CEOS-FRM assessment. ESA also participated in pre-flight calibration and characterizations workshop.

The GDWG subgroup will continue to support the GSICS Research working group in ushering in new services, products and deliverables.

The meeting ended with agency reports and a cross-cutting discussion. It was decided that the next (2026) GSICS Annual and EP Meetings would be hosted by the **National Research Council** in Ottawa, Canada.

Presentations and minutes of the Meeting are available at https://gsics.atmos.umd.edu/bin/view/Development/AnnualEP2025
The Actions, Decisions and Recommendations will be published on the GCC website.

Announcements

AOMSUC-15 and FYSUC-2025 to be held in Qingdao, China on Oct 26-31, 2025

By Allen Huang, SSEC, University of Wisconsin-Madison

The 15th Asia-Oceania Meteorological Satellite Users' Conference (AOMSUC-15) will be held in conjunction with the 2025 FengYun Satellite User Conference (FYSUC-2025) in October 2025 in Qingdao, Shandong Province, China. The meeting will be hosted by CMA and CNSA. Details can be found on the conference web page, including the first announcement and the registration information:
The sessions of the AOMSUC conferences are:

1. Space program updates
2. Data access and product generation
3. Forecasting
4. Nowcasting
5. Climate monitoring and applications
6. Belt and Road Initiative with special topics in the typhoon, heavy rain, fire, drought, and disaster
7. Space weather

Please contact fysat701@126.com for VISA support and visit AOMSUC-15 & FYSUC-2025 for more information

GSICS-Related Publications

Jiao, Y.; Zhang, F.; Liu, X.; Huang, Z.; Yuan, J. C-SAR/02 Satellite Polarimetric Calibration and Validation Based on Active Radar Calibrators. *Remote Sens.* **2025**, *17*, 282. https://doi.org/10.3390/rs17020282

Leahy, J.; Jabari, S.; Lichti, D.; Salehitangrizi, A. Enhancing Cross-Modal Camera Image and LiDAR Data Registration Using Feature-Based Matching. *Remote Sens.* **2025**, *17*, 357. https://doi.org/10.3390/rs17030357

Yan, B.; Beck, T.; Chen, J.; Buckner, S.; Jin, X.; Liang, D.; Uprety, S.; Huang, J.; Flynn, L.E.; Wang, L.; et al. Calibration and Validation of NOAA-21 Ozone Mapping and Profiler Suite (OMPS) Nadir Mapper Sensor Data Record Data. *Remote Sens.* **2024**, *16*, 4488. https://doi.org/10.3390/rs16234488

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Zhang, X.; Wang, P.; Xue, W.; Liu, X. Geometric Calibration of Parameters in the Perpendicular-Orbit Circular Scanning Satellite Camera. *Remote Sens.* **2025**, *17*, 472. https://doi.org/10.3390/rs17030472.

Submitting Articles to the GSICS Quarterly Newsletter:

The GSICS Quarterly Press Crew is looking for short articles (800 to 900 words with one or two key, simple illustrations), especially related to calibration / validation capabilities and how they have been used to positively impact weather and climate products. Unsolicited articles may be submitted for consideration anytime, and if accepted, will be published in the next available newsletter issue after approval / editing. Please send articles to manik.bali@noaa.gov.

With Help from our friends:

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