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The potential of deep convective clouds for vicarious calibration of Geostationary UV/VIS hyperspectral spectrometer

By Y. Lee, M.-H. Ahn and M. Kang, Ewha Womans University

The possibility of vicarious calibration with deep convective clouds (DCCs) is evaluated for the first geostationary ultraviolet and visible (UV/VIS) spectrometer, the Geostationary Environment Monitoring Spectrometer (GEMS). DCCs are well known calibration targets for VIS and infrared (IR) channels of meteorological imagers and they are one of the few calibration targets sufficiently observed within the field of regard (FOR) of GEMS. The possibility for calibration is closely related to the fact that the backscattered radiation from DCCs should be pseudo-invariant and uniform enough to represent sensor characteristics, especially in the UV/VIS spectral range. For the investigation, the underlying process detecting DCCs is addressed in [1] and here we provide an overview of the detection approach and important findings in the study.

GEMS is the first UV/VIS spectrometer onboard a geostationary orbit with the Geostationary Korea Multi-Purpose Satellite 2B (GK-2B) launched in February 2020 [2]. Before the launch, the applicability was evaluated with the Tropospheric Monitoring Instrument (TROPOMI) and Ozone Monitoring Instrument (OMI) of which the spectral range is similar with the GEMS. The conventional DCC detection approach for meteorological imagers is based on the brightness temperature and its spatial homogeneity of a scene along with observation angles [3], [4]. To incorporate the demonstrated detection conditions, the band 1 and 13 (0.47 and 10.4 μm, $R_{0.47}$ and $BT_{10.4}$) of the Advanced Himawari Imager (AHI) onboard Himawari-8 are used after collocation processes with OMI and TROPOMI.
The apparent reflectivity of DCCs is calculated as the ratio of measured Earth radiance to solar irradiance with the optical path length and Rayleigh scattering corrections [1]. The reflectivity of DCCs with the conventional detection method ($BT_{10.4} < 205$ K) shows a significant variability (in terms of standard deviation) and the variability is especially large at shorter wavelengths closer to 300 nm. The results confirm that the collected DCCs consist of clouds having disparate reflective properties (probably due to the optical depth and/or cloud coverage) which would make it hard to obtain consistent signals in the UV/VIS spectral range. As shown in Fig. 1, the detected DCCs seem to be near the cloud centers having homogeneous brightness temperature but showing a large variability in the AMI $R_{0.47}$. From the findings, cloud properties are investigated further for updating the DCC detection conditions in the UV/VIS spectral range.

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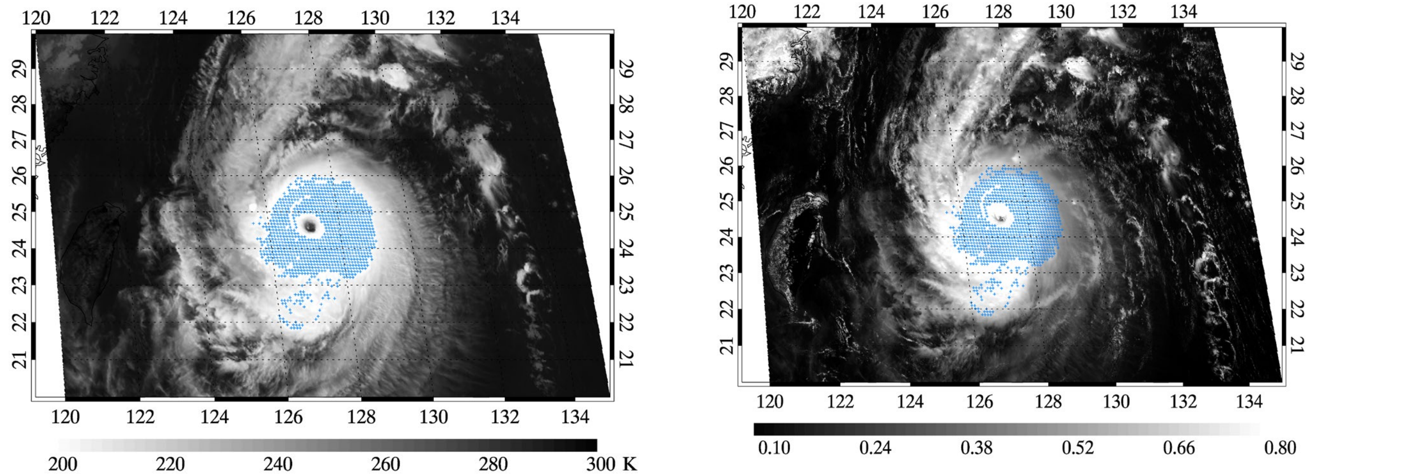

Figure 1. The detected DCCs represented by blue dots with the IR threshold methods. They are well correlated with (a) the AHI $BT_{10.4}$, while significant inhomogeneities are clearly visible in (b) the reflectance (AHI $R_{0.47}$). Both images show Typhoon Chaba on 3 October 2016 03:30 UTC.

The applied DCC detection largely determines general cloud properties such as the cloud optical thickness and cloud top height (see Fig. 2). In summary, the IR condition helps detect higher clouds which means without the information, very bright but low clouds are collected together of which the measured radiances are largely affected by atmospheric conditions. The reflectance condition at the UV wavelength (354 nm, $R_{0.354}$) is also effective to exclude optically thin ice clouds having low $BT_{10.4}$ and reduce inhomogeneous spectral features caused by the atmospheric interactions under and within the clouds. The interesting point is that the different detection conditions may also determine general spectral features of DCCs considering that the features are the sources for the retrieved cloud properties. As demonstrated in Fig. 2c, the reflectance of DCCs detected by both UV and IR conditions shows relatively stable signals while the DCCs detected only with the UV or IR condition show higher temporal variability.

Here we found that both UV and IR conditions are necessary to detect DCCs having homogeneous spectral features less affected by atmospheric states especially for the UV/VIS spectral range. Additionally, it can be deduced that the DCC detection should be carefully performed to extend the valid spectral range for calibration of hyperspectral data in which consistent signals could be obtained. The GEMS data more than a year are now available since the completion of the in-orbit test of GEMS in October 2020. It is also confirmed that abundant DCCs can be obtained by collocating GEMS measurements with the Advanced Meteorological Imager (AMI) onboard the Geostationary Korea Multi-Purpose Satellite 2A (GK-2A). Based on the findings introduced in this article, it is expected to further update the applicability of the vicarious calibration for GEMS in future study. It is also expected for various attempts to accelerate the development of vicarious calibration for UV/VIS spectrometers, considering that Sentinel 4 and Tropospheric Emissions: Monitoring Pollution (TEMPO) consisting of GEO-constellation are planned to be launched within a decade.

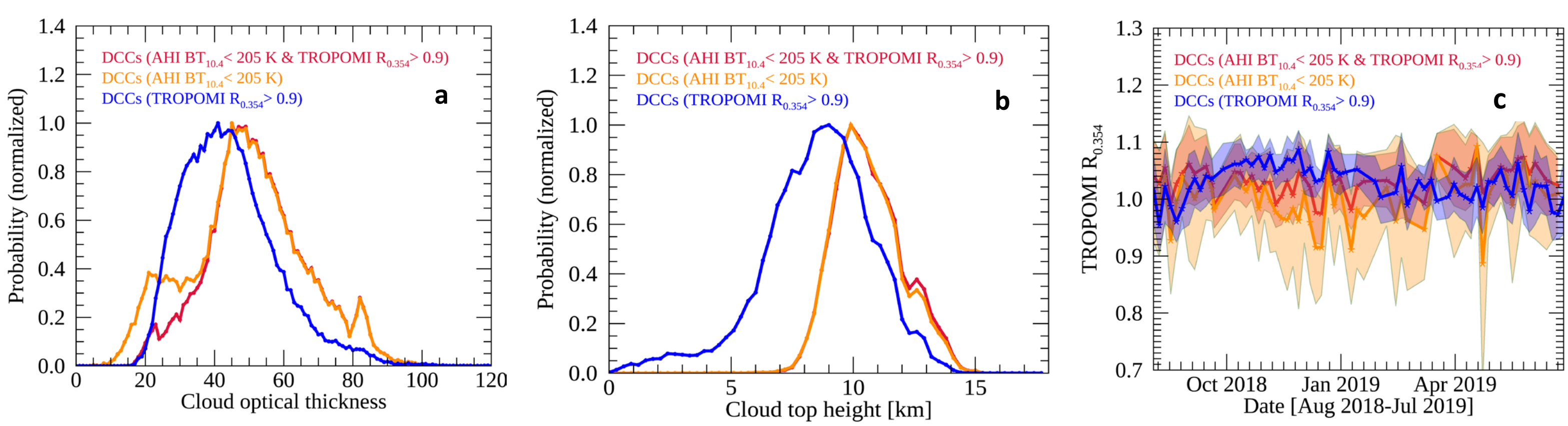

Figure 2. Histograms of (a) the cloud optical thickness and (b) cloud top height and the trend of (c) DCC reflectivity at 354 nm with five-days interval with different DCC detection thresholds. The red, orange and blue lines indicate the DCCs detected with UV and IR conditions, the IR condition only and the UV condition only, respectively and the shade in (c) represents the standard deviation of reflectance of DCCs. The cloud properties are the TROPOMI Level 2 cloud products in July 2018-June 2019.

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A New 32-Day Averaged Difference (32D-AD) Method for Calculating Inter-Sensor Calibration Radiometric Biases between SNPP and NOAA-20 Instruments within the NOAA ICVS Long-Term Monitoring

By Banghua Yan, Mitch Goldberg, Lihang Zhou (NOAA), Xin Jin (NOAA/SSAI), Ninghai Sun (NOAA/GST), Warren Porter (NOAA/SSAI) and Flavio Iturbide-Sanchez1 (NOAA)

Recently, an article was published in Remote Sensing in 2021 [Yan et al., 2021], which introduces a new statistical method or 32D-AD method for estimating inter-sensor biases at all sensor channels. This method is named by its computation procedure, i.e., computing 32-day (twice the duration of the orbital repeat cycle) averaged differences (32D-AD) of radiometric measurements for the same instrument onboard the Suomi National Polar-orbiting Partnership (SNPP) and NOAA-20 satellites. For these satellites and other JPSS satellites, each of them typically returns back to its initial point of measurement after every 16-day orbital repeat cycle.

Accordingly, comparable atmospheric and surface phenomena are observed by each satellite instrument aboard each platform throughout the entire orbital repeat cycle. The local diurnal viewing differences are due to the fact that while SNPP and NOAA-20 have the same Equator-crossing-times, they are separated by 50 minutes in their orbital tracks. These are removed through the average of the measurements during this period. In Yan et al. [2021], the new method has been validated by using the observations of four instruments flying on the SNPP and NOAA-20 satellites, i.e., Advanced Technology Microwave Sounder (ATMS), Cross-track Infrared Sounder (CrIS), Nadir Profiler (NP) within the Ozone Mapping and Profiler Suite (OMPS), and Visible Infrared Imaging Radiometer Suite (VIIRS). Two orbital repeat cycles of data are selected to further reduce diurnal variations. A brief summary of the 32D-AD method follows below, but details regarding its computation along with the impact assessment of the Quality Control (QC) criteria can be found in Yan et al. (2021).

The 32-day averaged difference of radiometric measurements per location (i, j) between the same instrument onboard two satellites, i.e., $\overline{\Delta O_{2\text{Cycles},Point}^{SAT_1-SAT_2}}(i,j)$, is given by

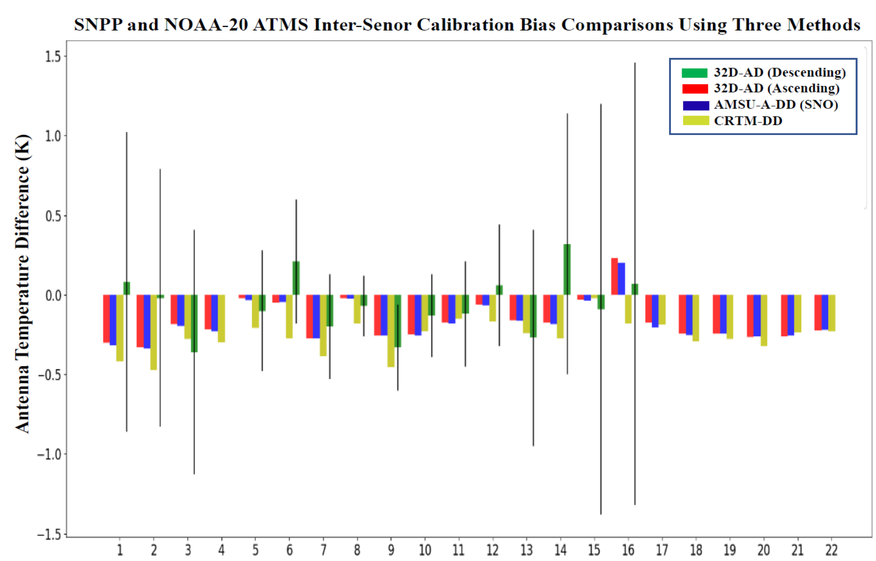

Figure 1. SNPP and NOAA-20 ATMS inter-sensor calibration radiometric biases at 22 channels using the 32D-AD method, with a date span from Nov. 1 2020 through Dec. 2, 2020. 32D-AD data sets are generated separately for ascending and descending nodes respectively. The figure also includes the inter-sensor biases that are calculated using the CRTM-DD and AMSU-A-DD methods [Yan et al., 2021].

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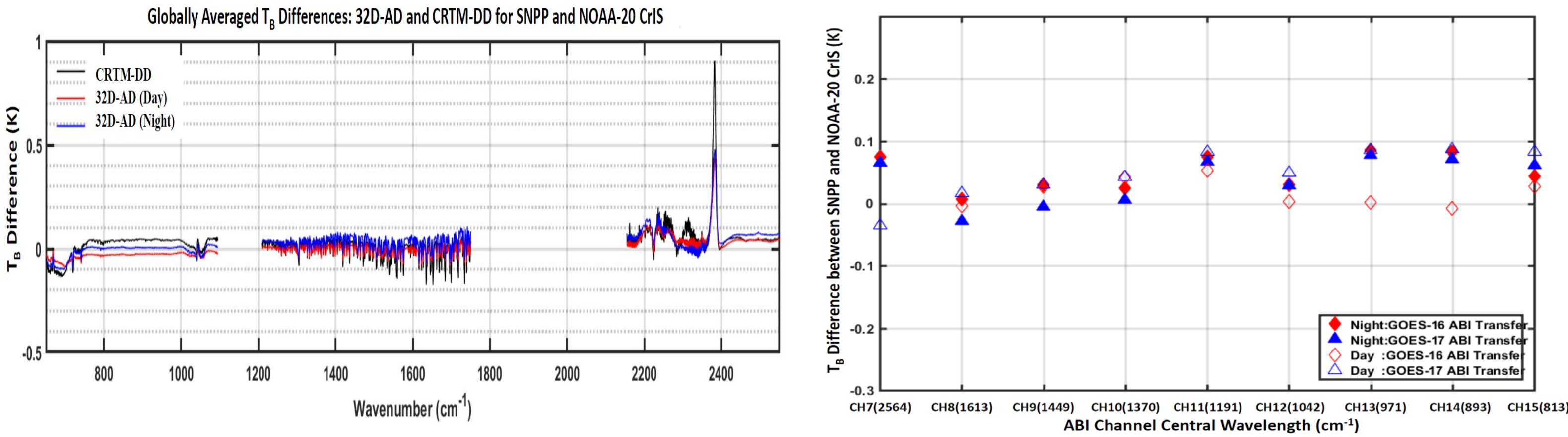

Figure 2. (a) Comparison of SNPP and NOAA-20 CrIS inter-sensor calibration radiometric biases at 2211 channels using the methods of 32D-AD and CRTM-DD, where the data cover the period from September 27 through October 28, 2019**. (b)** SNPP and NOAA-20 CrIS inter-sensor calibration radiometric biases using the ABI-DD method [Yan et al., 2021].

$$\overline{\Delta O^{SAT_1-SAT_2}_{2Cycles,Point}}(i,j) = \overline{O^{SAT_1}_{2Cycles,Point}}(i,j) - \overline{O^{SAT_2}_{2Cycles,Point}}(i,j)$$

(1) with

$$\overline{O^{SAT_x}_{2Cycles,Point}}(i,j) = \frac{1}{M(i,j)}\sum_{l=1}^{l=M(i,j)} R_l^{SAT_x}(i,j), x = 1 \ or\ 2,$$

(2)

where, $R_l^{SAT_x}(i,j)$ denotes the radiance (or antenna temperature or brightness temperature) in Sensor Data Records (SDR) or Temperature Data Records (TDR) at the location (i,j) for the instrument corresponding to the xth satellite; $\overline{O^{SAT_x}_{2Cycles,Point}}$ denotes the average of all radiance data at the location (i,j) within the two orbital repeat cycles; the subscript '2Cycles' represents two orbital repeat cycles and equals 32 days for both SNPP and NOAA-20 satellites; the superscript 'SAT_x' represents one of two compared satellites, where $SAT_1 = SNPP$ and $SAT = NOAA$-20. Other explanations are referred to Yan et al. [2021].

The $\overline{\Delta O^{SAT_1-SAT_2}_{2Cycles,Point}}(i,j)$ computed using (1) offers information about the global distribution of 32-day averaged radiance differences between the same instrument from two satellites. A QC scheme is desirable to effectively remove the outliers among the 32-day data sets that can amplify diurnal variations [Yan et al., 2021]. Therefore, only the 32-day data sets that pass the QC criteria, $\overline{\Delta O^{SAT_1-SAT_2}_{QC2Cycles,Point}}(i,j)$, are utilized to compute the globally and zonally averaged radiance differences respectively, which statistically represent the inter-sensor radiometric calibration biases at global and zonal mean levels respectively.

The performance of the 32D-AD method has been successfully validated by applying it to four SNPP/NOAA-20 instruments. The new method shows its advantages over some existing inter-sensor bias assessment methods in assessing zonal mean features of inter-sensor calibration biases. In particular, it successfully detects the solar intrusion anomaly occurring on NOAA-20 OMPS NP at wavelengths below 300 nm over the Northern Hemisphere [Yan et al., 2021]. Currently, there are two Double Difference (DD) methods widely used in the inter-sensor analysis, i.e., the RTM-DD that use a radiative transfer model (RTM) as a transfer, and 3rdSensor-DD that uses a third sensor as a transfer. Those two methods have no diurnal difference issues, so they are used to cross-validate the performance of the new method. Two examples are conducted below, while more cases are presented in the original paper.

Fig. 1 displays the calculated global averages of inter-sensor calibration radiometric biases between SNPP and NOAA-20 ATMS by using three different DD methods (32D-AD, CRTM-DD, and AMSU-A-DD), where the AMSU-A-DD method is available only at part of ATMS channels. Generally, a good agreement is observed among the three methods with some margins.

Figure 2(a) displays the calculated global averages of inter-sensor calibration radiometric biases at 2211 CrIS channels from 650 cm^{-1} to 2545 cm^{-1} using the 32D-AD method and CRTM-DD. The calculations are given separately for ascending (daytime) and descending (nighttime) nodes, showing a good consistency. The magnitudes of the QC-passing 32D-AD results are typically within ±0.1K, with a good agreement with those of the CRTM-DD results. An exception occurs at the channels nearby 2385 cm^{-1} due to a

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relatively large uncertainty in the RTM simulation. The results at the 9 ABI channels using the ABI as a transfer are also shown in Fig. 2(b). A good agreement is also depicted between the new method and the ABI-DD method for the 9 ABI channels.

Due to the excellent performance and certain advantages in channels and/or regions over the existing DD methods, the new method is being operationally adopted to monitor the long-term trends of (globally averaged) inter-sensor calibration radiometric biases at all channels for the above sensors within the NOAA Integrated Calibration and Validation System (ICVS) Long-term monitoring. While the computation procedure of the new method was developed using SNPP and NOAA-20 instruments, it can also be applied to other POES cross-sensor calibration bias assessments by updating days per orbital repeating cycle.

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Absolute Radiometric Reference Instrument (ARRI)

By G. Otter, Day ,J., Lorio E. D., Marcela P. P., Speet, B., Dijkhuizen, N., Snel, R., and Togt, O. (TNO, the Netherlands Organisation for applied scientific research)

Introduction

For many Earth Observation instruments the absolute radiometric calibration is mandatory for the science products. This radiometric calibration can be obtained by on-ground characterisation of the instrument and need to be monitored during the mission with in-orbit sources. For most accurate radiometric monitoring, on-board calibration hardware is required in the form of a sun diffuser. This calibration device needs to be in front of the instrument and requires a mechanism to move it in and out of the instrument's field of view. Sun diffusers will degrade over time and need monitoring to determine the level of degradation [1]. The sun diffuser itself often monitored by adding an additional diffuser that is used less frequently. This approach assumes that the degradation mechanism is correlated to exposure.

A cheaper method for an instrument to perform radiometric monitoring in orbit is to compare its radiometric response from a known stable scene to the known radiance of that scene. This is known as vicarious calibration. The known radiance of this scene comes mostly from other space instruments or ground measurements. The limiting factor of the vicarious calibration is the timeliness. Earth scenes may change over time, which limits vicarious calibration sites to quasi-stable scenes. The level of stability of these scenes limits the level of accuracy that can be achieved.

The size of the instrument determines the size of the calibration hardware. Large pupils and/or large fields of view require large diffusers and monitoring requires a mechanism with several positions. Therefore, using vicarious techniques would be beneficial if the required accuracy could be achieved.

Radiometric calibration concept using a reference instrument

To benefit from the advantages of vicarious calibration and still have a high level of accuracy the concept of ARRI is developed. ARRI stands for Absolute Radiometric Reference Instrument. This instrument will focus on delivering a reference radiance for the main instrument(s). To develop a concept some a-priori assumptions have been made. These assumptions are not critical to the concept of ARRI itself but are used to set some boundaries for the design. The following is assumed:

- The mission is in a low earth orbit.
- The main instruments use a pushbroom strategy (a relatively wide field of view across track and a small field of view along track using time to spatially sample along track). However, the ARRI concept could also be applied to scanning instruments
- The in-orbit radiometric degradation of the main instrument is not strongly spectrally or spatially dependent, meaning that degradation will not strongly vary from pixel to pixel but is a more gradual over the image. This means that the ARRI does not require the same spectral or spatial resolution as the main instrument(s).

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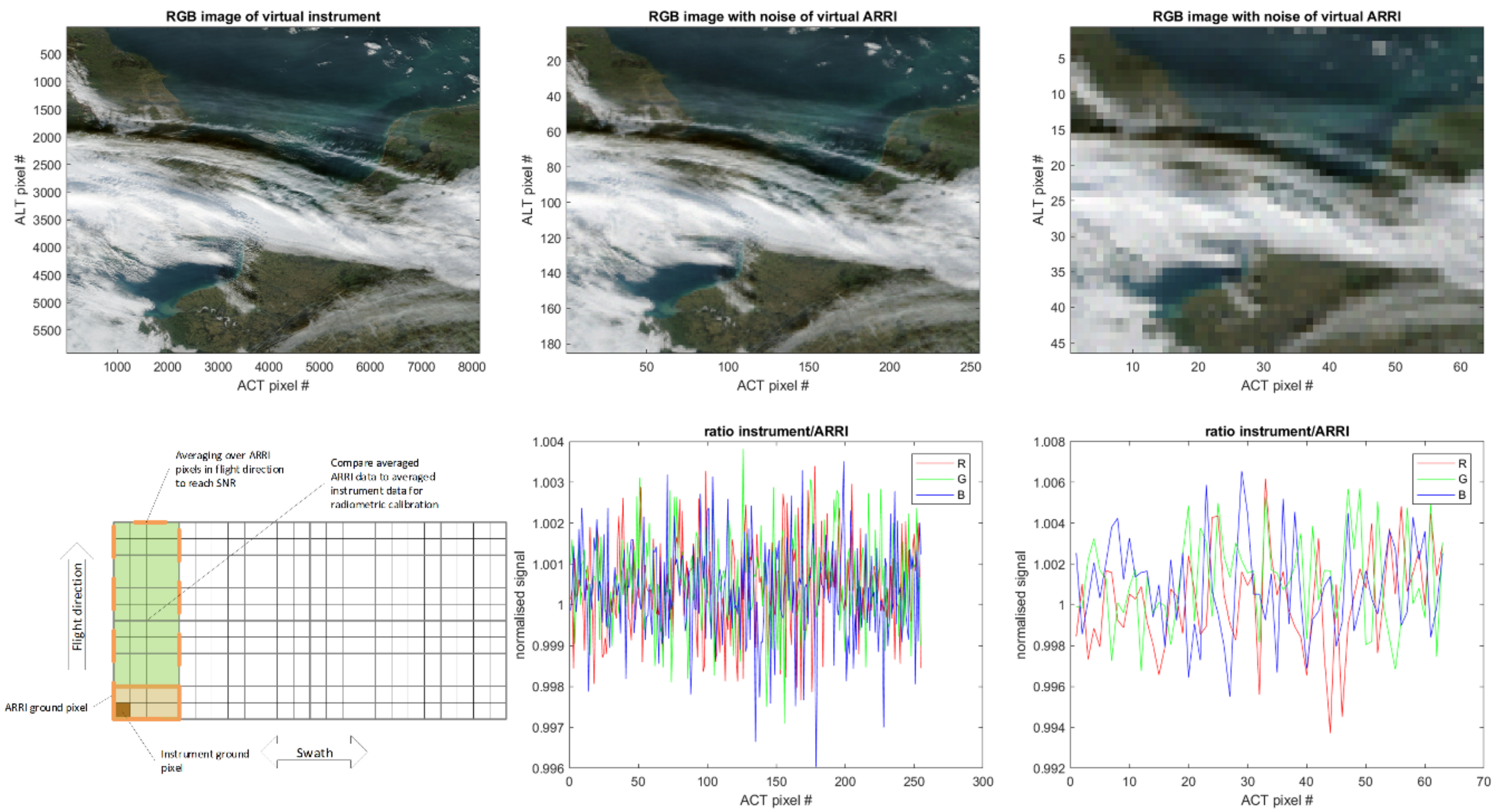

Figure 1. Working principle of ARRI. Top left, image of the "main instrument". Bottom left, depiction of the sampling. Top centre, resampled image by binning 32 pixels with noise added. Bottom centre, ratio of instrument data and ARRI data averaged over along track direction. Right, same as centre except for a binning of 128.

- It is assumed that the temporal degradation of the main instrument will be gradual so daily monitoring is sufficient. This is the strategy for hyper spectral imagers like OMI, GOME-2 and TropoMI, where sun calibration is performed once per day.

ARRI will deliver a calibrated Earth radiance with a coarser spatial and / or spectral resolution than the main instrument(s). In the along-track direction, ARRI will average the Earth's radiance over a long distance. This average can then be compared to the signal received by the main instrument(s) averaged over the same area. In this way the main instrument can monitor its degradation assuming the reference radiance from ARRI to be the truth.

During the lifetime of the mission ARRI will calibrate itself using the Sun as would normally be done by the main instrument. ARRI will therefore be equipped with state-of-the-art calibration equipment, which in case of the small ARRI will be small as well. The method shows some similarity to vicarious calibration except that in this case any scene is possible because ARRI is on the same platform and therefor measures at the same time as the main instrument(s).

To demonstrate the approach, a simple simulation is made and is depicted in Figure 1. Here an RGB image of the Earth with a spatial resolution of 125 m is binned to the ARRI resolution for two different cases of binning being 32 and 128. Noise is added such that a SNR of 100 is reached at the maximum signal.

The deviation found in this simple simulation is no bigger than 0.4% at binning 32 and 0.8 % at binning 128. With a poor noise level and using only a subsection of the orbit, this proves that noise will not be a driver for ARRI. In fact, it was found that the instrument size will be driven by the required spatial resolution, not the SNR.

Also, the radiometric calibration of the ARRI itself and the co-registration with the main instrument will determine the radiometric accuracy. The latter is not considered critical since the main instrument is oversampled with respect to ARRI, matching the two instruments' images should therefore be very accurate. The radiometric calibration is therefore the focus for the instrument concept design

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Concept design for ARRI

A concept for an ARRI instrument was made to study the feasibility of such an instrument, details can be found in [2] but here we summarize the main considerations. The focus of the concept was to make a small as possible spectrometer with a minimum amount of moving parts. The range of the spectrometer shall cover 400 till 2500 nm and the spatial resolution shall be 1 km and a swath of 150 km.

It was found that the pupil size was determined by the spatial resolution and the longest wavelength to be covered. To cover the full spectral range a pulse tube cooled detector was chosen. This pulse tube is the only moving part on the instrument, even the calibration system does not have any moving parts.

Conclusion

The approach of having a reference instrument dedicated to calibration seems solid based on the modelling. It is shown that a very small instrument that can serve a large spectral range is possible. The current design is only 4 litres and might even be smaller depending on the choices made.

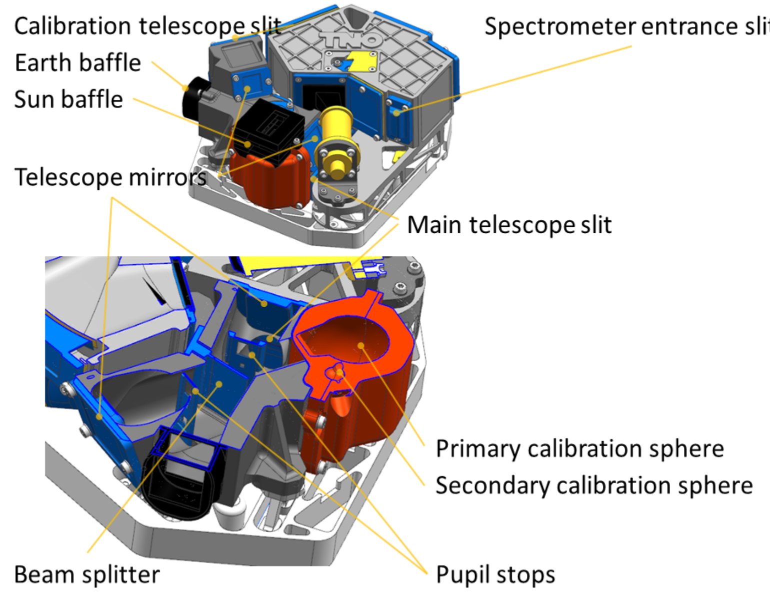

Figure 2 ARRI design

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JPSS-3 VIIRS radiometric performance assessment based on prelaunch testing

By Jeff McIntire[1], Jack Xiong[2], and Amit Angal[1] [1]SSAI, [2]NASA GSFC

The long-term data records used for scientific and climate studies will continue to be extended by the NASA and NOAA jointly developed VIIRS (Visible Infrared Imaging Radiometer Suite) instruments. Currently, the first two VIIRS instruments are operated onboard the SNPP (Suomi National Polar-orbiting Partnership) and the JPSS-1 (Joint Polar-orbiting Satellite System) platforms. The third VIIRS has been integrated onto the JPSS-2 spacecraft and is undergoing the final testing prior to an expected launch in 2022. The fourth VIIRS in the series has recently completed its main ground test program at the Raytheon facility in El Segundo, CA, and is scheduled to be shipped to the spacecraft vendor where it will be integrated into the JPSS-3 platform, with launch scheduled for 2027. The radiometric calibration of this fourth build (JPSS-3) via ground testing is the subject of this work.

Several improvements were made to the JPSS-3 VIIRS build in comparison to JPSS-2, based on lessons learned[1-3]. The day-night band (DNB) charged-coupled devices (CCDs) were redesigned as

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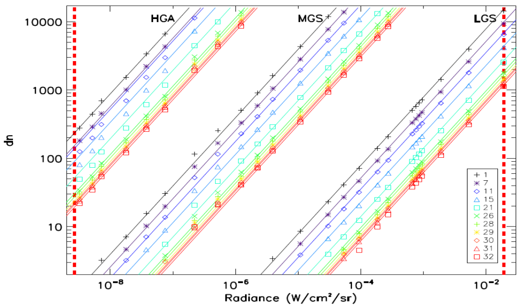

Figure 1. JPSS-3 VIIRS DNB response versus radiance for select aggregation modes (marked with different symbols) of the high-, mid-, and low- gain stages (HGS, MGS, LGS, respectively).

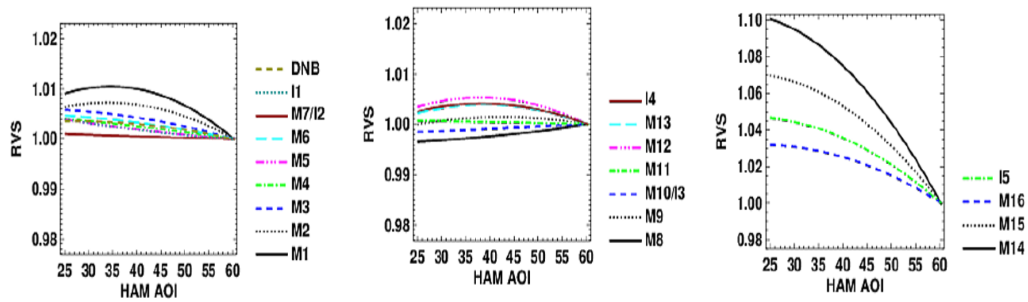

Figure 2. VIIRS response versus scan angle plotted as a function of half-angle mirror (HAM) angle of incidence (AOI)

no heritage CCDs were available; as a result, the bias voltages were also reset to achieve the desired performance. JPSS-2 experience showed that the rotating telescope assembly (RTA) experienced larger than expected wavefront error and line-of-sight error after environmental testing; this led the JPSS-3 tolerancing of the RTA to be tighter. On JPSS-2, the scans swath in the track direction does not overlap as designed, leaving a small gap between scans. The JPSS-3 effective focal length (EFL) bounds were tightened so that the EFL was within the tolerance of possible scan rate changes needed to maintain scan overlap once on-orbit. The first dichroic for JPSS-3 was redesigned to move the short wavelength cutoff to slightly bluer wavelengths. The JPSS-2 dichroic cut off on the blue edge of the M1 bandpass; this caused increased polarization sensitivity as splitting occurred between the *s* and *p* polarization states on the edge of the dichroic acceptance. The solar-diffuser stability monitor (SDSM) detectors were shown on JPSS-2 to have out-of-band leaks coming from long wavelength light passing through the filters at high incidence angles; these leaks were reduced by hardware changes.

The radiometric characterization of all spectral bands was performed in environmental testing to characterize several performance metrics. The offset corrected digital response was related to the radiance via polynomial fits (quadratic for the reflective solar bands and thermal emissive bands; linear for the day-night band). These fitting coefficients were well determined and documented for the transition to on-orbit operations. The dynamic range was assessed through measurements of the saturation radiances and gain transition radiances (where appropriate); all bands saturated above the required limits except for the DNB in aggregation mode 1. Figure 1 shows an example of the radiance versus measured (background-subtracted) digital number (dn) for select aggregation zones for the three gain stages. Overall, the relationship between the radiance and dn was well behaved, and the large nonlinearity in high gain stage (HGS) near the end of scan (present in JPSS-1 VIIRS) was not observed.

The noise characterization was performed by analyzing the SNR / NEdT (noise-equivalent change in temperature) at a typical scene radiance / temperature; all bands were well within the design requirements (Table 1). Stability was measured for all bands versus changes in time, instrument temperature, voltage, and focal plane temperature. The findings indicate compliance with sensor stability requirements. There were also assessments for possible image striping by analyzing detector responses to a uniform scene and comparing to the noise levels; differences above the noise level indicate potential for striping (observed in some higher scene temperatures for band M12 and some DNB detector / aggregation modes). In general, the radiometric performance of JPSS-3 VIIRS was as good as or better than previous VIIRS builds.

RSB	SNR/SNRspec		Lsat/Lspec		TEB	NEdT/NEdTspec	Tsat-Tmax (K)
	LG	HG	LG	HG			
M1	3.29	1.85	1.12	1.26	M12	0.326	8
M2	2.54	1.58	1.21	1.20	M13 LG	0.423	~
M3	3.00	1.81	1.26	1.07	M13 HG	0.518	23
M4	3.15	1.59	1.07	1.15	M14	0.582	27
M5	2.03	1.51	1.33	1.20	M15	0.386	17
M6	2.16		1.22		M16A	0.611	23
M7	2.79	2.62	1.12	1.17	M16B	0.597	24
M8	3.24		1.03		I4	0.138	7
M9	2.80		1.54		I5	0.335	41
M10	2.00		1.35				
M11	19.80		1.10				
I1	1.78		1.27				
I2	1.90		1.34				
I3	28.67		1.23				

Table 1. JPSS-3 VIIRS key performance metrics (LG=Low Gain, HG=High Gain): SNR/SNR spec and NEdT/NEdT spec are the ratios of signal-to-noise ratio (SNR) and NEdT to the specification; the Lsat/Lspec is the ratio of the saturation radiance to the specification; Tsat-Tmax is the difference between saturation temperature and the maximum temperature. All metrics shown here indicate compliance with the design specification and also comparable with the previous builds.

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Additional metrics tested included spectral response, polarization, scattered light performance, crosstalk, and response versus scan angle (RVS). The spectral response testing characterized the spectral response functions as well as spectral band metrics such as band center, bandwidth, and integrated out-of-band (IOOB) response. The measured values were within the design tolerances for most metrics, with the exceptions of band center (M15), bandwidth (M14, M16A, and M16B), and IOOB (I5). The polarization sensitivity was within the sensor requirements for all measured bands. Scattered light performance was assessed in two parts: near field response and stray light. In both cases the performance exceeded the design requirements. As illustrated in Figure 2, the sensor response versus scan angle was also well characterized and in line with expectations, showing similar wavelength dependent variation or behavior as observed in previous builds.

In all cases, the JPSS-3 VIIRS performance metrics either exceeded the design requirements or exhibited performance like previous VIIRS builds; this indicates that the JPSS-3 VIIRS mission will replicate the success of the SNPP and JPSS-1 VIIRS missions currently on-orbit.

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NEWS IN THIS QUARTER

Highlights of the 2022 Annual GRWG/GDWG Meeting

By M. Bali (UMD), L. Flynn (NOAA), D. Doelling (NASA), Quanhua (Mark) Liu (NOAA), R. Iacovazzi (NOAA/GST), T. Hewison (EUMETSAT), F. Yu (NOAA) and L. Wang (NOAA)

This year's meeting of the GSICS Research and Data Working Groups (GRWG and GDWG) was hosted virtually by NOAA on the 10, 14 - 18 March 2022. Members from CMA, CAS, CNES, DWD, ECMWF, EUMETSAT, ESA, IMD, ISRO, JAXA, JMA, KMA, LASP, NIST, NASA, NOAA, NPL, Planet Labs, RAL, Rayference, UKMO, USGS, VITO and WMO attended the meeting.

Mitch Goldberg (GSICS Executive Panel Chair) welcomed the participants, particularly Planet Labs for whom it was the first time a public satellite operator had participated in the Annual Meeting.

Plenary Day-1

The first session of the meeting was a Plenary which spread across the first two days of the meeting. The Plenary was chaired by Fangfang Yu (NOAA ESSIC) and covered topics vital to GSICS in the near future. The connections between GSICS products and Numerical Weather Prediction (NWP) bias adjustments was one of the themes of the Plenary reports this year. Tim Hewison (EUMETSAT) engaged the GSICS community by sharing with them the feedback that he received from the NWP community on Radiometric and Spectral Biases. Roger Saunder's (ECMWF Ret.) gave an overview of the application of the radiance simulated by NWP models in monitoring satellites. Leonhard Schek (XXX) provided results of the simulation of Solar Channels by ECMWF and ICON model. Hannah Bourne from Planet Labs gave an overview of the SkySat and SuperDoves missions and their comparisons with Sentinnel-2. The session concluded with talks by Fred Wu and Andy Heidinger (both NOAA). Fred's talk focused on Harmonization and implementation on GOES-ABI and Andy led a talk and discussion on GSICS –ISCCP interactions. Andy reported on the plans to develop cloud climatologies from GSICS corrections over the GEO-Ring and provided recommendations to GSICS on tuning their products to fulfill needs of the ISCCP community. Andy also sought feedback on ISCCP entities from GSICS community. CMA showed the benefits of using GSICS corrections and their focus in reprocessing and developing climate data records.

Plenary Day-2

The second day of the Plenary had the agency reports from EUMETSAT, JAXA, JMA, ROSHYDRO, NIST,

Return to Page One

doi: 10.25923/k616-bk13

NASA and NOAA. Arata Okuyama (JMA) provided details of GSICS correction products (H-8 and MTSAT-2) and mentioned that JMA is working on gap filling algorithms. Pradeep Thapliyal (ISRO) relayed advances in acquiring IASI data for intercalibration and the status of GSICS style monitoring of INSAT-3D/3DR. Misako Kachi (JAXA) provided a summary of JAXA activities which included inter-calibration of GCOM-C/SGLI by GIRO. She mentioned that JAXA has completed the reprocessing of AMSR-E, GOSAT and GOSAT-2. Pradeep Thapliyal (ISRO), provided an overview of ISRO missions and intercalibration algorithms developed with GSICS. Ashim Mitra (IMD) provided status of GSIC corrections for INSAT-3D/3DR. Jiyoung Kim (KMA) reported on KMA activities that included application of ap filling method on intercalibration and developing Raymatching for

comparisons with N-20/VIIRS Clémence Pierangelo (CNES) provided brief on IASI-NG and L1CPOP full versions. Chengli Qi (CMA) provided a summary of CMA satellites (FY-3E),

Reprocessing activities and performance of BRDF model. Philippe Goryl (ESA) gave a detailed summary of the ESA activities that include FDR 4ATMOS project, TRUTHS mission and the expansion of Copernicus missions. Tim Hewison (EUMETSAT) reported that they are moving to second generation of MetOp and third generation Meteosat. Tim provided a summary of GSICS products. Upcoming activities included DCC Calibration and FCDR generation.

Xianqian Wu (NOAA) provided a detailed overview of instrument monitoring (GOES-16/17) and the health of GSICS references (VIIRS and CrIS) and the State of Observing System maintained by NOAA. Jack Xiong (NASA) provided details on improvements made in S-NPP, NOAA-20 and JPSS-2/3, Landsat 8/9. Jack also mentioned NASA collaborations with the SmallSat community (Earth Fleet). Session concluded with Tom Stone (USGS) providing status of Landsat-9 and related calibration activities such as ground sites Landsat-8-Landsat-9 comparisons.

UV/Vis/NIR Spectrometer Sub-Group

There were approximately fifty participants for the UVN Spectrometer Subgroup Session. The session featured talks on the status of calibration and validation for most of the operational and planned UV/Vis spectrometers including radiance and irradiance measurements from FY-3F/OMS, NIER GEMS, TROPOMI, Metop (GOME-2, S4/UVN and S5/UVNS), JPSS (S-NPP & NOAA-20 OMPS),

DSCOVR / EPIC, TEMPO, and EOS Aura OMI. The OMPS, OMI and GOME-2 teams are reprocessing long-term records with improved consistency in the calibration characterization. The GEMS instrument is operating in a GEO orbit and provides new opportunities for GEO/LEO comparisons for LEO UV and Visible spectrometers. Significant calibration comparisons are taking place among the LEO instruments, and the GEMS instrument's measurements are providing the first opportunities to use LEO/GEO comparisons for this class of sensors.

A discussion topic on comparisons of Solar Spectra confirmed the subgroup recommendation of the TSIS-1 HRSR as the preferred reference spectrum for making comparisons. The subgroup also recommended that all instrument teams provide the "best" day 1 solar spectra along with spectral response and other information. A template for providing instrument information and resources is under development. There were additional recommendations for monthly meeting topics in the coming year including the following: (1) Hold a joint monthly meeting with Vis/NIR subgroup on Solar measurements and comparisons. (2) Hold a joint monthly meeting with the IR subgroup on OCO-n, GOSAT, CO2M, etc. (3) Hold a joint monthly meeting with the Vis/NIR subgroup on methods for calibration and comparison of reflective channels. (PICS, Rayleigh, Ice, DCC, etc.). And (4) Hold a monthly meeting with CEOS (WGCV ACSG and AC-VC) on calibration requirements and approaches for UV/Vis Spectrometer measurements for trace gas and aerosol retrievals.

IR Sub-Group

The IR group covered the inter-calibration of IR bands in narrow- and broad-band instruments and hyperspectral IR sounders through direct or indirect (double difference) comparison using NWP RTM simulations, Ground based measurements, and other observations. In lieu of the 2021 GSICS annual meeting, the IR group hosted two sessions. The first one was held on April 1 2021 and focused on general topics on IR calibration as well as the calibration of hyperspectral IR sounders. The second one was held on April 8 2021and included reports on the status of the GEO-LEO IR products from NOAA, CMA, JMA, EUMETSAT.

Overall, the reference instruments, CrIS and IASI, are very stable. One of the main thrusts has been to connect with the ISCCP and NWP community. The team continues to work on the PCA based gap filling method by further extending IASI shortwave spectra and covering more channels. An investigation of IASI -inter-calibration

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bias at SW (3.9 Micron) was found to be due to the incorrect handling of negative radiances. Efforts have been made to improve GEO-GEO and GEO-LEO inter-calibration algorithms.

The Subgroup needs a new chair – nominations will be accepted. In the future, we have to plan more meetings, support more cross-community efforts (ISCCP, WGCV), expand membership and share tools using github and the GSICS wiki.

MW Subgroup

The Microwave Subgroup (MWSG) breakout meeting started with a briefing from Xiaolong Dong (NSSC-CAS) the Chair of the Committee on Earth Observation Satellites (CEOS) Working Group on Cal/Val (WGCV) Microwave Sensors Subgroup (MSSG). This inaugural interaction between CEOS MSSG and GSICS MWSG inspired incentives for the two subgroups to engage and collaborate.

CMA reported that FY-3E MW instrument post-launch validation activities are revealing that MWTS-III and MWHS-II are operating within specifications, and WindRad performance is promising. NOAA reported JPSS-2 ATMS calibration and product retrieval systems launch readiness; an improved ATMS NEdT calculation method; more robust ATMS monitoring with COSMIC-2 RO data; public availability of recently reprocessed ATMS data; generation of over 40-year MW FCDRs; and applications of new MW hardware and data analysis software. ESA reported that the SMOS mission has nominal operating status; good agreement with SMAP data; and improved L2 dataset quality after the 3rd mission reprocessing. Information about their current SM and SSS validation and measurement initiatives, high-resolution SMOS follow-on mission activities, RFI monitoring and reporting, and the next Copernicus CIMR mission status completed their presentation.

The meeting ended with a MWSG planning discussion for 2022. Possible collaborative activities include MW lunar calibration and geolocation assessment; inter-calibration of SmallSat/Cubesat data with operational MW sounders; NWP sensitivity analysis to MWTS-III FY-3E early-morning orbit data; and obtaining TROPICS CubeSat lunar data obtained from its “sky-scan.” Meanwhile, possible deliverables are the lunar disk-average MW brightness temperature data base; and inter-calibration statistics between operational MW sounders and SmallSat/CubeSat L1b products.

VIS/NIR Sub-Group

One of the key activities over the past year has been to arrive at a reference solar. Odele Coddington (LASP) recommends the TSIS-HSRS dataset as the GSICS VIS/NIR reference solar spectra. (See the preceding article for details.) CLARREO PF (ISS 2023) and TRUTHS on orbit VIS/NIR traceable sensors will soon provide absolute calibration references. Among key achievements is that Raj Bhat (NASA) has come up with a new DCC calibration method needed for next generation GEO imagers. It uses a DCC PDF inflection point which shows stability in sparse sampling. The N20 VIIRS is the next GSICS recommended on-orbit calibration reference for Vis/NIR bands. Since differences between the two N20-VIIRS SDRs are small, either can be used as a reference.

Tom Stone (USGS) briefed on results for the Lunar area of Vis/NIR work. This included the Lunar workshop, and Lunar Model inter-comparison exercises, and more development on LIME and LESSSR. The GSICS Vis/NIR sub-group will have monthly meetings during the coming year.

GSICS Data Working Group

Kamaljit Ray, Chair GDWG started the breakout session with a review of the status of GDWG actions. She then followed this up with a summary of the GDWG activities by ESA, CMA, KMA and NOAA. Arata Okuyama from JMA gave members a brief overview of the JMA GPRC and their production of the MTSAT and Himwari-8 correction coefficients. Tian Lin from CMA presented the key areas of CMA GDWG activities that included reprocessing and recalibrating historical earth observation datasets. Tian also mentioned about plans to create high quality FCDR. Nitant Dube from ISRO reported that ISRO maintained their thredds server and integrated a GSICS product plotting tool in their GPRC. Paolo Ruti from ESA elaborated on the ESA EVDC website, their PI-MED website and salinity website to help calibration community with the state-of-the-art calibration data sets. The website integrates GSICS with CEOS activities. Manik Bali from NOAA informed members about the Google Colab notebooks developed at NOAA to help users use GSICS products and deliverables. Discussions in the data working group lead to six actions and a recommendation to share reprocessing plans.

Cross cutting discussions

The concluding day of the meeting was chaired by Larry Flynn (GCC Director / NOAA). This session held cross cutting discussions, attempted to summarize the discussions members had during the week of the Annual meeting and reviewed Actions, Decisions and Recommendations generated during the meeting. The session also discussed

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future hosting of the GSICS Annual Meetings.

As part of this session, GRWG, GDWG groups and subgroups, GIR, GMW, GUV and GVIS/NIR presented overviews of discussions they had in the breakout sessions, and the GCC report was presented by Larry, and indicated the growing trend in GSICS memberships and gave an update on the new products accepted into the GSICS product catalog. The GCC has proposed that next year's annual meeting be held as a hybrid meeting with in-person attendance at the NCWCP in College Park MD USA. In lieu of a users' workshop, the plenary session would be focused on the use of GSICS products in NWPs, and Executive Panel members would seek to have members of that community participate.

Mitch Goldberg (GSICS EP Chair / NOAA) discussed the GSICS State of the Observing System report and the status of the Special Issue of the GSICS Newsletter on the State of Observing System.

Participants agreed that despite difficulties due to COVID, GSICS member agencies maintained steady progress in GSICS activities. Member agencies reporting on results of re-processing activities demonstrated the benefits of using GSICS cross calibration in reducing biases and variance in satellite measurements. Members also agreed to increase the frequency of GSICS web meetings to once a month for most GRWG Sub-groups.

Chairs reported that most of the actions were closed and new actions were extracted from the discussions that would pave the way for future development of GSICS algorithms, data and collaboration.

The meeting agenda and presentations are on the GSICS wiki page http://gsics.atmos.umd.edu/bin/view/Development/Annualmeeting2022
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Announcements

Metrology for Climate Action: Online workshop 26-30 September 2022

By Emma Wooliams, NPL, UK

WMO and BIPM (International Bureau of Weights and Measures) are jointly organising an online workshop (26-30 September) that will identify existing and potential areas of collaboration between the metrology (measurement science) community and those making and using climate observations to support societal responses to climate change.

The workshop is being organised around two themes. Theme 1 is "Metrology in support of the physical science basis of climate change and climate observations" and theme 2 is "Metrology as an integral component of operational systems to estimate greenhouse gas emissions based on accurate measurements and analyses". The workshop aims to identify formal recommendations for new and expanded activities to support research and operational services in these areas.

This is an opportunity to influence the research direction of the world's national metrology institutes, to learn about the role metrology plays in the quality assurance of climate data records and to discover opportunities for future collaborative research.

The workshop is entirely online with two-hour live sessions, alongside pre-recorded presentations and posters. Day 1 will have live presentations to set the scene, days 2 and 3 will be a virtual poster fair enabling interactive conversations with presenters and days 4 and 5 will be discussion workshops to identify, prioritise and refine recommendations The deadline for receipt of abstracts for pre-recorded presentations and posters is 30 June 2022.

Detailed information can be found at: https://www.bipmwmo22.org.

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GSICS-Related Publications

Otter, G., J. Day, E. Di Iorio, M.P. Páscoa, B. Speet, N. Dijkhuizen, R. Snel, and O. van der Togt. 2021. 'Absolute Radiometric Reference Instrument (ARRI)'. In *Proceedings of the International Astronautical Congress, IAC*. Vol. B1. https://doi.org/10.1117/12.2596228.

F. Wang, M. Min, N. Xu, C. Liu, Z. Wang and L. Zhu, "Effects of Linear Calibration Errors at Low-Temperature End of Thermal Infrared Band: Lesson from Failures in Cloud Top Property Retrieval of FengYun-4A Geostationary Satellite," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 60, pp. 1-11, 2022, Art no. 5001511, doi: 10.1109/TGRS.2022.3140348.

K. Orzel, S. Fujimaru, T. Obata, T. Imaizumi and M. Arai, "The on-orbit demonstration of the small SAR satellite. Initial calibration and observations," *2022 IEEE Radar Conference (RadarConf22)*, 2022, pp. 01-05, doi: 10.1109/RadarConf2248738.2022.9764261.

Liang, Ding, Banghua Yan, and Lawrence Flynn. 2022. 'Characterization and Correction of Intersensor Calibration Convolution Errors Between S-NPP OMPS Nadir Mapper and Metop-B GOME-2'. *IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING* 60. https://doi.org/10.1109/TGRS.2021.3134206.

Niu, Chao, Kun Tan, Xue Wang, Bo Han, Shule Ge, Peijun Du, and Feng Wang. 2022. 'Radiometric Cross-Calibration of the ZY1-02D Hyperspectral Imager Using the GF-5 AHSI Imager'. *IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING* 60. https://doi.org/10.1109/TGRS.2021.3131485.

Tang, H.; Xie, J.; Tang, X.; Chen, W.; Li, Q. On-Orbit Absolute Radiometric Calibration and Validation of ZY3-02 Satellite Multispectral Sensor. *Sensors* **2022**, *22*, 2066. https://doi.org/10.3390/s22052066

Zhu, S., Z. Li, L. Qie, H. Xu, B. Ge, Y. Xie, R. Qiao, et al. 2022. 'In-Flight Relative Radiometric Calibration of a Wide Field of View Directional Polarimetric Camera Based on the Rayleigh Scattering over Ocean'. *Remote Sensing* 14 (5). https://doi.org/10.3390/rs14051211.

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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