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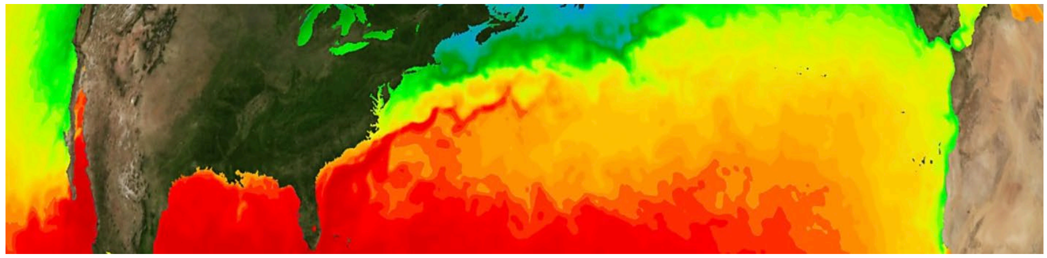

Sea surface temperature (SST) patterns across the North Atlantic. SST has been the test bed for bias aware methods in optimal estimation (See article "Bias Aware SST estimation" By Merchant et al.)

Development of the Chinese Space based Radiometric Benchmark Mission, LIBRA

By Peng Zhang (CMA), Naimeng Lu (CMA), Chuanrong Li (CAS), Lei Ding (CAS), Xiaobing Zheng (CAS), Xuejun Zhang (CAS), Xiuqing Hu (CMA), Xin Ye (CAS), Lingling Ma (CAS), Na Xu (CMA) , Lin Chen (CMA) and Johannes Schmetz (Retired from EUMETSAT)

To provide a space-based radiometric reference for Earth observation from multiple satellite platforms and in order to respond to requirements by the Global Climate Observing System (GCOS), the Chinese Space-based Radiometric Benchmark (CSRB) project has been approved and initially funded by the Ministry of Science and Technology (MOST) in 2014. The project has three phases: Phase A extended from 2014 to 2018 with the goal to develop the SI-traceable calibrator for thermal infrared band (IR), reflective solar band (RSB). Phase B, from 2018 to 2022, has the objective to develop an engineering model of the reference instruments. During Phase C, from 2022 to 2025, the flight model of Chinese radiometric benchmark satellite, named as LIBRA, will be developed and made ready for launch. The roadmap of the CSRB project is shown in Fig. 1.

Up to date, phase A has been completed. The prototypes including an absolute radiance standard IR calibrator based on ITS-90 miniature phase change points, a RSB self-correction absolute calibrator based on Spontaneous Parametric Down-Conversion (SPDC) principle with eight spectral bands spanning 450nm-1000nm, and a cavity-type absolute cryogenic radiometer (ACR) with 20K operational temperature were built, together with the corresponding radiometric scale transfer chains. In this exploratory phase, uncertainties better than 0.15K and 0.3% were achieved for all of the three benchmark calibrators. Based on these promising results, phase B of the CSRB project was started in 2018 and the engineering model development is on-going.

The LIBRA mission consists of one satellite carrying four payloads: an InfraRed Spectrometer (IRS) with hyperspectral resolution, an Earth-Moon Imaging Spectrometer (EMIS) measuring in reflected solar radiation, a Total Solar Irradiance (TSI) instrument,

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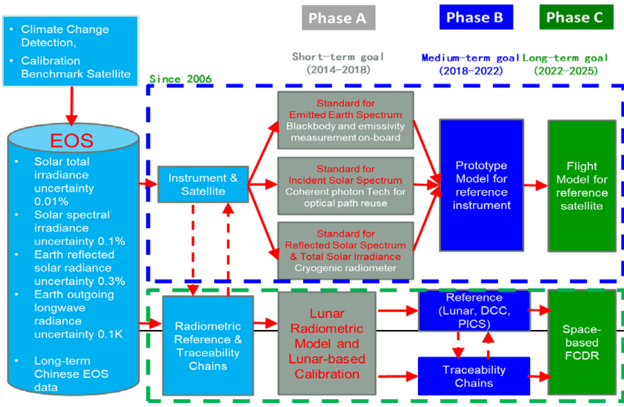

Figure 1. The roadmap of the CSRB project. In the Figure, EOS is the abbreviation of Earth Observation System, DCC is Deep Convective Cloud, PICS is Pseudo Invariant Calibration Sites, and FCDR is Fundamental Climate Data Record.

Satellite	LIBRA				CLARREO		TRUTHS		
Instrument Type*	IR	RS	TS	SS	IR	RS	RS	TS	SS
Spectral Coverage	600-2700 cm^{-1}	380-2350 nm	0.2- 35 μm	380-2500 nm	200-2000 cm^{-1}	320-2300 nm	380-2300 nm	0.2- 35 μm	320-2450 nm
Spectral Resolution	0.5 cm^{-1}	10 nm	--	3 ~ 8 nm	0.5 cm^{-1}	8 nm	5 ~ 10 nm	--	1~ 10 nm
Measurement Uncertainty	0.15K (k=2)	1% (k=2)	0.05% (k=2)	0.35% (k=2)	0.065K (k=2)	0.3% (k=2)	0.1% (k=2)	0.02% (k=2)	0.2% (k=2)
SI traceability	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 1. Comparison among radiometric benchmark satellite.

*In the line 'Instrument type', IR represents the instrument to measure the spectrally resolved infrared radiance, RS represents the instrument to measure the spectrally resolved reflectance of solar radiation, TS represents the instrument to measure the total solar irradiance, and SS represents the instrument to measure the spectrally resolved solar

and a Solar spectral Irradiance monitoring instrument Traceable to Quantum benchmark (SITQ).

A GPS/BD GNSS RO will be an optional instrument depending on the spacecraft bus capability. With an internal mirror, IRS will enable nadir, off-nadir, internal calibration, and deep-space (zenith) observations. The EMIS and TSI will be co-boresighted and mounted to a two-axis gimbal to enable nadir (nominal operations) and off-nadir Lunar and Solar observations.

The LIBRA experimental observatory has been designed for an operational lifetime of 5 years with consumables for 8 years. The follow-up operational satellites will be designed for a long-term mission (20 years or more) with satellites in orbit overlapping in time. Other potential platforms considered for the LIBRA mission include the Chinese Space Station (CSS) as an instrument platform and independent small satellite missions with only one SI instrument. Lagrangian orbit locations are also investigated for complementary observations.

As a space-based climate and calibration observatory, the proposed CLARREO and TRUTHS missions have important potential contributions to make both directly through well-calibrated measurements and indirectly through facilitating inter-calibration of the data from other platforms. By using advanced technologies, such as phase change points, a cryogenic absolute radiometer and spontaneous parametric down-conversion (SPDC), LIBRA will provide measurements with SI traceability for both the IR and the reflected solar component. As a summary, the main characteristics of LIBRA, CLARREO and TRUTHS are listed in Table 1.

In the calibration mode, LIBRA will be considered as the reference satellite to inter-calibrate the target satellite with radiometric traceability. Inter-calibration and the radiometric transfer from LIBRA to other satellite require the measurements from two spacecraft are taken along similar lines of sight, and within a few minutes of each other. Similar techniques are currently used for inter-calibration of orbiting satellite sensors as part of GSICS, an international effort to improve the consistency and accuracy of satellite inter-calibration. LIBRA would serve the international community by inter-calibrating other Earth-observing instruments. The following models are the possible standard transfer methods from LIBRA reference instruments.

As a complementary project to the CLARREO and the TRUTHS, the LIBRA is expected to join into the Earth observation satellite constellation which will create a cooperated space-based climate and calibration observatory. Inter-calibration of data from space-based observation falls Working Group on Calibration and

Table 2. Products to support inter-calibration with radiometric traceability

Instruments	Products	Inter calibration Method
IRS	Spectral resolved infrared radiance	Quasi-synchronous inter-calibration*
		LEO-LEO SNO
		GEO-LEO SNO
EMIS	Spectral resolved reflectance of solar radiation	Quasi-synchronous inter-calibration*
		LEO-LEO SNO
		GEO-LEO SNO
	Selected DCC reflectance	DCC
	Selected PICS reflectance	PICS
	Selected Lunar reflectance	Lunar

** Quasi-synchronous inter-calibration transfer mode by orbital maneuver: LIBRA will be operated such that its sub-satellite track is close and overlaps the track of the satellite to be inter-calibrated. The inter-calibration is carried out near real-time in the nadir zone.*

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Validation (WGCV) and GSICS. The intensive cooperation with WGCV and GSICS is highly recommended during the instrument development and data utilization of the LIBRA.

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Bias-aware optimal estimation

By Christopher J. Merchant (University of Reading, UK)

Improving the calibration of a satellite-borne sensor and retrieving geophysical information from that sensor's radiances are generally considered separately. But there may be merit in addressing these problems jointly.

Jointly quantifying sensor calibration and the observed geophysical state can be tackled by turning *optimal estimation* (a formulation of retrieval) into *bias-aware optimal estimation* (BAOE).

The first step is to expand the list of retrieved variables beyond geophysical quantities to include sensor calibration parameters. This expanded retrieval is solvable by also expanding the observed variables with reference data. Reference data are not assumed to be error free, but should be negligibly biased overall. Of two papers describing BAOE [1,2], one uses as a reference in situ data, the other, satellite data.

In the latter example, calibration adjustments for the infrared channels of the Advanced Very High Resolution Radiometer on Metop-A (AVHRR-A) were inferred with reference to sea surface temperature (SST) from the Advanced Along-Track Scanning Radiometer (AATSR) and the Sea and Land Surface Temperature Radiometer (SLSTR). We used matches of the AVHRR-A to AATSR from early in the AVHRR-A's mission, and to SLSTR from late in its mission. Similar AVHRR-A calibration adjustments were obtained from both reference sensors. This suggests that AATSR and SLSTR have compatible calibration, while AVHRR-A provides a stable bridge across the intervening gap of more than four years.

BAOE works as follows. For each match, we have as observations (1) the sensor radiances, and (2) the reference measurement of the geophysical quantity. The sensor radiances "respond" to the sensor calibration and to the geophysical state observed. The quantities to be retrieved are the geophysical state and the sensor calibration parameters. The latter could comprise external calibration corrections or parameters within the calibration equation ("recalibration" [3]). The optimal estimate (OE) yields a better estimate of the geophysical state and refines the calibration parameters. Repeated many times across many matches, the calibration parameters converge.

The converged solution is optimal (i.e., is the best estimate) only if the error covariances used in the OE are well estimated. Estimating error covariance matrices for OE is a long-standing problem in its own right. Often simplistic assumptions are made. BAOE repurposes equations from bias-aware data assimilation [4] to re-estimate (given the newly adjusted calibration) the observation and prior error covariances (fig. 1). With iteration, the system of parameters converges, and the final estimates of the calibration parameters are obtained.

Next, let me point out some strengths and limitations of BAOE, describe possible extensions relevant to GSICS, answer a question, and plea for clemency.

Strengths. (1) Since the reference data may be in situ measurements, BAOE provides a systematic means of using

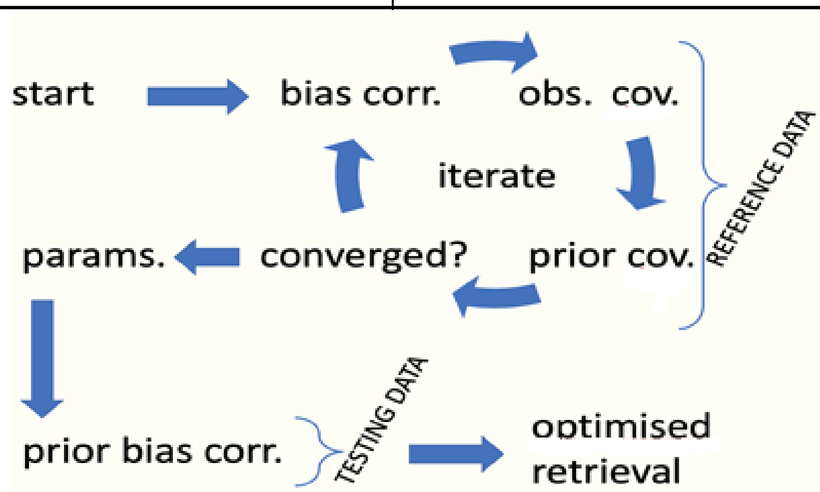

Figure. 1 A procedure for BAOE: bias correction of satellite calibration relative to a forward model ("bias corr."); estimation of the observation error covariance matrix ("obs. cov.") and prior error covariance matrix ("prior cov."). After convergence to a stable set of results ("params."), further elements of prior bias may also be inferred, and the parameters can be tested on independent data.

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reference measurements on Earth to constrain the calibration of sensors in space. (2) New estimates are also found for: the uncertainty of the reference data; the uncertainty of the satellite observations, and their cross-channel error correlations, and thus their observation error covariance; the error covariance of the prior state; and a bias correction for the prior state in locations with no matches. These can all be found as functions relevant state and instrument parameters. This is a very powerful set of information for improving geophysical retrievals.

Limitations. (1) The calibration parameters are not pure: although anchored to the reference data, they are also obtained relative to the radiative transfer simulation. The calibration parameters correct the bias in simulation-minus-observation, not that of the instrument alone. We can nonetheless use the results for geophysical retrieval because OE "responds" to the difference between the observation and the simulation. (2) Although BAOE is robust and objective, there is judgement in choosing the parameterisation of bias adjustments and error covariances.

Possible extensions. BAOE has been applied to a single pair of sensor and reference data. Extension of the concept to systems of sensors and multiple sources of reference to obtain sets of mutually consistent inter-calibration is plausible, the main challenge being the book-keeping of the larger optimisation.

How does BAOE differ from "bias-aware data assimilation" within a numerical weather prediction system? Biases associated to satellite observations within such systems include some model bias: attribution of bias to the satellite radiances is done so as not to perturb too greatly the dynamical model. While in BAOE there is mixing of instrument and radiative transfer biases, the reference data are chosen to have low bias; thus, the calibration is aligned to an objective reference, rather than to the time-varying preferred state of a dynamical-assimilative model.

Finally, a plea for clemency. Woolliams et al. [3] carefully linked "recalibration" and "harmonisation", nomenclature I fully support. But I carelessly entitled [2] as "Harmonisation ...", despite the paper being about "external" calibration corrections. *Mea culpa*.

Conclusion

New estimates for sensor calibration parameters can be obtained by extending optimal estimation to include these parameters as retrieved quantities, while anchoring retrievals to in situ or satellite references. Many other informative parameters for retrieval are also obtained. The iterative approach is conceptually applicable for inter-calibrating systems of many sensors in space.

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The moon as a diagnostic tool for the High-resolution Infra Red Sounder

By Martin Burgdorf (Universität Hamburg, Hamburg, Germany), T. Müller (Max-Planck-Institut für extraterrestrische Physik, Garching, Germany), S. A. Buehler and M. Prange (Universität Hamburg, Hamburg, Germany)

The High-resolution Infra Red Sounder (HIRS) is part of the ATOVS sounding instrument suite (Advanced TIROS [Television and Infra-Red Observation Satellite] Operational Vertical Sounder) since 1975. Three more generations followed, numbered HIRS/2, /3, and /4, with the latest version still operational at the time of writing. In spite of its long service, however, there is considerable disagreement among the values given even for quite fundamental properties of this family of instruments in books (e.g. Cracknell, 1997), reports (e.g. Koenig, 1979), and websites (e.g. ESA or WMO, 2016). We have used appearances of the Moon in the deep space view (DSV) of HIRS to establish, correct or consolidate various performance parameters (Burgdorf et al., 2020). The signal obtained from such an event is shown in Figure 1. A linear relationship between counts and flux density was derived from the signal obtained from space, before and after the Moon intrusion, and the internal calibration target. This relationship was used to calculate the radiance of the Moon in each channel of HIRS (Labrot et al., 2019)

Optical Field of View: As the Moon, unlike the cold and warm calibration targets, does not fill the field of view (FoV) of HIRS, its calculated radiance depends on the solid angle seen with this instrument. By measuring the radiance of the Moon with different instruments, we could therefore settle the question, whether the diameter of the FoV is the same for HIRS/2 and HIRS/3 and for long-wave and shortwave channels. We found the diameters of the field of view of HIRS/2, HIRS/3, and HIRS/4 to be 1.4°, 1.3°, and 0.7°, respectively, with all channels.

Spectral Channels Co-registration: Sometimes, when the Moon enters the deep space view of HIRS, it is never fully included in the FoV, not even in the moment of closest approach to the pointing direction. This closest approach corresponds to the time when the number of counts in the light curve reaches its minimum, because HIRS produces less counts for more flux. Hence if the minimums of the light curves from different channels do not happen at the same moment in time, this finding betrays a misalignment of the channels in the along-track direction. We derived a linear relationship between the central wavelengths of the channels and their displacement. This relationship is different for shortwave and long-wave channels, but in either case larger wavelength means larger shift in the flight direction.

Inter-Channel Uniformity: The wavelengths of the sounding channels 1 - 7 differ at most by 1.5 μm (EUMETSAT, 2017). As they are so similar, and the emissivity of the Moon changes only very little in this range, its brightness temperature measured with these channels can be used to search for inconsistencies in their flux calibration. We found that such discrepancies among the channels must be smaller than approximately 1%.

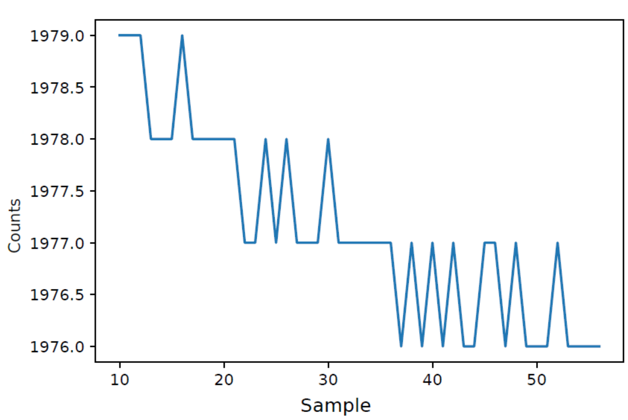

Figure 1: Plot of the signal from all measurements of the space radiance performed by HIRS/3 on NOAA-17 on 2002-09-26 at 7:01 UTC. The pointing approached the Moon during the calibration procedure until it was fully included in the field of view after sample 35.

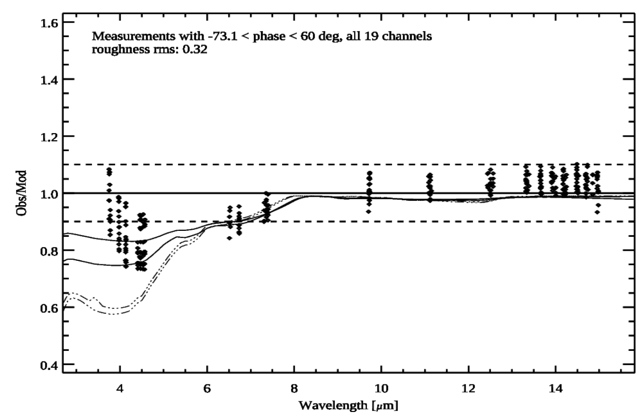

Figure 2: The HIRS measurements of the Moon divided by our TPM predictions (assuming a constant hemispherical emissivity of 1.0 and without reflected light contributions). A few emissivity spectra are shown for comparison (https://speclib.jpl.nasa.gov/library): two extreme values for the Lunar Maria (solid lines) and also for the Lunar Highlands (dashed-dotted lines). The HIRS data are well explained by the Maria spectra, except at short wavelengths where reflected sunlight is seen by the short-wavelengths HIRS channels.

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Non-Linearity: The sub-solar region of the Moon reaches surface temperatures of almost 400 K. Hence the shortwave channels of HIRS/4 receive much higher fluxes from the full Moon, when it is present in their DSV, than from Earth. We took advantage of this peculiarity when we derived an upper limit for the non-linearity by comparing the radiance measured with different versions of HIRS. HIRS/2 is here the perfect reference, because the solid angle of its FoV is four times larger than with HIRS/4. In this case the internal calibration target provides approximately the same flux as the Moon, and as a consequence the non-linearity term in the measurement equation becomes very small. Again we could find no anomalies and conclude that non-linearity can be neglected in calibration, at least for the shortwave channels.

Comparison with a Model: The HIRS measurements of the Moon provide absolute fluxes of the entire Moon (seen over a wide range of phase angles) in 19 channels, covering the wavelength range from 3.8 to about 15.0 μm. These values can be compared to a thermophysical model (TPM) of the Moon, which is based on the known global thermal and other physical properties, see Figure 2.

Critical model quantities are the Moon's surface roughness, its hemispherical spectral emissivity, and the true viewing geometries based on the position of the satellite as included in the raw data. The final TPM absolute flux predictions agree within 5-10% with the HIRS data over phase angles from -70° (waxing Moon) to +60° (waning Moon). At wavelengths below about 4.2 μm (channels 17, 18, and 19) reflected Sun light contributes to the observed fluxes and a small (non-thermal) flux excess is measured. The Moon's (global) spectral emissivity in the HIRS range is dominated by the darkest spots, i.e., the large, dark, basaltic Maria plains. At very extreme waning phases of the Moon (≥+60°) there are indications from our TPM analysis for higher surface roughness values. More intrusions of the Moon in the DSV of HIRS need to be analyzed to dissent inter-satellite calibration issues from shortcomings in the TPM and small changes in the Moon's effective properties for different aspect angles.

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Radiometric Cross-Calibration for Multiple Sensors with the Moon as an Intermediate Reference

By Lu Zhang (CMA), Peng Zhang (CMA), Xiuqing Hu (CMA), Lin Chen (CMA), Min Min (SYSU), Na Xu (CMA) and Ronghua Wu (CMA)

For satellites without onboard calibration systems, the instrument can be calibrated through comparisons with other reference instruments. This technique is typically referred to as cross-calibration. For solar reflective bands, the cross-calibration processing must consider different relative spectral responses (RSRs), different viewing, or illuminating geometries of the target, and many other factors (Kieffer and Stone, 2005; Chander et al., 2013a). Chander et al. (2013b) grouped the methods and measurements involved in sensor radiometric cross-calibration into a number of categories. We focus on radiometric cross-calibration using lunar observations. The change of the lunar irradiance is about 1% in a 1.4-giga year (Gyr) period (Kieffer, 1997). The moon is neither strongly colored nor strongly variegated in color, and it is surrounded by a black field (Kieffer, 1997) and is thus a suitable candidate for use in calibration.

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There are two popularly used lunar irradiance models: the Robotic Lunar Observatory (ROLO) model and the Miller–Turner (2009) (MT2009) model (Miller and Turner, 2009)). The ROLO model was developed by the United States Geological Survey and was used as a standard for calibration in the wavelength ranging from 350 to 2500 nm. The MT2009 used the moon as a source of visible radiation for nighttime sensing of the earth's atmosphere and surface. It covered 202–2800 nm (Kieffer and Stone, 2005; Miller and Turner, 2009). These two models express the lunar reflectance as a function of viewing and illumination geometry, and the uncertainties of ROLO model (311g version, implemented by ourselves, based on Kieffer et al.,2015) model and MT2009 are 5%–10% and 7%–15%, respectively (Kieffer and Stone, 2005; Miller and Turner, 2009; Shao et al., 2014). Since it is difficult to use the current lunar model as an absolute calibrator, the lunar model is commonly used as an intermediate reference for cross-calibration (Wang et al., 2011).

A lunar calibration method is proposed to cross-calibrate the sensors among satellite instruments. The ROLO model (version 311g) is used as an intermediate reference to bridge the instrument calibration. To reduce the errors from the difference of RSRs and the lunar observation geometry, we use the reflective spectrum of the Apollo sample to compensate for the difference in the instrument RSRs and the double ratio between the observed and the simulated lunar irradiance.

The details of the **Spectral band adjustments (SBA) using scaled lunar reflectance** are shown in Lu Zhang et al. (2019). Here, we just show the result of reflectance differences between the Moderate Resolution Imaging Spectroradiometer (MODIS) and Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) with and without an SBA. In Fig. 1, the black dashed line with asterisks indicates a direct comparison between the SeaWiFS and MODIS without the SBA, and the black solid line with rectangles corresponds a comparison with the SBA. Except for bands 2 and 8 of the SeaWiFS, the reflectance differences between these two instruments have been clearly reduced with the SBA. This method can also be used to simulate the new channels, which the reference instrument did not cover. For example, SeaWiFS bands 4 (410.3 nm) and 7 (767.80 nm) were not covered by the MODIS (red rectangle in Fig. 1.). To correct the impact of the lunar observation geometry, the "double difference" method is proposed to bridge the gap in the viewing geometry between the two instruments (Chander et al., 2013c). In this paper, another similar method called the "double-ratio" method is also proposed as a comparison. The error analysis are shown in Zhang et al. (2019), here we just show the result of the comparisons.

The lunar irradiance was measured by MODIS at 2000-03-24T20:21:31Z from the lunar phase angle of 54.70° and was chosen as a radiometric reference while the lunar irradiances of the other 42 samples in the MODIS were used to evaluate the Methods. The calibration difference between the double difference and double ratio (Zhang et al., 2019) are shown in Table 1.

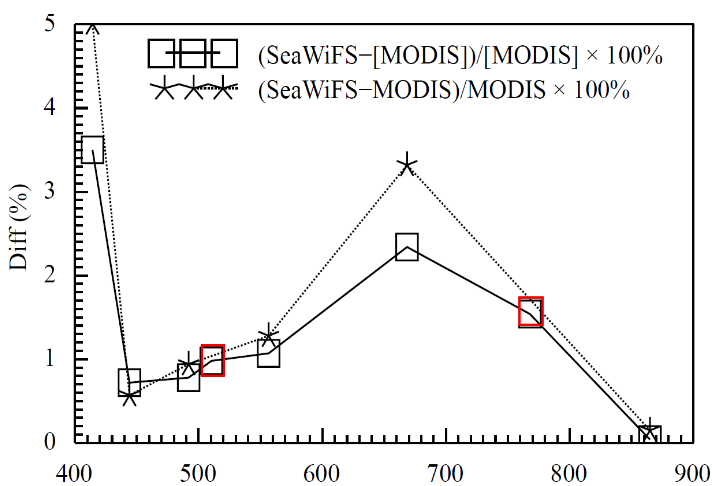

Figure. 1 The difference between the SeaWiFS and MODIS before and after SBA application.

	ROLO model		MT2009	
MODIS band	Difference double difference ; %	Difference double ratio"; %	Difference double difference"; %	Difference double ratio"; %
1	2.163±0.012	2.150±0.012	4.101±0.082	3.988±0.065
2	2.195±0.012	2.183±0.013	4.120±0.103	4.040±0.074/
3	2.209±0.012	2.198±0.013	5.413±0.772	5.300±0.823
4	2.208±0.013	2.182±0.013	4.876±0.523	3.549±0.413
8	2.368±0.014	2.290±0.013	5.618±0.154	4.998±0.080
9	2.194±0.012	2.000±0.012	5.351±0.132	5.002±0.992
10	2.167±0.012	2.141±0.013	4.128±0.922	3.473±0.847
11	2.237±0.014	2.208±0.014	4.057±0.744	3.216±0.649
12	2.197±0.013	2.151±0.013	4.124±0.853	3.240±0.745
17	2.362±0.016	2.197±0.012	4.980±0.976	4.677±0.823
18	2.433±0.017	2.160±0.011	4.774±0.904	4.549±0.671
19	2.465±0.017	2.154±0.012	4.143±0.077	3.786±0.062

Table 1 . The calibration difference between the double difference and double ratio methods

As shown in Table 1, the lunar phase angle ranges from 50.93° to 55.60°. In addition, the ROLO model and MT2009 are used as intermediate references. For the double ratio method used in the ROLO model, the minimum relative difference is 2.00% in band 9 and the maximum is 2.30% in band 8. The average relative difference is 2.20%. For the double difference method, the minimum difference is 2.20% in band 10 and the maximum is 2.50% in band 19. The average relative difference is 2.30%. When the MT2009 model is used, the error in the double ratio method is also less than the double difference method. The results show that the double ratio method performs better than double difference approach. Since the double difference error relies on the combined accuracy of the lunar model and the reference instrument while the double ratio error primarily results from the accuracy of the reference instrument. In addition, the double ratio and double-difference approaches within ROLO perform better than they do with MT2009 since the ROLO has better model accuracy.

Summary

The lunar irradiance of MODIS, SeaWiFS are used to check the methods. It is shown that the mean difference between MODIS and SeaWiFS is less than 3.14%.

Inconsistent RSRs and the difference in lunar observation geometry can have a great effect on the cross-calibration of different sensors and their long-term characterization. When comparing the double difference and double ratio, the uncertainty of the benchmark instrument is less than that of the intermediate reference, and the intermediate reference has a good consistency; the double ratio method is thus better than the double difference approach. When the uncertainty of the intermediate reference is large, the double difference can amplify the uncertainty of the cross-calibration, and the double ratio performs better. Moreover, the lunar viewing and illumining geometry is closer, and the double ratio error becomes smaller. In general, the double ratio performs better than the double difference.

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NEWS IN THIS QUARTER

21st GSICS Executive Panel Meeting (GSICS-EP-21) held via web

By Mitch Goldberg (NOAA), Kenneth Holmlund (EUMETSAT), Werner Balogh (WMO), Lawrence Flynn (NOAA), Manik Bali (NOAA), Kamaljit Ray (IMD), Scott Hu (CMA) and Dohyeong Kim (KMA)

The 21st Session of the Global Space-based Inter-Calibration System Executive Panel (GSICS-EP-21) was held as an online meeting on 18 and 19 May 2020, prior to the Working Group meetings of the Coordination Group for Meteorological Satellites (CGMS) at CGMS-48.

The meeting was organized by WMO with support from EUMETSAT/CGMS Secretariat (hosts) and the GSICS Coordination Center at NOAA.

There were 31 participants. This included EP members from 13 GSICS member agencies, members of WMO secretariat, GSICS Coordination Center, and Chairs of GSICS Groups and Subgroups.

The meeting agenda proposed by the EP-Co-Chair and WMO was approved by the meeting attendees. The EP welcomed Mr. Kazutaka Yamada as a new member of GSICS EP from JMA and approved the nomination of Ms. Kamaljit Ray (IMD/Ministry of Earth Sciences) as the new Chair of the GSICS Data Working Group (GDWG).

A.GEP.20200519.15: GSICS-EP members to review membership of GSICS-EP at https://gsics.wmo.int/en/focal-points and to notify WMO, of any changes

On the main agenda were key items regarding decisions, endorsements and guidance from the EP on topics related to in-orbit monitoring of meteorological satellites by member agencies, GSICS's connection with user community (e.g., ISCCP-NG) and discussions and decisions on strengthening the connection with WMO observing system groups (CEOS, GCOS, and WIGOS). Some of the items that were covered are described below.

Werner Balogh (WMO Secretariat) led off the meeting discussions with a presentation on the reforms taking place within WMO and how these developments impacted activities of GSICS. He noted that it was important for GSICS to be represented in the new working structures established under the WMO Constituent reform, to ensure that GSICS was well integrated with other activities contributing to the WMO Integrated Global Observing System (WIGOS). Subsequent to the meeting, Lawrence (Larry) Flynn, Director of the GSICS Coordination Centres, was appointed a Member of the WMO Standing Committee on Measurements, Instrumentation and Traceability (SC-MINT).

A.GEP.20200519.4: Further discussions needed to ensure that GSICS activities are well integrated with WIGOS and the WIGSO Data Quality Management System (WDQMS). Werner and Manik Bali to prepare white paper and present in EP-22

A.GEP.20200519.2: Work with WMO Space Programme Office to ensure that GSICS documents describing the links to WIGOS are updated (see https://gsics.wmo.int/en/product-services-and-technical-information).

In response to (A.GEP.20190517.4 and SWCG/9) Ken Holmlund (member Space Weather Task Force for Inter-Calibration of High Energy Sensors) provided a brief overview of space Weather activities and how the activities can benefit (are linked) to GSICS inter-calibration, for example, the impact of space weather events on Satellite monitoring. A White Paper submitted by the Co-Chair of the SW Task force, Tsutomu Nagatsuma, was provided for review, and he was requested to present a final version to the CGMS-49.

A.GEP.20200519.13: GSICS to review the white paper by Nagatsuma San before end of June.

The next report was in response to (A.GEP.2020.1f.1), Mitch Goldberg went over Andy Heidinger's (ISCCP-NG member) presentation. The Executive Panel members in attendance recognized this as a key initiative that will drive GSICS activities over the next three years as ISCCP-NG is viewed as a user of GSICS products and algorithms. GSICS expects to provide a system to monitor calibration of all VIS+IR channels of all GEO imagers from 2023 onwards & develop corrections if necessary. Andy had pointed out that GSICS and ISCCP-NG need each other's expertise to excel.

A.GEP.20200519.17: Andy to coordinate with VIS and IR GRWSG to discuss the next steps for the GSICS – ISCCP collaboration.

Larry Flynn (Director GCC) provided an overview of GSICS Coordination Center (GCC) activities. He first gave an overview of meetings organized and supported by GCC, publication of GSICS Quarterly Newsletters in the past year and GSICS Membership status. EP was also informed of new initiatives undertaken which include: 1) Setting up the GSICS Listserv, 2) New features in the GSICS Action Tracker, and 3) The migration of the GSICS Wiki to a new server dedicated to the GSICS activities at the University of Maryland. Larry

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thanked the EP, GPAT members and reviewers for enabling the acceptance of six new products to the GSICS product catalog via the GPPA. He sought EP guidance on interaction of GSICS with the SmallSat community and interaction with WIGOS and the 3G community. Discussion resulted in following Action:

A.GEP.20200519.16: Mitch and Ken to contact Small Sat community and support GSICS participation in JACIE and AMS Small Satellite sessions   Mitch to send an email to Phil Ardeno who is organizing a Small Sat conference in AMS.

Xiuqing (Scott) Hu/Dohyong Kim (GRWG Chairs) gave overviews of the GSICS research activities. This included the status of Actions, recent and upcoming meetings and the overview of key tasks performed by each subgroup (MW, IR, VIS/NIR and UV).
Scott also provided a summary of GSICS product status and their maturity. Scott mentioned that most of the meetings this year have been either postponed for next year or were converted to web meetings. Members should stay tuned for announcements on these meetings via the GSICS listserv.
Likun Wang (IR Subgroup Chair) presented the main activities of the IR subgroup, status of actions, status of GEO-LEO products and provided a range of future directions. The IR subgroup made major contributions towards Development of NWP intercalibration methods, Development of GUAN Radiosonde Intercomparisons, Collocation Improvements, and had Interactions with other groups – SI traceability workshop & ISSCP-NG,
The summary of Microwave subgroup activities was presented by Qifeng Lu (CMA). Qifeng reported that MW subgroup had regular web meetings on topics related to Microwave instrument calibration. The main achievements were to introduce RTM references and double difference for Vicarious calibration, acceptance of in-orbit references and its connection with CEOS Working Groups and the 3G (GSICS- GRUAN and GNSS) group.

A.GEP.20200519.5: EP recommended the chairs and members of IR, VIS, and reflected solar for internal review of Manik's white paper on MW reference.

Dave Doelling (Chair VIS/NIR) provided an overview of the VIS/NIR subgroup activities. The GSICS VIS/NIR calibration strategy ilooks for agreement amongst multiple independent calibration methods (Earth invariant targets, lunar, inter-sensor). The VIS/NIR subgroup has designated NOAA-20 VIIRS as a GSICS reference. The VIS/NIR will be documenting the GEO DCC calibration paper and will extend DCC to all GEO across the agencies thereby creating a DCC calibration opportunity all along the equator. Dave also provided status of CLARREO and interaction with ISSCP-NG. Dave mentioned a novel re-calibration approach that would optimize recalibration process dramatically by providing components of the re-calibration process to users which they can execute at their data. .
Rosemary Munro (Chair UV/Reflective Solar Bands) provided an overview of the GSICS activities in the Solar bands (mainly UV bands). She mentioned that the subgroup focuses on calibration of spectrometers whose purpose is to measure trace gases (Ozone and other GHG's). Collectively, the group is working on calibration of OMS, SBUV, OMPS, GOME,SCIAMACHY, GOME-2, OMI, Sentinel-5 Precursor, Sentinel-5, Sentinel-4, GEMS, TEMPO, EMI, GOSAT, OCO-2 &- 3, TanSat, and Copernicus CO. EUMETSAT is leading a white paper on ground based characterization. The UV Solar Reference project is led by Larry Flynn at NOAA. Larry suggested the UV subgroup to connect with the Korean GEMS since it is the only GEO instrument taking UV measurements (for the first time underflights can be made) to trigger more activity in the subgroup. There is a GEMS science meeting planned before the quadrennial ozone symposium and members should participate in it.
Following the Group reports, GPRC reports were presented by all the participating agencies and showed the progress made in using GSICS-formulated best practices in monitoring their instruments, creating FCDR's and ensuring that GSICS reference and transfer targets are exploited to the fullest in achieving high quality instrument monitoring.

A.GEP.20200519.14: Mitch to follow up with DOD to check the planned location of GOES-13 over an Indian Location.

A.GCC.20200519.7: GCC to edit/publish a special issue of the GSICS Quarterly on the State of Observing System.

The GPRC reports were followed by the state of observing system report presented by JMA. The report summarized the performance of instruments across GSICS members in terms of mean bias, standard deviation and time series over the past year. GPRC's were encouraged to work with GRWG to help reprocess their measurement records.
Mitch Goldberg, highlighted the State of Observing System Report. The report provided an overview of the status (biases/offsets/anomalies) of satellites across GSICS member agencies. Overall the satellites are performing as per agencies requirements and it is envisaged GRWG collaboration would help monitor instruments in a harmonized way. GSICS also reviewed the High-Level Priority Plan (HLPP) and suggested the inclusion of two new HLPP targets.
GSICS-EP-21 meeting presentation and related documents are available at **https://community.wmo.int/meetings/gsics-ep-21**

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Announcements

Microrad, IGARSS, AGU, and AMS conferences go online; AOMSUC and Lunar Workshop postponed until 2021

By Vinia Mattioli (EUMETSAT) and Manik Bali (NOAA)

IGARSS (International Geoscience and Remote Sensing Symposium)

The new dates of IGARSS 2020 are from 26 September to 2 October 2020. The registration fee is reduced and applied to presenters. The fee for general attenders to the meeting has also been reduced to a small contribution. The IGARSS 2020 technical program will include specific sessions on Missions, Sensors and Microwave radiometer Calibration and RFI. Further information is available at the conference web site: https://igarss2020.org/

MicroRAD (Microwave Radiometry and Remote Sensing of the Environment)

The 16th meeting on Microwave Radiometry and remote Sensing of the Enviroment (MicroRAD 2020) will be moved to a completely virtual event, organized by the Centro di Telerilevamento a Microonde (CETEM) and the Instituto di Fisica Applicata (IFAC-CNR) in Florence, Italy. The Meeting Dates are 16-20 November, 2020. The registration fee is reduced and applied only to presenters. The participation to the meeting will be open to everyone and free. Details on the event can be found at the Meeting Webpage: http://www.microrad2020.it/

AGU (American Geophysical Union) Fall 2020

AGU FALL MEETING
Online Everywhere | 1–17 December 2020

The AGU Fall Meeting continues to be the global convening meeting for the Earth and space sciences community however, this year, it would be a fully online. With more than 1,000 sessions as well as hours of networking and poster hall time, all of them will be scheduled to work for multiple time zones around the world. Content will also be live and on-demand so you can watch (or binge) at your convenience. The most updated information can be found on the meeting website https://www.agu.org/fall-meeting

American Meteorological Society

AMS101
101st Annual Meeting
New Orleans | 10–14 January 2021

The annual meeting will occur on 9-14 January 2021 and will be convened virtually due to the COVID-19 pandemic. The most update-to-date information can be found at https://annual.ametsoc.org/index.cfm/2021/about-the-meeting/

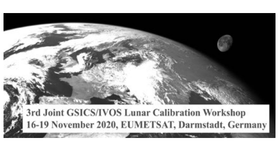
From a GSICS standpoint, this is an exciting platform to discuss Satellite calibration topics. Mitch Goldberg (GSICS EP Chair) and Ken Holmlund (GSICS EP ViceChair) are co-chairs of the AMS Committee on Satellite Meteorology, Oceanography and Climatology (SATMOC). The SATMOC committee coordinates four conferences and symposiums related to environmental satellite data observations and applications, with each having their own area of interest and focus. Details on SATMOC can be found at SATMOC

Asia Oceania Meteorological Users Conference

AOMSUC-11

Due to the Covid-19 pandemic, and after consultation with CMA it has been decided to postpone the Eleventh Asia Oceania Meteorological Satellite Users' Conference (AOMSUC-11) until the Fall of 2021. AOMSUC-11 will be sponsored and hosted by CMA.

3rd Lunar Workshop 2020



Due to the current situation with the Coronavirus, it has been decided to postpone the 3rd Joint GSICS/IVOS Lunar Calibration workshop to 2021. We are currently investigating the possibility and the feasibility of organising dedicated interim web meetings in November 2020 in order to maintain close interactions within the Lunar Calibration Community and to prepare the 2021 workshop. The scope and duration of those meetings are still to be discussed and confirmed. Updates on the workshop can be found at **workshop page**

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2020 IASI Conference Cancelled

By Tim Hewison, EUMETSAT

CNES and EUMETSAT regret having to inform you that due to the ongoing COVID-19 restrictions the next IASI conference cannot take place in November 2020 as planned. We are currently looking for alternative dates in 2021 and will issue a new call for papers in due time.

GSICS-Related Publications

Angal, A., X. Xiong, and A. Shrestha. 'Cross-Calibration of MODIS Reflective Solar Bands with Sentinel 2A/2B MSI Instruments'. *IEEE Transactions on Geoscience and Remote Sensing* 58, no. 7 (2020): 5000–5007. https://doi.org/10.1109/TGRS.2020.2971462.

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Stone, T.C., H. Kieffer, C. Lukashin, and K. Turpie. 'The Moon as a Climate-Quality Radiometric Calibration Reference'. *Remote Sensing* 12, no. 11 (2020). https://doi.org/10.3390/rs12111837

Chu, Mike, and Menghua Wang. 'The Two-Year Radiometric Evaluation of Sentinel-3A OLCI via Intersensor Comparison With SNPP VIIRS'. *Ieee Transactions on Geoscience and Remote Sensing* 58, no. 7 (July 2020): 4494–4500. https://doi.org/10.1109/TGRS.2019.2938974.

Mizuochi, H., S. Tsuchida, K. Obata, H. Yamamoto, and S. Yamamoto. 'Combination of Cross-and Inter-Band Radiometric Calibrations for a Hyperspectral Sensor Using Model-Based Spectral Band Adjustment'. *Remote Sensing* 12, no. 12 (2020). https://doi.org/10.3390/rs12122011.

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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.

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With Help from our friends:

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