Quarterly

doi: 10.25923/77r0-wm17

Newsletter Fall 2019 Issue

Editor: Manik Bali, ESSIC UMD

CMA • CNES • ESA • EUMETSAT • IMD • ISRO • JAXA • JMA • KMA • NASA • NIST • NOAA • ROSCOSMOS . ROSHYDROMET • SITP • USGS • WMO

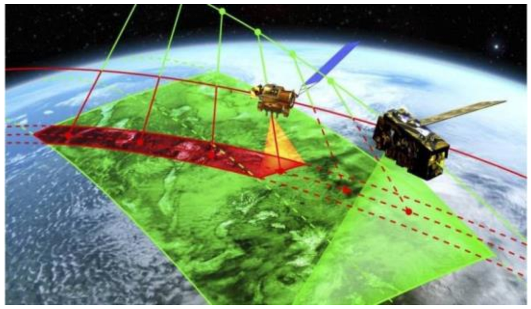
In this Issue

Articles

News in This Quarter

Announcements

GSICS Related Publications



Artist rendition of CLARREO on board International Space Station

CLARREO Spectrum (Curtsy NASA)

Defining an optimised space-based sensor-to-sensor calibration strategy based on a global end-to-end simulation

By Javier Gorroño and Nigel Fox, NPL

The last decade has seen the development of concepts and missions such as TRUTHS (Traceable Radiometry Underpinning Terrestrial and Helio-Studies) and CLARREO (Climate Absolute Radiance and Refractivity Observatory) capable of providing highly accurate and trusted SI-traceable climate records. In preparation for a scenario where the reference sensor does not limit the uncertainty of an inter-calibration process and thus facilitates a ‘reference-calibration’, effort has been focused on the study and correction of errors related to the calibration transfer process, e.g. spectral, spatial and temporal mismatch. One of the first broad scale studies of such error sources was carried out by Wielicki, et al. [1] in the context of reference calibration using the CLARREO mission. The study identified eight dimensions for consideration during the match-up and comparison of two spacecrafts in orbit and studied several of these dimensions individually. Similarly, more recently in the work by Gorroño, et al. [2], the uncertainty associated with the spectral, spatial and temporal dimensions in a reference-calibration against the TRUTHS sensor was studied.

Further work has been carried out in different studies exploring each of the dimensions individually. For example, the study in Lukashin, et al. [3] proposed the correction of polarisation effects by introducing the concept of a Degree of Polarisation Model (DPM) and in the spectral dimension, the work presented in Wu, et al. [4] describes the effect of spectral sampling and resolution of CLARREO in a potential reference-calibration. This has recently been complimented by a proposal on how to correct for spectral mismatch as well as filling of spectral gaps [5].

doi: 10.25923/77r0-wm17
GSICS Quarterly: Fall Issue 2019 Volume 13, No. 3, 2019

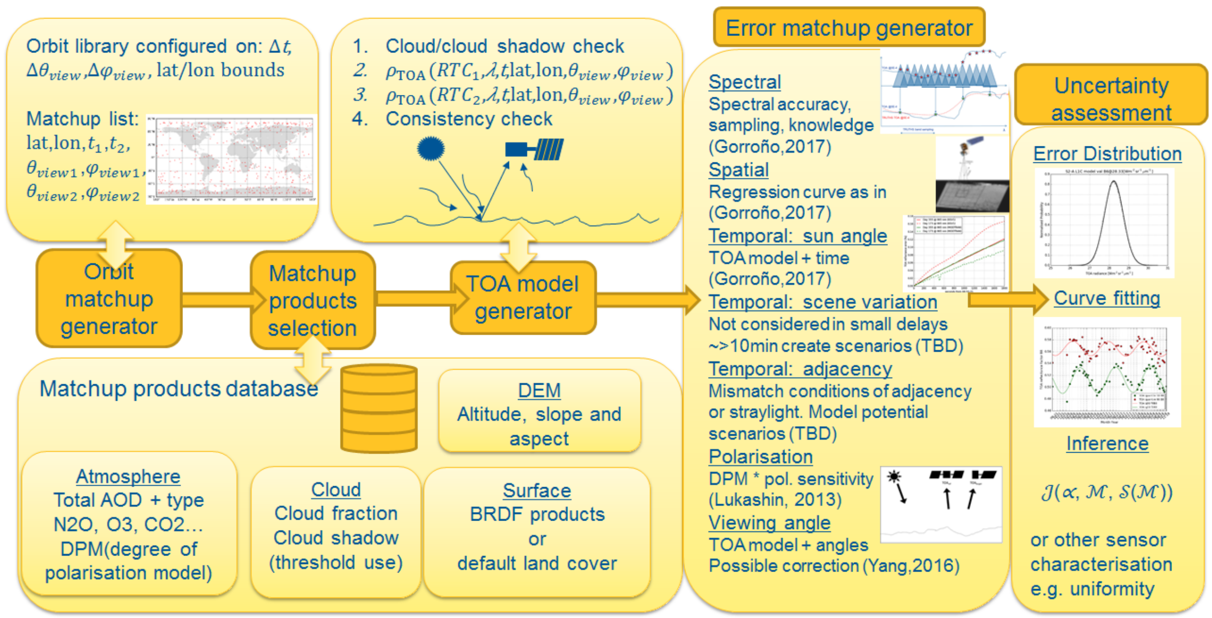


Figure 1. Flowchart describing the end-to-end approach considered for an inter-calibration simulation study of TRUTHS and a target sensor.

As the CLARREO Pathfinder mission approaches the launch, the team is currently developing techniques for the correction of angular differences using the principal component-based radiative transfer model in the solar spectral region (PCRTM-SOLAR). This radiative transfer code can simulate Top of Atmosphere (TOA) spectrum under various scene conditions with various solar illumination angles and instrument view angles [6].

The consequence of orbit and the evolution of gains derived from reference-calibration is another critical step that must be accounted for. An orbital model that identifies the match-ups between CLARREO and other sensors such as CERES or VIIRS is presented in Roithmayr, et al. [7]. The work not only identifies valid match-ups between the sensors, but also discusses the number of potential samples required to achieve the required uncertainty through the reference-calibration process. However, despite the comprehensiveness of the approach, the study does not consider all the potential uncertainty sources and the correlation among them.

Although the above summarizes a significant effort expended in the characterization and potential correction of the error sources in an inter-calibration process, little work is directed towards the understanding of its combined effect in a single match-up between sensors and how these changes over an accumulation of match-ups. The studies above tend to assume bounds of uncertainty and/or that different error sources/match-ups are uncorrelated.

Figure 1 presents the flowchart proposed to define an optimised reference-calibration strategy for the TRUTHS mission. The strategy must be based on a **case-by-case** optimum solution related to an **end-to-end global** scenario. The 'orbit match-up generator' in the flowchart produces a match-up list between a reference and target satellite. Based on the timestamp and position, a set of products / information can be retrieved that define the status of the surface and atmosphere ('match-up products selection'). Using this information, the TOA radiance can be modelled in a 'TOA model generator'. At this point, the importance of the modelling is not based on an accurate simulation but must capture the relevant spatio-temporal patterns at a local and global scale. This model together with other information is combined in an 'error match-up generator' capable of estimating an error for each one of the match-ups. Finally, an 'uncertainty assessment' is performed based on the obtained errors.

The proposed reference-calibration strategy will allow products of the calibrated sensor to not only be of improved accuracy but also have robust SI-traceable uncertainty, particularly valuable for the new space constellations as well as more mainstream sensors. In addition, using this strategy/model in simulation mode helps to evaluate inter-calibration scenarios that can provide feedback for mission design. For example, it may be helpful to select an optimised orbit type or the amount of time/match-ups needed to reach a certain uncertainty level. It is worth noting that match-up uncertainty is critical as a constraint of calibration inversion processes. The development of the match-up uncertainty and its correlation will be a significant complement to harmonisation frameworks as described in Giering, et al. [8].

Our current work is directed towards a proof of concept, with several modules under development so that a subset of the contributions can be modelled end-to-end. Further development of the concept is expected to continue and be helpful in the design and operations of missions such as TRUTHS.

References

[1] B. A. Wielicki, D. R. Doelling, D. F. Young, N. G. Loeb, D. P. Garber, and D. G. MacDonnell, "Climate Quality Broadband and Narrowband Solar Reflected Radiance Calibration Between Sensors in Orbit," in *IGARSS 2008 - 2008 IEEE International Geoscience and Remote Sensing Symposium*, 2008, pp. I-257-I-260.

[2] J. Gorroño, A. C. Banks, N. P. Fox, and C. Underwood, "Radiometric inter-sensor cross-calibration uncertainty using a traceable high accuracy reference hyperspectral imager," *ISPRS Journal of Photogrammetry and Remote Sensing*, vol. 130, pp. 393-417, 8// 2017.

[3] C. Lukashin, B. A. Wielicki, D. F. Young, K. Thome, J. Zhonghai, and S. Wenbo, "Uncertainty Estimates for Imager Reference Inter-Calibration With CLARREO Reflected Solar Spectrometer," *Geoscience and Remote Sensing, IEEE Transactions on*, vol. 51, pp. 1425-1436, 2013.

[4] A. Wu, X. Xiong, Z. Jin, C. Lukashin, B. N. Wenny, and J. J. Butler, "Sensitivity of Intercalibration Uncertainty of the CLARREO Reflected Solar Spectrometer Features," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 53, pp. 4741-4751, 2015.

[5] W. Wu, X. Liu, X. Xiong, Y. Li, Q. Yang, A. Wu, *et al.*, "An Accurate Method for Correcting Spectral Convolution Errors in Intercalibration of Broadband and Hyperspectral Sensors," *Journal of Geophysical Research: Atmospheres*, vol. 123, pp. 9238-9255, 2018.

[6] Q. Yang, X. Liu, W. Wu, S. Kizer, and R. R. Baize, "Fast and accurate hybrid stream PCRTM-SOLAR radiative transfer model for reflected solar spectrum simulation in the cloudy atmosphere," *Optics Express*, vol. 24, pp. A1514-A1527, 2016/12/26 2016.

[7] C. M. Roithmayr, C. Lukashin, P. W. Speth, G. Kopp, K. Thome, B. A. Wielicki, *et al.*, "CLARREO Approach for Reference Intercalibration of Reflected Solar Sensors: On-Orbit Data Matching and Sampling," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 52, pp. 6762-6774, 2014.

[8] R. Giering, R. Quast, J. P. Mittaz, S. E. Hunt, P. M. Harris, E. R. Woolliams, *et al.*, "A novel framework to harmonise satellite data series for climate applications," *Remote Sensing*, vol. 11, p. 1002, 2019.

Discuss the Article

Introduction and radiometric performance during commissioning and early operation of GEO-KOMPSAT-2A

By Dohyeong Kim, Minju Gu, and Eunkyu Kim, KMA

The Geo-KOMPSAT-2A (located at 128.2°E) geostationary meteorological satellite managed by the Korea Meteorological Administration (KMA) began operation at 00 UTC on 25 July 2019 (launched on 4 December 2018), continuing the Communication, Ocean and Meteorological Satellite (COMS) mission of strengthening Korea's capability to monitor the atmospheric environment over Asia-Pacific region. The Geo-KOMPSAT-2A (GK-2A) data and images are now available through NMSC webpage (http://nmsc.kma.go.kr/enhome/html/main/main.do).

KMA produces 52 geophysical products with categorized information such as scene/surface, cloud/rainfall, radiation/aerosol, and atmospheric condition and aviation. These products have been validated to evaluate the maturity and improve their algorithms. KMA also utilizes the Advanced Meteorological Imager (AMI) data focusing on nowcasting and short-range forecast application, and expects to improve Numerical Weather Prediction (NWP) performance as increased in number of inputs as well as temporal resolution.

doi: 10.25923/77r0-wm17

Table 1 : The specifications for GK2A/AMI, GOES-R/ABI, and Himawari-8/AHI channels

	Band Name	Center wavelength (um)			Resolution (km)
		AMI	ABI	AHI	
Visible	VI004	0.47	0.47	0.46	1
	VI005	0.51		0.51	1
	VI006	0.64	0.64	0.64	0.5
	VI008	0.86	0.87	0.86	1
Near-infrared	NR013	1.37	1.38		2
	NR016	1.61	1.61	1.61	2
			2.26	2.25	

	Band Name	Center wavelength (um)			Resolution (km)
		AMI	ABI	AHI	
Infrared	IR038	3.83	3.90	3.89	2
	IR063	6.21	6.19	6.24	2
	IR069	6.94	6.95	6.94	2
	IR073	7.33	7.34	7.35	2
	IR087	8.59	8.50	8.59	2
	IR096	9.62	9.61	9.64	2
	IR105	10.35	10.35	10.41	2
	IR112	11.23	11.2	11.24	2
	IR123	12.37	12.3	12.38	2
	IR133	13.28	13.3	13.28	2

GK-2A AMI will also be utilized in various fields such as climate change monitoring, hydrology and so on. For the meteorological observation, KMA operates the 10-minute timeline (3 observation areas: Full Disk, Extended Local Area (ELA, 3,800 by 2,400 km^2) and Local Area (LA, 1000 by 1000 km^2). Among the observation areas, LA can be used to KMA provide rapid scan imagers (two minutes interval) to users over the Asian Pacific region (RA II and RA V) by receiving the users' official request via dedicated web tool. KMA expects that the rapid scan images could provide significant improvements in the real-time monitoring of hazardous weather such as Typhoons, thunderstorms and volcanic events.

KMA broadcasts all 16 channels of AMI in full resolution via GK2A Ultra HRIT and also maintains HRIT broadcast corresponding to COMS five channels. And the landline based real-time FTP data service (cloud-like service) is also available. Registration is required and currently eleven countries are registered.GK2A AMI specifications on the channel and spatial resolution are summarized and compared with other imagers in Table 1.

Figure 1 shows 10-min timeline of AMI observation areas and frequencies. The scans performed by the AMIs are Full Disk (FD), Extended Local Area (ELA) and Local Area (LA). AMI scans the Full Disk once and ELA five times and LA five times with the 10-minute timeline. KMA has been testing and checking GK2A AMI radiometric performance after its launch. GK2A AMI has two onboard calibration targets: a blackbody for emissive bands, referred to as the Internal Calibration Target (ICT); and a solar diffuser for the reflective bands called the Solar Calibration Target (SCT). In addition to the in-orbit operation using the onboard solar diffuser and the vicarious calibration using the Earth targets as the calibration reference, the Moon which is a very stable reflector is also routinely reviewed for long term characterization.

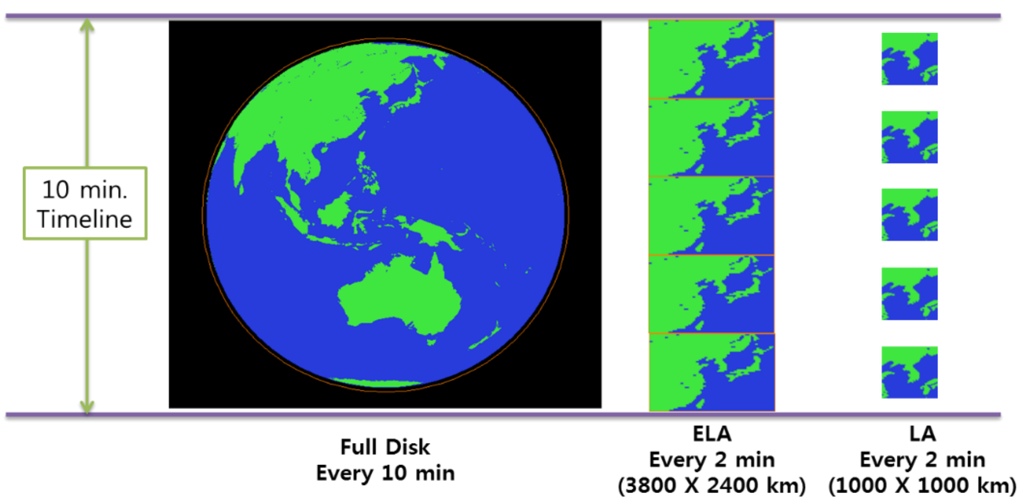


Figure 1. GK2A AMI observation areas and frequencies in a 10-minute timeline.

doi: 10.25923/77r0-wm17

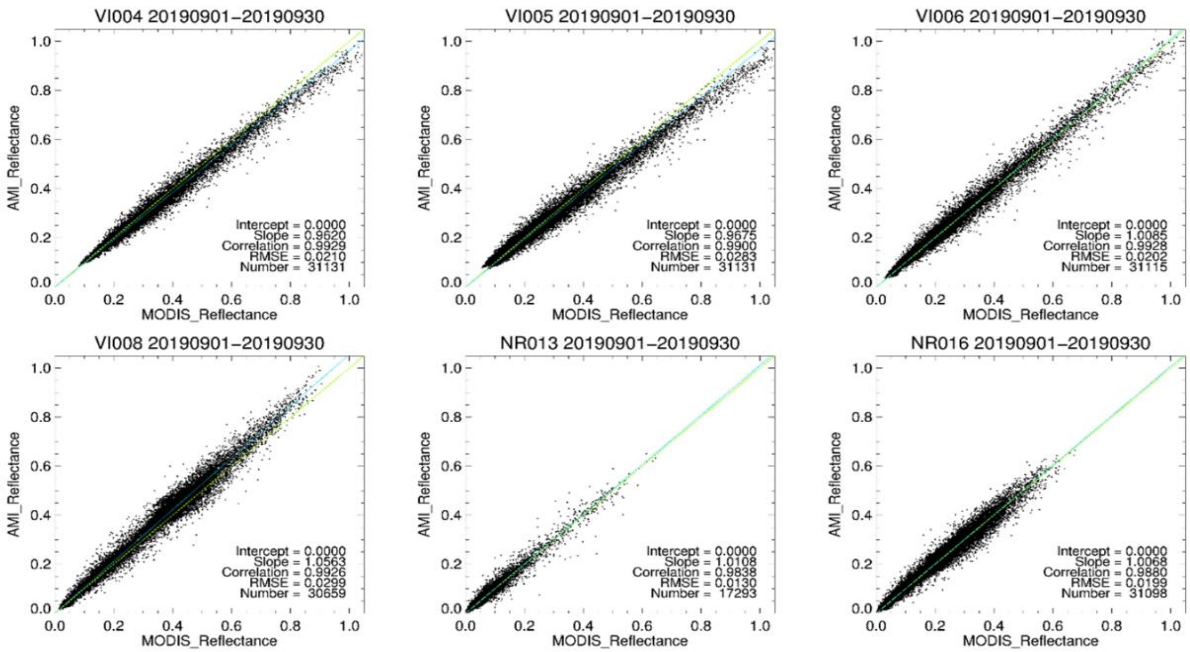


Figure 2. Ray-matching results in September 2019 (VI004, VI005, VI006, VI008, NR013, NR016)

Vicarious Calibration of visible channels

The visible channel of the GK2A includes four channels of 0.4, 0.5, 0.6, and 0.8 µm, and two near infrared channels 1.3 and 1.6 µm having characteristics of the visible channel. KMA has been monitoring AMI visible channels (6 channels) using GEO-LEO inter calibration method (called ray-matching method). Ray-matching method is temporal and spatial matching between two satellites (GK2A AMI and Terra MODIS) data within ±5 minutes, latitude 30°N to 30°S, and longitude 98.2°E to 158.2°E in a grid of 0.1° × 0.1° and after matching, comparison AMI grid and MODIS grid directly. AMI and MODIS have different spectral response functions (SRFs), therefore the MODIS SRF's is adjusted to AMI using SBAF (Spectral Band Adjustment Factor). From June to September 2019, the results of the visible channel performance analysis using the ray-matching method are as follows. Comparisons of AMI and MODIS reveal a difference of less than 5%, except VI0048 channels, and almost channels have Root Mean Square Error (RMSE) < 0.3. However, time series of ray-matching in Figure 3 show that the trend of the ratio between AMI and MODIS is very stable.

The AMI VI004 channel has ~3.8% difference compared with MODIS. But, the ratio (AMI Reflectance/MODIS Reflectance) is very stable with a slope of 0.0002/day. Therefore, GK2A AMI visible channels maintain accuracy without significantly reducing their radiometric performance after launch. And KMA/NMSC are developing ray-matching method using Suomi-NPP

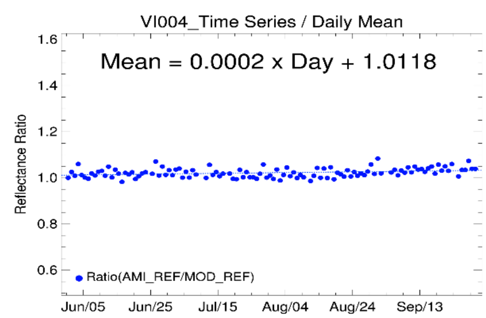


Figure 3. Time series of ray-matching result from June to September 2019 (VI004 channel)

VIIRS and vicarious targets method using the DCC (Deep Convective Cloud), Water Cloud, Desert & Ocean.

GEO-LEO inter-calibration of infrared channels

AMI Infrared channels (3.8µm, 6.3µm, 6.9µm, 7.3µm, 8.7µm, 9.6µm, 10.5µm, 11.2µm, 12.3µm, and 13.3µm) data have been monitored using five well-calibrated hyper-spectral sounders on

.

AMI-IASIB	SW038	WV063	WV069	WV073	IR087	IR096	IR105	IR112	IR123	IR133
standard scene Tb(K)	285.97	234.98	244.09	254.56	283.75	259.06	286.01	286.08	283.78	269.38
bias@st	0.15	0.08	-0.09	-0.00	0.02	-0.08	0.11	0.11	0.09	-0.02
mean bias	-0.32	0.00	-0.18	-0.02	0.16	-0.06	0.19	0.19	0.15	0.03

Table 2 : Tb mean bias and bias at standard scene Tb with respect to IASI-B

doi: 10.25923/77r0-wm17

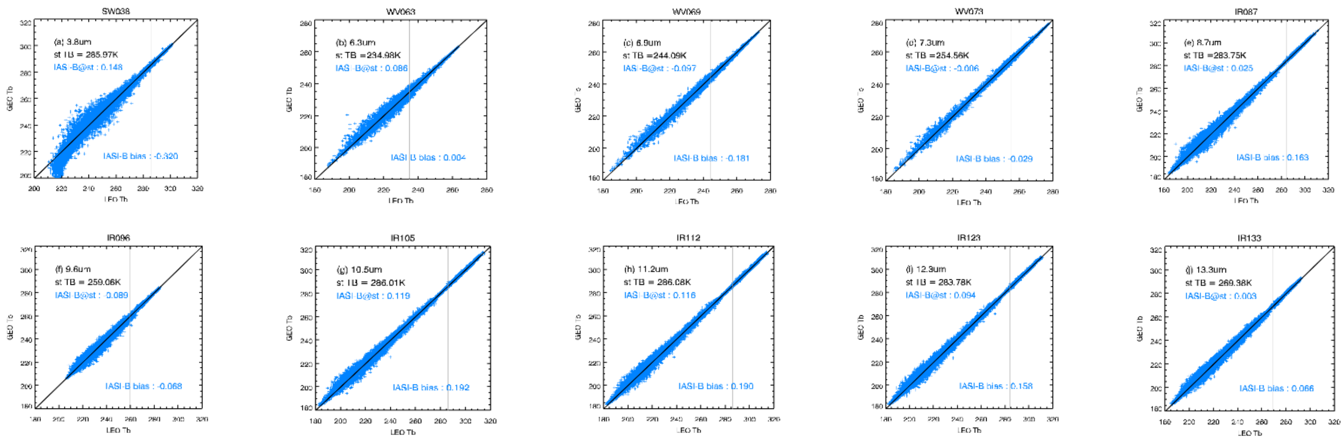


Figure 4. Scatter plot of Tb from GK2A/AMI and IASI-B(blue) for IR channels

LEO (Low Earth Orbit) satellites, he Infrared Atmospheric Sounding Interferometers (IASI) on MetOp-A, B and the Cross-track Infrared Sounders (CrIS) on SNPP (Suomi NPP), NOAA-20, and the Atmospheric Infrared Sounder (AIRS) on Aqua, as references for inter-calibration AMI data from 1 June to 30 September 2019 (from 23 July for IR133) were analyzed based on GSICS procedure. Figure 4 and Table 2 show a scatter plot of Tb from AMI and LEOs and statistical results of inter-calibration for IR channels.

The results show small biases at standard scene Tb less than 0.15K in all channels and the mean biases through the whole Tb dynamic range are less than 0.2K in channels except SW038.

Reference

Schmit, Timothy J.; Gunshor, Mathew M.; Menzel, W. Paul; Gurka, James J.; Li, Jun and Bachmeier, A. Scott. Introducing the next-generation Advanced Baseline Imager on GOES-R. Bulletin of the American Meteorological Society, Volume 86, Issue 8, 2005, pp.1079-1096, DOI : 10.1175/BAMS-86-8-1079

Schmit, Timothy J.; Li, Jun; Gurka, James J.; Goldberg, Mitchell D.; Schrab, Kevin J.; Li, Jinlong and Feltz, Wayne F. The GOES-R Advanced Baseline Imager and the continuation of current sounder products. Journal of Applied Meteorology and Climatology, Volume 47, Issue 10, 2008, pp.2696-2711, DOI : 10.1175/2008JAMC1858.1

Discuss the Article

SNPP/CrIS retains GSICS reference Status

By Dennis Tremblay and Flavio Iturbide-Sanchez, NOAA

The SNPP/CrIS is a GSICS reference instrument that is currently being used by the GSICS community to monitor GEO instruments. Instruments such as AHI, COMS and GOES-16/17 are routinely monitored by utilizing SNPP/CrIS underpasses under these GEO instruments.

A recent anomaly (on 3/26/2019) in the CrIS instrument rendered side-1 electronics inoperable; thereby affecting the generation of the mid-wave IR band (MWIR) measurements. The switch to the electronic side 2 occurred on 6/24/2019, and the MWIR band measurements were recovered. Because of the use of the new electronic side, the CrIS instrument needed to be recalibrated and revalidated. On 7/29/2019, the CrIS SDR product (radiance) reached the “provisional” maturity following the upload of the so-called engineering packet version 40. It was assessed that the CrIS performance of the electronic side 2 was as good as the electronic side 1 prior to the MWIR failure. The review for the “validated” maturity level is planned for early February 2020

Below is the comparison of the Radiometric properties of the instrument before and after the anomaly. The GSIC community is encouraged to continue using the SNPP/CrIS as a reference instrument to monitor their in-orbit instruments.

doi: 10.25923/77r0-wm17

SNPP/CrIS FSR SDR Side-2 uncertainties (blue) vs. specifications (black)

Band	Spectral Range (cm^{-1})	Resolution (cm^{-1})	Number of Channels	NEdN* ($mW/m^2/sr/cm^{-1}$)	Frequency Uncertainty (ppm)	Geolocation Uncertainty** (km)	Radiometric Uncertainty @287K BB¥ (%)	Radiometric Stability @287K BB (%)
LWIR	650-1095	0.625	713	0.099 (0.14)	2 (10)	0.25 (5)	0.16 (0.45)	0.17 (0.40)
MWIR	1210-1750	0.625	865	0.0536 (0.084)	2 (10)	0.25 (5)	0.19 (0.58)	0.21 (0.50)
SWIR	2155-2550	0.625	633	0.00752 (0.014)	2 (10)	0.25 (5)	0.40 (0.77)	0.28 (0.64)

SNPP/CrIS FSR SDR Side-1 uncertainties (blue) vs. specifications (black)

Band	Spectral Range (cm^{-1})	Resolution (cm^{-1})	Number of Channels	NEdN* ($mW/m^2/sr/cm^{-1}$)	Frequency Uncertainty (ppm)	Geolocation Uncertainty** (km)	Radiometric Uncertainty @287K BB¥ (%)	Radiometric Stability @287K BB (%)
LWIR	650-1095	0.625	713	0.101 (0.14)	2 (10)	0.25 (5)	0.16 (0.45)	0.17 (0.40)
MWIR	1210-1750	0.625	865	0.0522 (0.084)	2 (10)	0.25 (5)	0.19 (0.58)	0.21 (0.50)
SWIR	2155-2550	0.625	633	0.00741 (0.014)	2 (10)	0.25 (5)	0.40 (0.77)	0.28 (0.64)

* Mean value averaged over nine FOVs and over entire band.

** Geolocation uncertainty is based on the largest 3-sigma value found over all scan angles (FORs). Accounts for in-track and cross-track errors. The specification is based on 3-sigma mapping uncertainty of 5 km (474-00448-01-03_JPSS-SRS-Vol-I-Part-3_0200G-2).

¥ S-NPP Radiometric Uncertainty (RU) does not accounts for the polarization correction effect. RU values with polarization correction are expected to be lower than those reported in the table.

Discuss the Article

Improving Spatial Resolution of Microwave Sounder Images through Machine Learning

By Likun Wang(RTI/NOAA), Kevin Garrett, Sid Boukabara and Mitch Goldberg(NOAA)

Microwave (MW) sounders (like ATMS - Advanced Technology Microwave Sounder) have an ability to penetrate thick clouds and thus can "see" the inner structures of severe weather systems (especially window channel). Therefore, their images are valuable for users to evaluate storm's internal processes and its strength. However, compared to visible and infrared sensors, the measurements acquired by MW sounding instruments often have relatively poor spatial resolution (due to relatively large field of view (FOV)) and thus result in blurry images with low quality (shown in Figure 1a). On the other hand, high spatial resolution MW images can facilitate geolocation assessment of microwave sounding instruments (i.e., coastline inflection method).

Therefore it is needed in a practical sense to take a low resolution MW image and produce an estimate of a corresponding high-resolution image. One of the most common techniques for upscaling an image is interpolation. Although simple to implement, this method leaves much to be desired in terms of visual quality. Recently, a deep learning method for single image super-resolution (SR) [Dong et al. 2014] has been successfully applied in computer vision field. The idea behind this method is to exploit internal similarities of low-resolution images and their high-resolution counterparts in training datasets, effectively learning a mapping between them. As a preliminary study, a super-Resolution Convolutional Neural Network (SRCNN) has been experimentally applied to ATMS low resolution images in order to enhance its image quality. We use the high spatial resolution Advanced Microwave Scanning Radiometer (AMSR)-2 (3x5 km) data convolved with ATMS antenna patterns to generate original low (2.2° FOV size with 96 FOVs per scan) and high resolution (1.1° FOV size with 96x2 per scan) ATMS training datasets. These data are then used to train the SRCNN models, including 1) patch

doi: 10.25923/77r0-wm17

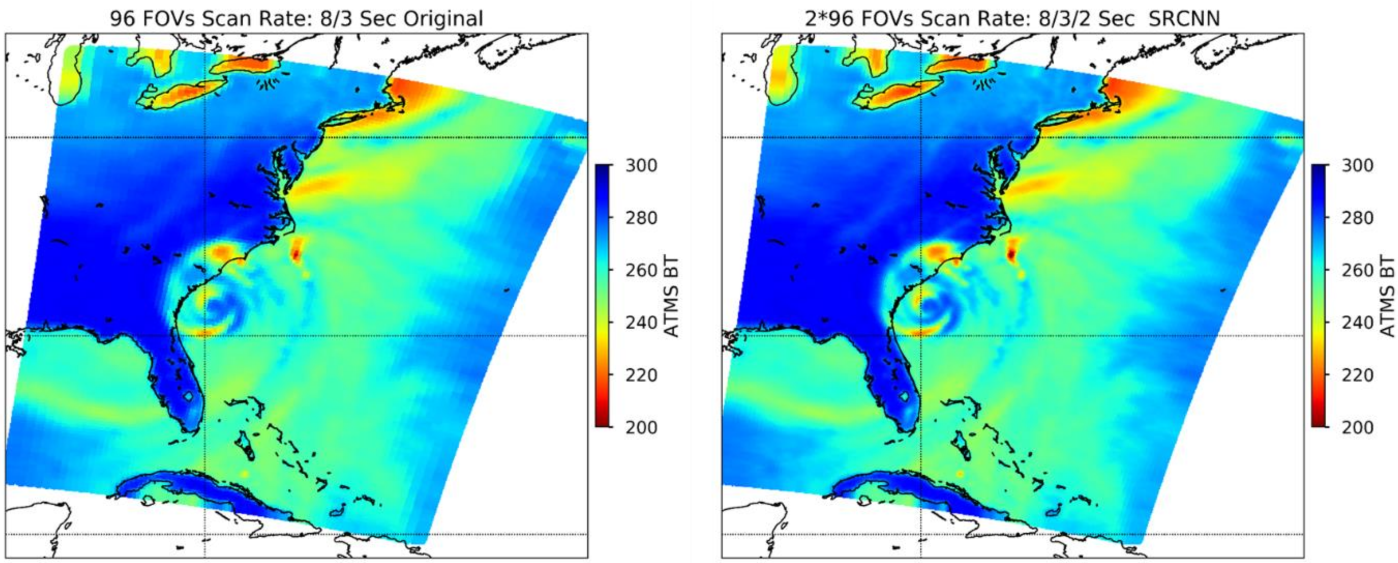


Figure 4 a) Original low resolution ATMS image at channel 18 and b) Enhanced high resolution (2X) images using the SRCNN model.

extraction and representation, 2) non-linear mapping, and 3) reconstruction. As demonstrated in Figure 1, we applied this model to ATMS images at channel 18 (183GHz) for Hurricane Dorian on 5 Sep 2019. The enhanced image with 2x resolution improvements more clearly discloses internal structures of hurricane (Figure 1b). While the preliminary results are encouraging, there are still some remained questions for future work, such as signal-to-noise ratio change, model improvements, and comparison with Backus-Gilbert (B-G) method. Furthermore, we are testing the model that can predict high spatial and temporal resolution images of using geostationary imager infrared channels through Artificial Intelligence methods.

References

Chao Dong, Chen Change Loy, Kaiming He, Xiaoou Tang. Learning a Deep Convolutional Network for Image Super-Resolution, in Proceedings of European Conference on Computer Vision (ECCV), 2014.

NEWS IN THIS QUARTER

Outcomes of the GSICS Users Workshop 2019

By M. Bali (UMD), L. Flynn (NOAA), Viju John (EUMETSAT), Bomin Sun(NOAA) and Cheng-Zhi Zou (NOAA)

The GSICS Users Workshop returned this year after missing last year. It was organized as a part of the ITSC-XXII in Saint Saviour, Canada. Topics vital, not only to the GSICS Community, but also to the wider calibration and validation community were on the agenda. The workshop aimed at understanding requirements of the ITOVS Community, Climate Community, Cubesat community, WIGOS and its components (e.g., GRUAN and GNSS) and providing those communities an opportunity to learn about GSICS algorithms and inter-calibration data.

Mitch Goldberg (GSICS Executive Panel Chair) kickstarted the meeting by providing an introduction of GSICS to the audience. The introduction included the purpose and history of GSICS, and showed how GSICS-style instrument monitoring is critical to the users of Earth Observation data. Channels for providing GSICS knowledge and data sharing include the GSICS product catalog, the GSICS Newsletter and the yearly State of Observing System report that GSICS delivers to the CGMS. This report summarizes the performance of instruments monitored by the individual GPRCs. The talk conclude with identification of GSICS connections to the WMO Integrated Observing System (WIGOS).

GSICS is now a component of the WIGOS and has prepared documents that are under review by WIGOS.In-orbit references are crucial tools used by the GSICS community to monitor instruments through inter-comparison. Dave Tobin from the University of

Wisconsin touched on this topic and suggested a selection matrix (attributes) that can be used to identify an in-orbit reference. Being a member of the CrIS (Cross-track Infrared Sounder) calibration team, he took CrIS as an example and showed that the CrIS and IASI (Infrared Atmospheric Sounding Interferometer) family of instruments GSICS are references in the IR. The infrared community is a very active in GSICS and has several GEO-LEO cross calibration products. Dorothea Coppins from EUMETSAT gave a talk focused on GSICS IR inter-calibration activities. The four main GSICS IR products include Classical GSICS Products, GSICS Prime Products, GSICS IR Reference Products and Future GSICS Products. Dorothea provided an overview of recent changes to processing to IASI-A after it entered its end-of-life phase. She recommended that GSICS members should switch to IASI-B or IASI-C as references. In summary, the IASI-A has the following behavior currently.

- SWIR: V. small positive differences (<<0.1K)
- MWIR: V. small positive differences (<<0.1K)
- LWIR window: Small negative differences (<~0.1K)
- LWIR absorption: Larger negative differences (<~0.3K)

In the future KMA and CMA are expected to provide intercalibration products of AMI and FY-3.
Small satellites and cubesats are steadily acquiring new importance in the Earth Observation community**.** However these low cost solutions often lack an onboard calibration mechanism and need external references to maintain quality of measurements. Tiger Yang from NOAA gave an overview of Lunar Calibration target. His talk touched on various issues, a key issue for microwave cubesats and small satellite constellation is implementing a consistent calibration algorithm. Permanent Reference Targets (PRTs) with high stability and well-known microwave brightness temperature can not only help to evaluate the instrument calibration accuracy, they can also be used to evaluate the long-term calibration stability of microwave sensors. The radiation of the Moon is very stable in microwave spectrum; attributed to its stable geophysical properties. The only factors that change the magnitude of lunar microwave radiation in satellite observations are its surface temperature, which is determined primarily by its phase angle, and its position in the Field of View (FOV). Therefore, there is potential to take the Moon as a PRT to evaluate the calibration accuracy and assess the long-term calibration stability for microwave radiometers. In this study, a microwave brightness temperature simulation model for moon's disk was developed and validated based on ATMS space view observations. To demonstrate the effectiveness of proposed lunar calibration model, five years of lunar observations from NPP ATMS were collected and evaluated by the model simulations. Results show that ATMS calibration accuracy and stability can be well assessed by taking the moon as a reference calibration target.

Qifen Lu (CMA, MW Subgroup Co-Chair) shared a vision of the GSICS Microwave Subgroup. He gave the scope of the GSICS MW subgroup. A key was to understand user requirements for monitoring and CDR creation. Sharing of tools such as SNO, Double Difference, RTM are recognized as the near term goals. He also spoke about the response of the GSICS MW subgroup to the CGMS actions to organize the expert meeting on the inter-calibration of operational PMW sensors to meet the WIGOS targets of 2040. The expert meeting was organized at the CEOS WGCV MWSC meeting in Darmstadt and the GSICS Annual Meeting in Frascati 2019. The talk concluded with a summary of plans for generating MW NRT GSICS products, and stressed the need for explaining MW Subgroup activities and strengthening the connections with other groups including GPM-X, CEOS, and ISWG.

GSICS is now a part of the WMO Integrated Observing System (WIGOS). GSICS should be able to achieve interoperability with other components of the WIGOS observing system. One such component of WIGOS is the GRUAN (GCOS Reference Upper-Air Network). The next talk from Bomin Sun provided an overview of progress in using GRUAN observations to monitor Satellite Infrared and Microwave Sensors thereby exploring a method of interoperability between GSICS and GRUAN.
GRUAN is a reference observing network designed to provide fully characterized data records for upper-air climate change detection. A concerted effort to utilize GRUAN to supplement the Global Space-based Inter-Calibration System (GSICS) in the monitoring and assessment of environmental satellite sensors was initiated at the GSICS Annual meeting in 2017. Those sensors include the Cross-track Infrared Sounder (CrIS), the Infrared Atmospheric Sounding Interferometer (IASI), the High-resolution Radiation Sounder (HIRS), the Advanced Technology Microwave Sounder (ATMS) and the Advanced Microwave Sounding Unit (AMSU).

In this work, the feasibility of using GRUAN observations to monitor satellite sensor data are explored in two areas. The first is to compare the GRUAN temperature observations with polar satellite microwave data in trends and inter-annual variability. The

doi: 10.25923/77r0-wm17

satellite microwave dataset includes calibrated fundamental Climate Data Records (FCDRs) generated by NOAA Center for Satellite Applications and Research (STAR). The second is to understand the consistency of GRUAN radiosonde humidity observations with satellite water vapor sensitive sensor data. Radiative Transfer Model (RTM) simulations are used to convert GRUAN atmospheric profiles into the radiance space for comparison with collocated hyperspectral infrared sensor data. Collocation uncertainty and uncertainty in satellite sensor, GRUAN and RT model are taken into account in the assessment.

This work supports GSICS and GRUAN objectives to monitor microwave and infrared sensors from space-based platforms including the determination of the absolute accuracy of the sensors.

Users of GSICS products and algorithms are crucial to devising goals of GSICS. The Climate Data Record developers are one of the main users of GSICS algorithms. The next talk by Viju John (FIDUCEO expert from EUMETSAT) provided an important overview of the algorithms and data the FIDUCEO team used to produce Climate Data Records from Satellite observations. One of the main objectives of the FIDUCEO was to develop a widely applicable metrology framework for Earth Observation to establish traceable uncertainty and Climate information and subsequently develop climate Data records. At the heart of the algorithm of generating FCDR lies the Measurement Function Centered Analysis. Another novel idea developed in the project is the harmonisation of sensor time series. He gave an overview of the Harmonization, Spectral Shifts and Uncertainty estimates that are developed by the FIDUCEO project. The FIDUCEO project generated AVHRR, HIRS, MW Humidity Sounder, and Meteosat Visible channel FCDR. The final portion of the talk provided suggestions, recommendations and discussion topics to the GSICS community on possible improvements to GSICS products and algorithms. These included:

- Starting at the count level will enable a FIDUCEO style analysis;
- Knowledge transfer: How can it continue? Can GSICS adapt FIDUCEO methods?
- GSICS should consider inter-channel correlations in bias analysis.
- Request for open availability of GSICS matchup databases and inter-calibration code.

NOAA undertook a major reprocessing activity wherein they regenerated the SDR for various instruments on board the JPSS missions. Cheng-Zhi Zou from NOAA provided an overview of the JPSS/SNPP reprocessing of the ATMS SDR. The goal of the reprocessing of the SDR was to update initial calibration algorithms update and apply a unified calibration algorithm to generate consistent SDR. The main benefits were an improvement in EDR and gather building blocks of Climate data records and climate trend analysis. The new ATMS SDR is available in addition to reprocessed CrIS, VIIRS and OMPS SDRs. Presently over six years of SNPP SDR has been reprocessed and a software repository for the reprocessing system has been developed.

The last two talks were given by Manik Bali and Larry Flynn from the GSICS Coordination Center. These talks covered GSICS Products, Deliverables, Inter-operability platform and the ways in which one can participate in GSICS. Manik reported that GSICS has over 60 products in VIS and IR wavebands and four deliverables spanning VIS, IR, and MW. The GSICS Products can be accessed at https://www.star.nesdis.noaa.gov/smcd/GCC/ProductCatalog.php and the deliverables are accessed via the GSICS Wiki. Work is proceeding on building a new inter-operability platform combining TYPHON, PYGAC, PTROLL, SATPY and ARTS model that has the ability to intercompare different observing platforms (e.g., GRUAN vs. GSICS).

Larry covered the various pathways by which one could connect with GSICS activities and participate in them. These include the Quarterly Newsletter, Product Catalog, the GSICS Wiki and the information Kiosk maintained by GCC.

The presentations and discussions in the GSICS Users Workshop were well received by the ITSC community and its subgroups. Discussions resulted in key actions for the GCC.

The International Issues And Future Systems (IIFS) subgroup of ITSC made the following recommendation – Action **IIFS22-A18** to CGMS, "IIFS extended support to the GSICS effort and appreciated the presentations given on GSICS in the GSICS Workshop at ITSC-22."

The detailed agenda and minutes can be found at http://gsics.atmos.umd.edu/bin/view/Development/20191101

Discuss the Article

doi: 10.25923/77r0-wm17

Summary of GSICS/CEOS Workshop of SI-Traceable Space-based Climate Observing System

By Tim Hewison, EUMETSAT

This three-day workshop was hosted by NPL with backing by the UK Space Agency, who are supporting the ESA Earth Watch TRUTHS mission. With about 90 registered in-person attendees plus several more joining by WebEx, it combined the best of being small enough to be a true "workshop" yet large enough to span diverse disciplines. The conference format included a series of broad, topical presentations and discussions. These were uniformly of high quality, reflecting the calibre of the participants from a diverse range of communities. The high-level discussions focused on the common themes emerging and how to structure these into a concrete outcome in the form of a white paper, intended to provide guidance to decision makers to support the case for dedicated satellite missions operating instruments whose calibrations can be demonstrated on-orbit as directly traceable to SI-standards with well-described uncertainties. The key benefits of such missions are to provide:

a. Climate benchmark observations
b. Inter-calibration anchor references
c. Anchors for NWP – both for forecasts, but particularly for climate reanalyses

The outline of the white paper was circulated before the workshop and draft inputs where provided in key areas, which were presented at the workshop. These were revised after the workshop and are currently being consolidated and a synthesis of the key issues is being written by the organising committee. From the GSICS perspective, key issues are:

- GSICS working together with designers and operators of SI-traceable satellite missions to optimise their sampling strategy for inter-calibration.
    - Model + Observation Communities should aim to converge on assigning uncertainties.
- General lessons learnt from design of SI-Traceable satellite missions applicable to operational missions:
    - Design for stability key to using SITSATs/Vicarious Calibration – especially for a swarm of small satellites
    - Perform a thorough error analysis
    - Validated and tuned by pre-launch testing
        - Following "Test as you fly" principles
    - Importance of polarisation sensitivity – being low and well-characterised
    - Importance of Out-Of-Band sensitivity
    - Build-in checks post-launch and at end-of-life:
        - E.g. manoeuvres to vary temperatures, characterise RVS, view Moon, …
    - Consider use of some simple technology transfer
        - E.g. phase change materials to fix thermometry to absolute scale
    - Importance of independent analysis of common datasets to understand uncertainty characteristics
        - This requires Open access to L0 data and
        - establishing collaborative frameworks

Participants in the GSICS/CEOS Workshop (Image Courtesy NPL Management)

Discuss the Article

doi: 10.25923/77r0-wm17

Announcements

GSICS Annual Meeting 2020 to be held March 16-20, in Seoul, Korea

By Dohyeong Kim, KMA

The 2020 GSICS Joint Meeting on Research and Data Working Groups will be hosted by KMA/NMSC. The Venue is the GLAD Hotel Yeouido, Seoul, Korea from 16 (Monday) - 20 (Friday) March 2020.

The meeting will begin with a Mini-Conference, which is a half-day session to introduce topics of interest to the host organization and cover topics related to future inter-calibration products. This will be followed by a Plenary session. The plenary is a member session and will cover topics related to the UV-VISNIR-IR-MW subgroups of GRWG and to activities of the GDWG and GCC. Reports from GSICS Processing and Research Centers (GPRC s) and discussion on cross-cutting issues will also be included. Following this, the GSICS Data Working Group (GDWG) and the GSICS Research Working Group (GRWG) will break out into parallel sessions while converging on important topics. The meeting will finish with a wrap up session where participants will discuss a summary of the meeting and the status of action items.

For details about participation and accommodation visit nmsc.kma.go.kr/gsics2020.html (http://106.10.44.188/)

Important dates and deadlines

- VISA Application 31 January 2020
- Meeting Registration 29 February 2020
- Hotel Reservation 29 February 2020

For plans regarding meeting agenda and the planning meeting minutes visit

http://gsics.atmos.umd.edu/bin/view/Development/20191122
http://gsics.atmos.umd.edu/bin/view/Development/MeetingsAndConferences
http://gsics.atmos.umd.edu/bin/view/Development/AnnualMeeting2020

Seventh WMO Workshop on the Impact of Various Observing Systems on NWP

By World Meteorological Organization

The 7th WMO Workshop on the Impact of Various Observing Systems on Numerical Weather Prediction will be organized by the Korea Meteorological Administration in Seoul, Republic of Korea, 12-15 May 2020. Participants are expected from all the major NWP centers that are active in the area of impact studies.

With the ultimate goal to support the optimization of the observing effort, the Workshop will discuss the results of a range of studies evaluating the impact of specific components of the space and ground-based observing system, including observing system experiments (OSEs), adjoint and ensemble-based forecast sensitivity observation impact (FSOI and EFSOI), and estimates of analysis uncertainty.

Information about the workshop is available at https://community.wmo.int/meetings/NWP-7

doi: 10.25923/77r0-wm17

Call for SPIE Optics and Photonics Earth Observing Systems XXV conference to be held in San Diego Aug 23-27, 2020

By James J. Butler and Jack Xiong, NASA

The annual SPIE Optics and Photonics' Earth Observing Systems XXV Conference will be held August 23-27, 2020 at the San Diego Convention Center, San Diego, CA.

SPIE. The international society for optics and photonics

The Earth Observing Systems XXV conference welcomes the submission of papers over a wide range of remote sensing topics. Papers are solicited in the following general areas:

- Earth-observing mission studies including new system requirements and plans
- commercial system designs
- electro-optical sensor designs and sensitivity studies
- ultraviolet through thermal infrared, microwave, radar, and lidar remote sensing systems
- hyperspectral remote sensing instruments and methodologies
- instrument sub-system and system level pre-launch and on-orbit calibration and characterization
- vicarious calibration techniques and results
- satellite instrument airborne simulators
- techniques for enhancing data processing, reprocessing, archival, dissemination, and utilization
- conversion from research to operational systems
- on-orbit instrument inter-comparison techniques and results
- enabling technologies (optics, antennas, electronics, calibration techniques, detectors, and models)
- sensor calibration traceability, uncertainty, and pre-launch to on-orbit performance assessments
- lunar radiometry and photometry
- remote sensing data acquisition and analysis.

The conference call for papers is available online at http://spie.org/OP420. Conference abstracts are due February 12, 2020, and proceedings manuscripts are due July 29, 2020.

GSICS-Related Publications

Alhammoud, Bahjat, Jan Jackson, Sebastien Clerc, Manuel Arias, Catherine Bouzinac, Ferran Gascon, Enrico G. Cadau, Rosario Q. Iannone, and Valentina Boccia. "Sentinel-2 Level-1 Radiometry Assessment Using Vicarious Methods From DIMITRI Toolbox and Field Measurements From RadCalNet Database." *Ieee Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 12, no. 9 (September 2019): 3470–79. https://doi.org/10.1109/JSTARS.2019.2936940.

Doelling, D.R., K. Khlopenkov, C. Haney, R. Bhatt, B. Bos, B. Scarino, A. Gopalan, D.S. Lauretta, Inter-Calibration of the OSIRIS-REx NavCams with Earth-Viewing Imagers, Remote Sens. 2019, 11, 2717; doi:10.3390/rs11222717

John, Viju O., Tasuku Tabata, Frank Ruethrich, Rob Roebeling, Tim Hewison, Reto Stockli, and Joerg Schulz. "On the Methods for Recalibrating Geostationary Longwave Channels Using Polar Orbiting Infrared Sounders." *Remote Sensing* 11, no. 10 (May 2, 2019): 1171. https://doi.org/10.3390/rs11101171.

Mahesh Shrestha, L. Leigh, D, Helder, Classification of North Africa for Use as an Extended Pseudo Invariant Calibration Sites (EPICS) for Radiometric Calibration and Stability Monitoring of Optical Satellite Sensors, Remote Sens. 2019, 11(7), 875; https://doi.org/10.3390/rs11070875 (I looked over previous quarterlies, I do not see this one)

Ruethrich, Frank, Viju O. John, Rob A. Roebeling, Ralf Quast, Yves Govaerts, Emma R. Woolliams, and Joerg Schulz. "Climate Data Records from Meteosat First Generation Part III: Recalibration and Uncertainty Tracing of the Visible Channel on Meteosat-2-7 Using

Reconstructed, Spectrally Changing Response Functions.” *Remote Sensing* 11, no. 10 (May 2, 2019): 1165. https://doi.org/10.3390/rs11101165.

Shrestha, Mahesh, Md Nahid Hasan, Larry Leigh, and Dennis Helder. “Extended Pseudo Invariant Calibration Sites (EPICS) for the Cross-Calibration of Optical Satellite Sensors.” *Remote Sensing* 11, no. 14 (July 2, 2019): 1676. https://doi.org/10.3390/rs11141676.

Shrestha, M., N. Hasan, L. Leigh, and D. Helder. “Derivation of Hyperspectral Profile of Extended Pseudo Invariant Calibration Sites (EPICS) for Use in Sensor Calibration.” *Remote Sensing* 11, no. 19 (2019). https://doi.org/10.3390/rs11192279.

Sterckx, S., and E. Wolters. “Radiometric Top-of-Atmosphere Reflectance Consistency Assessment for Landsat 8/OLI, Sentinel-2/MSI, PROBA-V, and DEIMOS-1 over Libya-4 and RadCalNet Calibration Sites.” *Remote Sensing* 11, no. 19 (2019). https://doi.org/10.3390/rs11192253.

Tiejun Chang, Xiaoxiong (Jack) Xiong, and Ashish Shrestha "Assessment of MODIS TEB calibration performance using deep convective clouds", Proc. SPIE 11127, Earth Observing Systems XXIV, 111271J (9September2019); https://doi.org/10.1117/12.2528043

Zhang, L., P. Zhang, X. Hu, L. Chen, M. Min, N. Xu, and R. Wu. “Radiometric Cross-Calibration for Multiple Sensors with the Moon as an Intermediate Reference.” *Journal of Meteorological Research* 33, no. 5 (2019): 925–33. https://doi.org/10.1007/s13351-019-9008-y.

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:

The GSICS Quarterly Editor would like to thank Lawrence Flynn (NOAA) and Fangfang Yu (NOAA) for reviewing articles in this issue.

Published By

GSICS Coordination Center
NOAA/NESDIS/STAR NOAA
Center for Weather and Climate Prediction,
5830 University Research Court
College Park, MD 20740, USA