Quarterly

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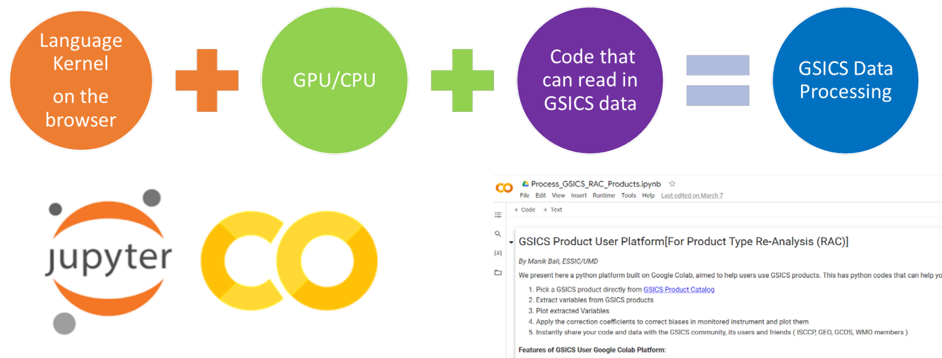

Figure above shows the Colab/Jupyter platform for code instance and data sharing.

GSICS and CEOS Notebooks: Delivering processing Code and Data to the Users

By Manik Bali (UMD) and Paolo Castracane (Rhea System for ESA)

Starting in 2022, GSICS and CEOS underwent a paradigm shift in the way products, algorithms and data are delivered to the users. Users are now provided code (Python/C/C++), which can read and generate visualizations for the GSICS Products and CEOS Data directly from the browser itself. The code can be directly plugged into production pipelines with minimal overhead.

Notebooks add a new dimension to the GSICS and CEOS data distribution theme wherein data can be processed directly in the browser and processing algorithms can be shared in real time among developers worldwide. Since Notebooks are built on the Google Colab, they allow access to CPU/GPU/TPU directly in the browser. Notebooks can be saved locally as Jupyter notebooks and run on local machines. We present here some of the GSICS Notebooks and describe the underlying architecture.

GSICS Notebooks

GSICS has over 72 products distributed through the GSICS Products Catalog (LINK). In addition, there are deliverables and data sets. The following notebooks are written in Python and are able to process the data

- **GSICS RAC Products** (see here): Processes GSICS RAC products.
- **GSICS NRT Products** (see here): Process GSICS NRT products.
- **Simultaneous Nadir Overpass (**see here**):** Identifies Collocated pixels.
- **OSCAR Webpage (**see here**):** Identifies instruments of interest on WMO OSCAR page.

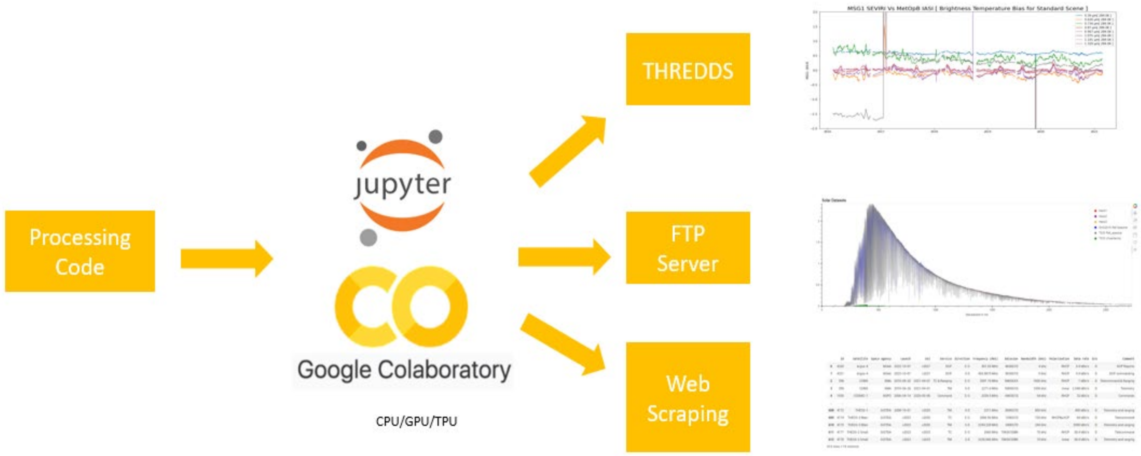

Figure1: Shows the architecture of GSICS and CEOS Notebooks

- **GMX inter-calibration tables** (*Google Colab*) and Reference Radiance (*Google Colab*): Notebook visualize calibration coefficients. Creates a platform to apply them for constructing adjustments.
- **GSICS Deliverables** (GIRO SRF): this notebook visualizes GIRO SRF calibration coefficients.
- **Solar Data Sets** (Notebook, visualize several Solar Data Sets and compares them see here): Compares TSIS-1 Solar data set with multiple solar data sets
- **State of Observing System** (Colab file): Creates the State of Observing System charts for annual reports.

System requirements

- Browser with internet connection
- A free Colab account visit here.

CEOS Notebooks (Metrological Notebooks – CoMet Toolkit)

The Quality Assurance framework for Earth Observation (*QA4EO*) was established and endorsed by the Committee on Earth Observation Satellites (*CEOS*). QA4EO ensures credible and reliable interpretation of environmental observations from satellites and in-situ measurements by requiring that associated uncertainty information is provided. The approaches defined within QA4EO enable the Earth observation (EO) community to develop quantitative characterization of uncertainty in EO data. However, practically implementing these methods is not trivial and can be time consuming. To facilitate this, the *CoMet* (Community Metrology) Toolkit has been developed to enable easy handling and processing of dataset error-covariance information. This toolkit aims to abstract away the complexity of dealing with uncertainties. There are a number of tools included in this toolkit which are available on github and are installable via pip. More modules are planned to extend the toolkit capabilities.

The current included tools are:

- **comet_maths**: is a python module with useful mathematical algorithms (including interpolation with uncertainties) for general use as well as for use in the other tools in the CoMet toolkit.
- **obsarray**: an extension to xarray for defining, storing and interfacing with uncertainty and measurement error-covariance information in NetCDF files using standardized metadata.
- **punpy**: is a tool for "Propagation of UNcertainties in Python". It propagates uncertainties on input quantities through any python function, evaluating the uncertainty on the output. These input data uncertainties can be defined using **obsarray**.

Corresponding documentation and Jupiter notebooks are available in *Tools* and *Examples* section respectively.
The CoMet Toolkit has been developed at NPL and has been funded by: The UK's Department for Business, Energy and Industrial Strategy's (BEIS) National Measurement System (NMS) programme and by the IDEAS-QA4EO project funded by the European Space Agency.
The relevant links for both GSICS Notebooks and CoMet Toolkit are reported on the Tools section of the CEOS Cal/Val Portal (https://calvalportal.ceos.org/tools)

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An updated version of the Cross-Calibrated Multi-Platform Wind Analysis

By Carl A. Mears[1], Tong Lee[2], Lucrezia Ricciardulli[1], Xiaochun Wang[3] and Frank Wentz[1] [1]Remote Sensing Systems, [2]NASA JPL,[3]UCLA

Accurate estimates of ocean surface vector winds (OSVW) are important for numerous areas of Earth system science and applications including oceanography, meteorology, climate, maritime safety, and renewable energy**.** Over the past decades, substantial progress has been made for observing OSVW using a number of techniques and instruments, including in situ measurements from moored buoys, fixed platforms and sail drones, and remote sensing retrievals from satellite and airborne sensors. OSVW varies on a wide range of spatial and temporal scales, posing a significant challenge to OSVW monitoring. Moored buoys provide accurate winds at low and moderate winds, but are sparsely distributed and mostly in the tropics and the continental margin. Satellite winds have more uniform sampling and good geographical coverage, but suffer from gaps between the satellites' swaths and infrequent temporal sampling for a single sensor. Reanalysis systems assimilate satellite and in situ winds to produce a spatially complete and uniform OSVW product, but have uncertainties due to errors of the modeling and assimilation system. In particular, reanalysis winds are typically too low at high winds when compared to satellite retrievals and *in situ* measurements. The Cross-Calibrated Multi-Platform (CCMP) OSVW product is designed to alleviate these shortcomings. By combining measurements from a constellation of wind-sensing satellites with a background field from reanalysis using a variational analysis method (VAM), level-4 wind products closely tied to the satellite winds were produced (Atlas et al., 2011; Mears et al., 2019). The VAM is tuned so that when satellite retrievals are available at times within 6 hours of the analysis time, the results closely follow the satellite vector wind (or wind speed, for the cases when the satellite is only capable of retrieving wind speed). Where no retrievals are within 6 hours, the results revert to the background wind field (i.e., reanalysis winds). The accuracy of previous versions of CCMP (1.1, 2.0, 2.0 NRT) is compromised by systematic wind speed biases between the satellite retrievals and the reanalysis-based background fields. For the new version, version 3.0 (Mears et al., 2022), the background field is adjusted to agree with satellite retrievals from scatterometers (QuikSCAT and ASCAT-A) in a statistical sense. Using a histogram matching technique, a multiplicative adjustment was derived that depends on wind speed, latitude, and time of year. The systematic differences in wind speeds retrieved from passive microwave radiometer instruments and those retrieved from scatterometers were removed using seasonally varying, location-dependent adjustments to make the radiometer winds more closely match the scatterometer winds. Satellite wind retrievals, inferred from wind-induced ocean-surface roughness, are relative to the moving ocean surface. Surface current speed can reach up to 1 m/s in some parts of the ocean. The background wind field, however, is relative to a stationary frame on the Earth. Therefore, we also adjusted the background wind field so it is relative to the moving ocean surface. The adjustment is made using the OSCAR ocean-surface current analysis real-time (Dohan & Maximenko, 2010).

Neither CCMP 2.0 or CCMP 3.0 include measurements from ASCAT-B allowing ASCAT-B to be used as an independent validation source. In the comparison, we consider ASCAT-B measurements within one hour of the CCMP time. For our validation, we divide these colocations into two subsets: all colocations ("all"), and only those colocations where a satellite observation was not included in the CCMP analysis ("NOSAT").

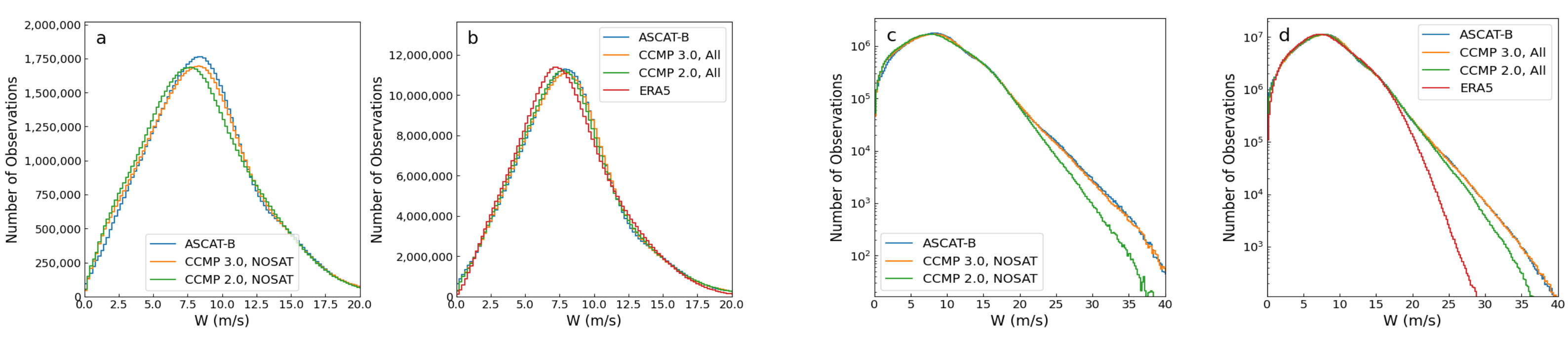

Figure 1. Histograms of windspeeds for CCMP 2.0 and CCMP 3.0 collocated with observations made by ASCAT-B. The panels a and c show locations and times where no satellite observations were included in the CCMP analysis but an ASCAT-B observation was available for comparison. The panels b and d show all colocations with ASCAT-B. The two graphs on the right are the same as the two on the left except that they are plotted using a log scale for the y-axes to emphasize high wind results. The analysis was done using data from 2012 to 2019.

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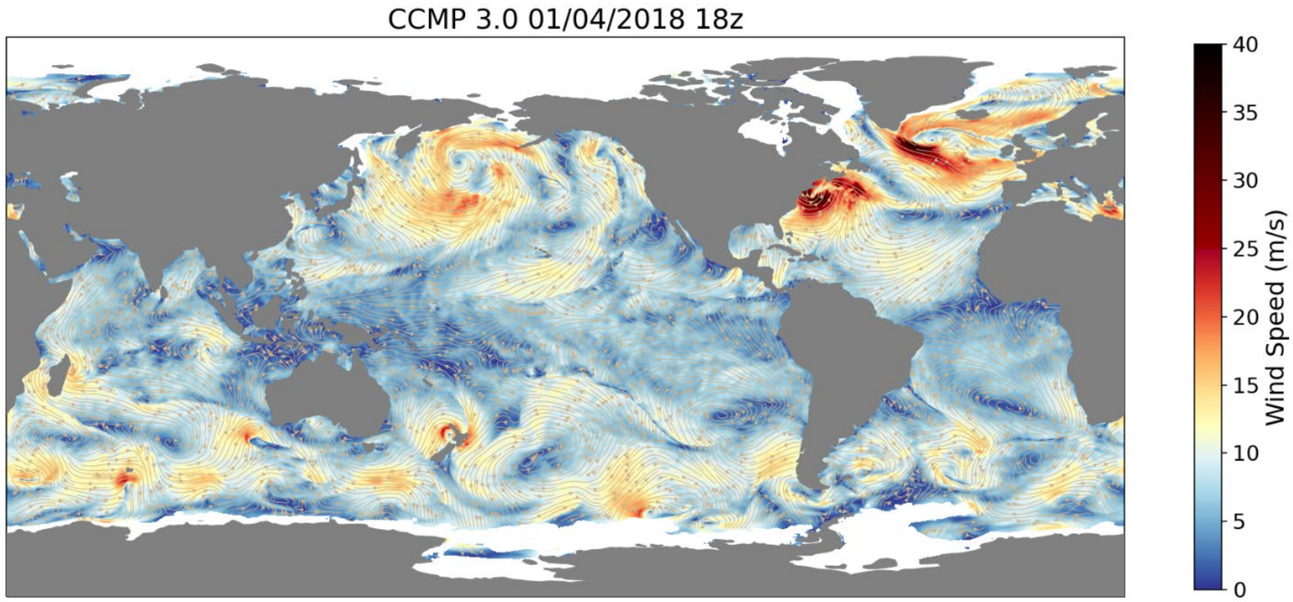

Figure 2. Global map of Ocean Surface Vector Winds from CCMP 3.0 for January 4, 2018, at 1800Z.

The NOSAT colocations occur in gaps between all available satellite swaths or in locations/times where precipitation makes retrieval of wind information impossible. If the NOSAT location is more than ~50 km from a satellite measurement then CCMP output is close to the background wind. If it is closer (less than ~50 km from a satellite measurement), the CCMP output is affected by nearby satellite observations via the smoothness constraints in the VAM. Figure 1 shows histograms of wind speed for the cases with no satellite retrievals included (NOSAT) and all colocations with ASCAT-B (all). CCMP 2.0 shows fewer high winds than ASCAT-B with the difference being larger for the NOSAT case. In panels b and d, the wind speed histogram for ERA5 wind speeds collocated with ASCAT-B is also shown. ERA5 peaks at a lower wind than CCMP and ASCAT-B, and has also fewer high wind events.

The dataset CCMP 3.0 is currently available from 1993-2019 at www.remss.com/measurements/ccmp. Work is in progress to extend it to the current time. Satellite data included come from 13 radiometers (5 SSM/I, 3 SSMIS, AMSR-E, TMI, WindSat, AMSR2, and GMI) and two scatterometers, QuikSCAT and ASCAT-A. We withheld ASCAT-B as an independent source of vector winds for evaluation of uncertainty in CCMP, but it will be included in an updated version.

Figure 2 shows an example global map of the CCMP 3. 0 analysis for January 4, 2018. At this time, there was an intense storm (a "nor'easter") impacting the east coast of the United States and Canada as well as another intense storm in the North Atlantic.

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Determining pseudo-invariant calibration sites for comparing inter-mission ocean color data

By Jun Chen (Xi'an Jiaotong University), Na Xu (China Meteorological Administration), Xianqiang He (Second Institute of Oceanography, Ministry of Natural Resources), Wenting Quan (Shaanxi Meteorological Service Center of Agricultural Remote Sensing and Economic Crop), Qingyin He (China University of Geosciences), Qijin Han (Xi'an Jiaotong University), Delu Pan (Second Institute of Oceanography, Ministry of Natural Resources)

Comparing inter-mission space instrument performance is crucial to accurate satellite measurements which guarantees the quality of ocean color products. However, comparing inter-mission instrument performance is limited by strong dispersion, which clearly originates from the spatial and temporal variability inside the oceanic sampling sites[1]. This study designed a novel comprehensive score metric (CSM) to quantitatively identify the candidate pseudo-invariant calibration sites (PICS) for inter-mission comparisons[2]. The CSM is calculated from a year of ocean color and meteorological products from 2018 using a pixel-by-pixel method with a simple average of a temporal meteorological metric, a spatial aerosol metric, a temporal optical metric, a spatial optical metric, a data quality metric, a spectral shape metric, and a directional homogeneity metric. The study finds that atmospheric and oceanic conditions from two smooth belts in the low latitude open ocean were more clear, stable, and homogeneous than other regions when the threshold CSM > 0.6. With image data from the Visible Infrared Imaging Radiometer (VIIRS) and Medium Resolution Spectral Imager II (MERSI II), the candidate PICS with CSM larger than 0.6 were more effective than regions with low CSM in providing stable synchronous data for inter-mission comparisons.

To quantitatively describe the importance of meteorological, oceanic, and angular parameters in finding a stable homogeneous ocean region, a score metric ranging from 0 (poor) to 1 (good) for each item of our criteria is designed as (Fig1):

$$score = \begin{cases} 1, for|x < x_l \\ \dfrac{x_u - x}{x_u - x_l}, for|x_l < x < x_u \\ 0, for|x > x_u \end{cases}$$

where x is a variable that reflects the covarying relationship of the meteorological, oceanic, or angular parameter with the stability of ρ_t, including but not limited to interday standard deviation (ISTD) , unbiased mean relative error (UMRE), and the coefficient of variation (CV). The subscripts, *l* and *u*, are the lower and upper limits of *x*, which represent the "good" and "poor" states of the criteria. Finally, the comprehensive score metric as the average score of all potential criteria (N) is defined as following:

$$GSM = \frac{1}{N}\sum_{i=1}^{N} Score_i$$

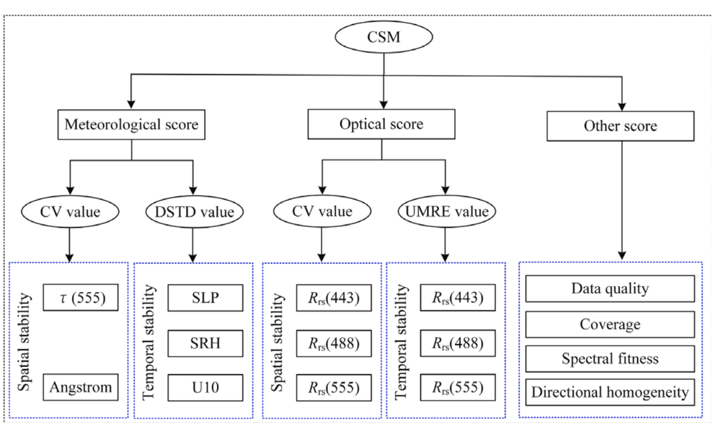

Fig. 1. Flowchart of the system to determine candidate pseudo-invariant calibration sites for inter-mission comparison

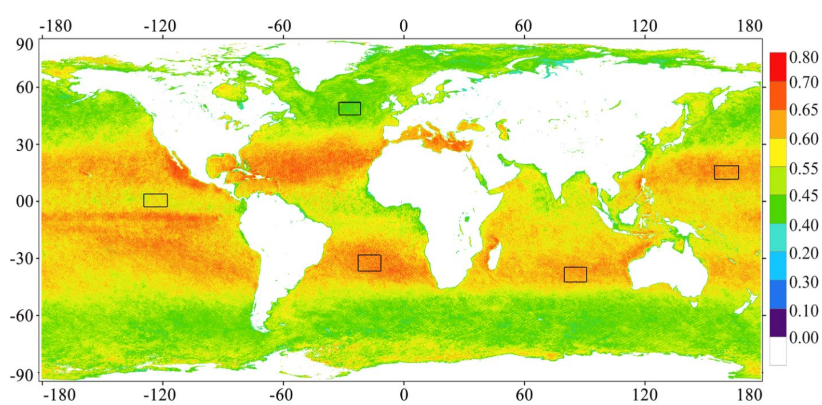

Fig.2 CSM for the global oceans derived from the satellite data from 2018. Each score includes meteorological elements, optical properties, data quality, spectral shape, and directional homogeneity for each of which the within-class average was used to estimate the CSM when there were several different elements in the same category. The white color represents land.

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To assess the spatial and temporal homogeneity of the global oceans in CSM calculation, this study collected one year of Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua (MODISA) and Terra (MODIST) Global Area Coverage (GAC) Level-3 data from 2018. These ocean color data include aerosol optical depth at 869 nm (τ(869)), aerosol angstrom, and *R*rs data with a 4-km spatial resolution. In addition, the IOPs data processing system, IDAS (Chen et al. 2016) is employed to estimate the residual error in the satellite *R*rs to improve the data quality. Furthermore, 12226 FY-3D Level-1 images of the global oceans from 2018 were randomly selected to find regions with acceptable spectral shapes and directional homogeneity for cross calibration analysis. 55 Visible Infrared Imaging Radiometer Suite (VIIRS) images were collected to determine how the MERSI II instrument degrades over time over the open oceans, because the spectral characteristics of VIIRS are much closer to MERSI II than the MODIS spectral characteristics. NCEP ancillary data from 2018 for determining the most temporally homogeneous candidate sites with regard to meteorological conditions. The NECP data included the 10m wind speed (U10), sea level pressure (SLP), and relative humidity (RH). All above data had a six-hour time resolution and 1°×1° grid resolution

Based on the ocean color and meteorological products, the average of the seven scores from the meteorological and optimal score metrics are calculated. Then, the CSM was calculated and the CSMs for the global oceans are shown in Fig. 2. Compared with score metrics, the temporal meteorological scores, spatial aerosol scores, temporal optical scores, spatial optical scores, and data quality scores that supported the open oceans be the regions for candidate PICS, there were two metrics with the spectral shape scores and directional homogeneity scores that considered the coastal and polar oceans were better options for PICS than the open oceans. Briefly, the gradual differences in the CSMs were not very significant for the global oceans, with the mean and STD being 0.551 and 0.066, respectively. The CSMs that exceeded 0.6 represented the Atlantic, Pacific, and Indian Gyres, and the CSM < 0.5 represented the equatorial, coastal, mid-latitude, and high-latitude oceans. The lower CSMs at low latitudes occurred because there was more spatial and temporal stability , and the atmospheric and oceanic conditions were more homogeneous even though the spectral shapes of the lower latitudes were slightly steeper than the coastal and polar region spectral shapes. Generally, an intermission comparison should follow rigorous illumination-observation criteria, so the directional homogeneity score metric might be not very relevant with regard to intermission comparison. Specifically, when we excluded the homogeneity score metric from our analysis, the CSMs for the polar and coastal regions decreased, but the spatial pattern stayed consistent with the results shown in Fig 2. These findings imply that when comprehensively considering the spatial and temporal variability of the meteorological and oceanic conditions, the low latitude open ocean with CSM > 0.6 could be a candidate PICS. At low latitudes, the CSM was > 16 % higher than the CSMs for the other regions such as the coastal and polar oceans

The CSM spatial distribution result reveals that the candidate PICS were mainly in two smooth belts in the open oceans in low latitude regions except for the equatorial oceans where the CSM was clearly higher than for the non-equatorial open ocean regions. The two smooth belts were ideal because they had clear, stable, and homogeneous meteorological conditions and oceanic optical properties that scored significantly better than the coastal and high latitude oceans. However, due to natural optical properties found in the oligotrophic open ocean, the spectral shape fitness and directional homogeneity of our ideal two smooth belts were slightly poorer than for the other regions. These results suggested that the CSM values were “experimental” but, under restrictive conditions, were sufficient for an inter-mission comparison and calibration application.

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An Overview of the Landsat 8 and Landsat 9 Underfly Cross-Calibration Analysis

By G. Gross, South Dakota State University

Over its 50-year history, the Landsat Program has launched numerous satellites into orbit to observe planet Earth for various applications. Cross-calibration is often required to keep radiometric consistency between old sensors and new ones. A maneuver has been performed on multiple occasions to help with this process, known as the Underfly. In November 2021, the newly launched Landsat 9 flew underneath Landsat 8 to collect coincident images before settling into its final orbit. These near identical images would minimize many forms of uncertainty in the cross-calibration analysis. The sensors on board each of the satellites also reduced several sources of uncertainty due to the instruments being near clones of each other. The first calibration took place at the end of the initial on-orbit verification (OIV) period, and the results from that analysis are shown in this article.

In the months leading up to the Underfly Event, three main sources of uncertainty were identified: geometric, spectral, and angular in the form of the Bidirectional Reflectance Distribution Function (BRDF) effect. The first of these, geometric, was already predetermined "to be consistent within 12m" according to geometry experts at USGS EROS [1]. Since the sensors on board each satellite were nearly identical, spectral uncertainty had very little effect on the cross-calibration analysis compared to previous ventures. However, there were still minor differences in the relative spectral responses (RSRs) between the instruments, which could be corrected for using a Spectral Band Adjustment Factor (SBAF). These SBAFs were target-dependent, so SBAFs were calculated for various land cover types. The land cover types used in this analysis were the International Geosphere–Biosphere Programme (IGBP) surface classifications, which is a system that many projects in the remote sensing community use. Once such example is the MODIS land cover type product [2].

For the BRDF analysis, this MODIS product was used in conjunction with the MODIS BRDF product to determine the BRDF parameters for each IGBP land cover type. This analysis provided insight into how much reflectance change to expect depending on where the two sensors were in relation to each other, the sun, and the target. It was determined that the view zenith angle difference (VZAD) between the sensors had the greatest effect on observed reflectance difference. This was especially the case if the sensors and the sun were azimuthally aligned with respect to a target, which is referred to as the principal plane. In Figure 1a, the cross-section along the 90° azimuth angle signifies the principal plane and is directly in the "hot spot" of the model. The closer the sensor's view azimuth angle (VAA) is to the principal plane, the steeper the cross-section due to that hot spot, shown in Figure 1e. The analysis of how VZAD affected BRDF eventually became the basis of the cross-calibration analysis.

Once the BRDF parameters were determined for each IGBP type using MODIS data, this analysis somehow needed to be carried over to Landsat. The Extended Pseudo Invariant Calibration Site (EPICS) project at South Dakota State University solved the problem [4]. "EPICS was developed to identify every potential Pseudo Invariant Calibration Site (PICS) on the planet" and sorts every identified pixel into one of 500 clusters [3]. Using average reflectance profiles produced from the IGBP MODIS data, these 500 clusters were matched with their closest IGBP land cover type.

With the world sorted into land cover types, the underfly data could then be processed. Each Landsat 8 scene was overlapped with its corresponding Landsat 9 scene, with each of their reflectance statistics recorded as well as the reflectance ratio statistics. These statistics were binned by 0.25° VZAD, so any scene pair could have up to six VZAD slices. By plotting VZAD and ratio mean against each other, a linear trend is obtained, shown in Figure 2. As can be seen, there is very little data around VZAD = 0°, where the sensors would have been directly over each other. During the actual underfly event, the instruments were orbiting over the ocean when they were at VZAD = 0°, so no data was collected. To account for this, a linear equation was fit to the data in Figure 2. The intercept at 0° almost completely

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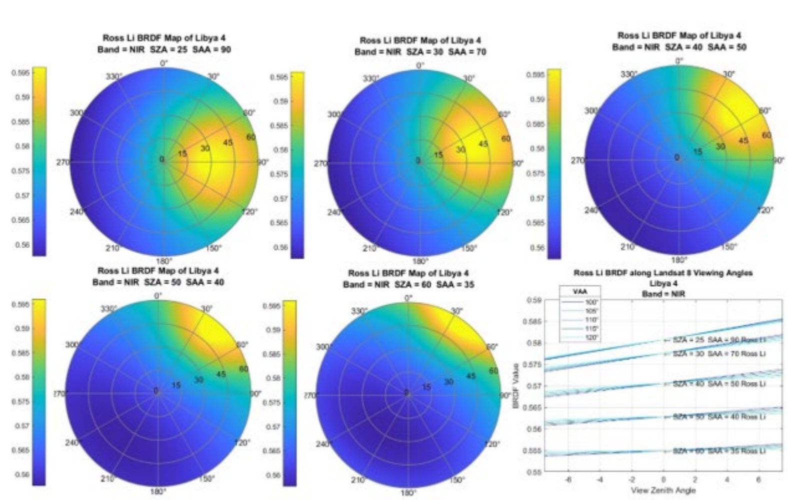

Figure 1. (a–e): BRDF models of desert area for various solar zenith and azimuth angle locations. Note how bright spot follows solar location as the sun moves lower in the sky. **(f):** Linearity of BRDF versus VZA for entire range of Landsat viewing angles. Note how the slope is greater as the sensor view angle moves closer to the "hot spot". Image source: [3].

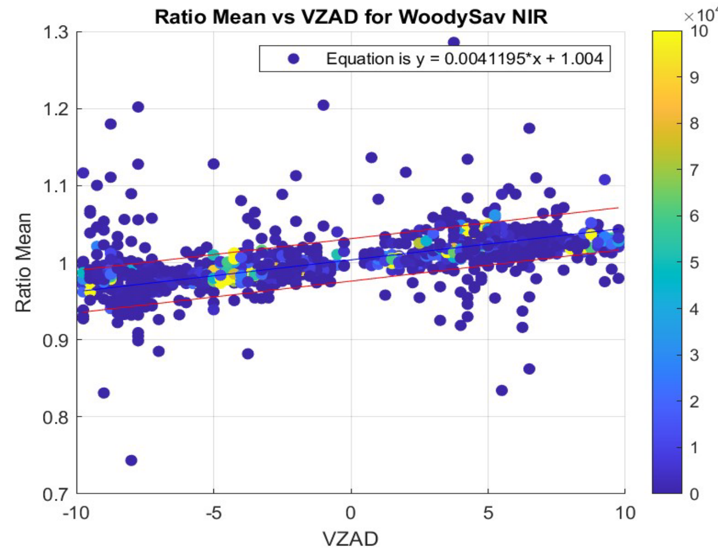

Figure 2. VZAD vs. ratio mean plot. Note the intercept at VZAD = 0°, which is used as the cross-calibration gain estimation for this band and IGBP land cover type. The red lines indicate the 68% confidence interval on the intercept and are sed as the 1-sigma uncertainty for the estimate. Image source: [5].

accounts for several effects of BRDF, so it was considered the cross-calibration estimate. The VZAD intercept should be noted as one the key discoveries in this analysis since it essentially interpolates the ratio value where the sensors are directly over each other with high precision. An extended uncertainty analysis showed there was less than 0.3% . BRDF uncertainty on the VZAD intercept. The capability of this approach is described in [5], which is under peer review and will be published soon. Because Landsat 8 and 9 are near clones of each other, the underfly presented a perfect opportunity for cross-calibration. With the analysis performed on the data and discoveries such as the VZAD intercept, the cross-calibration gains applied to Landsat 9 have a total uncertainty of less than 1%, an unprecedented result for spaceborne optical imaging systems.

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NEWS IN THIS QUARTER

Highlights of the 2023 Annual GRWG/GDWG Meeting

By M. Bali (UMD), L. Flynn (NOAA), D. Doelling (NASA), Quanhua (Mark) Liu (NOAA), Siena Iacovazzi (NOAA/), 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 in hybrid mode by NOAA at College Park, MD, USA 27 Feb – 3 March 2023. Members from BIRMM, CMA, CAS, CNES, DLR, DWD, ECMWF, EUMETSAT, ESA, EWHA, IMD, ISRO, JAXA, JMA, KMA, LASP, NIST, NASA, NOAA, NPL, Jupiter Intel, Rayference, UW, UKMO, USGS and WMO attended the meeting. Space Weather was formally added as a new GRWG subgroup and the subgroup held its firsts breakout session chaired by Tsutomu Nagatsuma from NICT Japan.

Mitch Goldberg (GSICS Executive Panel Chair) welcomed the participants. Mitch stressed the need for maturing the State of Observing System reports and the need for GSICS to contribute to the rapidly growing commercial satellite calibration community. Mitch's welcome was followed by the welcome by the host from by Doug Howard, Director NOAA/NESDIS/STAR.

Plenary Day-1

The first session of the meeting was a Plenary which spread across the first two days of the meeting. The first day of the Plenary was a mini-conference chaired by Fangfang Yu (NOAA) and covered topics vital to GSICS in the near future.

The Plenary covered a range of topics: Radiative Transfer Models (Mark Liu), Application of Metrological Processes (Emma Wolliams) and a tool to calculating error covariance (https://www.comet-toolkit.org/).

Andrew Collard spoke on Error Budgets in data assimilation. Betsy Weatherhead spoke on constructing Climate Data Records from Satellite Observations and Paolo Castracane spoke about ESA's strategy for satellite interoperability. Robert Levy's talked on transitioning from MODIS to VIIRS.

Andy Heidinger led a discussion on GSICS–ISCCP interactions. Andy provided recommendations to GSICS on fine tuning their products to fulfill needs of the ISCCP community. He sought feedback on ISCCP entities from the GSICS community and encouraged the GSICS Data Working Group to integrate GSICS corrections with Satpy.

Image Above: Participants of the GSICS Annual Meeting 2023 at NOAA College Park, MD, USA

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Talks in this session also included the use of RTM and NWP data to monitor the FY-3E instruments performance (Fanglu Dou), overview of instrument cal/val plans (Rob Rosenberg and Ruediger Lang), some early promising results of NOAA-21 cal/val activities (Changyong Cao), application of inter-comparison in the geometric calibration validation (Vladimir Kondratovich), and an overview of EUMETSAT's operational calibration and inter-calibration system (Mounir Lekouara).

Plenary Day-2

A total of fourteen agencies and organization, including CMA, CNES, JAXA, ISRO, WMO, IMD, JMA, EUMETSAT, ESA, KMA, NASA, NIST, NOAA and USGS, made their annual reports on the GSICS related activities over the past year. After the agency reports, Tim Hewison led the discussion on the revisions of GSICS product classes to combine the IR and VIS-NIR products and the needs to accommodate several algorithm improvements.

Space Weather Subgroup Breakout Session

The Space Weather Subgroup Breakout Session started with Piers Jiggens (ESA) introducing ESA assets that could be included in an intercalibration system. Several space weather related observations (SWARM and SMOS) onboard ESA's Earth observation are introduced by Raffaele Crapolicchio (ESA).

Activities on intercalibration of high energy electron sensors were reported by Ingmar Sandberg (SPARC). Intercalibration activities were also reported by Tsutomu Nagatsuma (NICT) and Dae-Hyeon Oh (KMA). They introduced the long-term trend

(EWHA) gave the status of current and planned comparisons of GEMS

about background flux level of Himawari-8/SEDA data and weak semi-annual changes of correlation coefficients between GK2A/KSEM and GOES16/MPS-HI, respectively. Terry Onsager (NOAA) introduced the need to monitor and provide SW products for MEO, LEO – in addition to GEO, using inter-calibrated measurements, and need also to focus on low-energy electrons which are critical for surface charging effects.

Qiao Song, Jinping Dun, and Qian Song (CMA) introduced results of calibration and data processing about space weather sensors (solar X-ray instrument, EUV imager, and Triple Ionospheric photometer) onboard FY-3E satellite.

Tsutomu Nagatsuma also introduced the draft about the scope of GRWG Space Weather subgroup which would be discussed in a virtual meeting.

UVN Spectrometer Subgroup

The UVN Spectrometer Subgroup breakout session had a good mix of updates ranging from CDRs for past instruments (GOME/SCIAMACHY), to End-of-Life (Metop-A GOME-2), to "operational" sensors (EPIC, NPP OMPS), to newer sensors (GEMS / TropoMI), to recently launched (NOAA-21 OMPS), to soon to be launched (TEMPO, OMS) with excursions to solar irradiance studies (OMI / TropoMI) and product comparisons (OCO-3 and GEMS). Further details will be in the minutes, or you can view an entire talk at the meeting website.The first presentation by Yuan Li (CMA) gave the status of calibration for the OMS instrument. The planned date of the OMS Launch on FY-3F is August 2023.

The second presentation by Melanie Coldewey-Egbers (DLR) gave

measurements to other GEO and LEO instruments.

information on the status of TropoMI calibration and reprocessing.

The third presentation by Antje Ludewig (KNMI) continued with results for reprocessing with emphasis on the improved straylight corrections for TropoMI.

The fourth presentation by Alessandra Cacciari (EuMetSat) gave a summary of end-of-life tests and analysis for the Metop-A GOME-2.

The fifth presentation by Melanie Coldewey-Egbers (DLR) introduced the ESA FDR4ATMOS project with initial target of harmonization of GOME and SCIAMACHY Level 1 records.

The sixth presentation by Banghua Yan (NOAA) gave an update on the validation of the New NOAA-21 OMPS Nadir Mapper and Nadir Profiler measurements.

The seventh presentation by Mijin Eo (EWHA) gave information on the status of GEMS in-flight characterization and reprocessing including solar measurements.

The eighth presentation by Jay Herman (UMBC) discussed the use of EPIC and its hourly measurements of the full sunlit disk for comparisons to instruments on all platforms.

The ninth presentation by Xiong Liu (CFA) gave an extensive description of the planned pre- and post-launch calibration and validation activities for the TEMPO instrument (April 2023 launch date).

The tenth presentation by Sergey Marchenko (SSAI/NASA) looked at the state-of-the-art capability of using solar measurements of Fraunhofer lines to identify drifts in stray light correction performance with OMI and TropoMI as examples.

The eleventh talk by Yeeun Lee

The twelfth talk by Thomas Kurosu (JPL) looked at SNO comparisons of

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OCO-3 XCO2 and GEMS NO2 products.

The thirteenth talk by Larry Flynn (NOAA) presented results using the V8TOz retrieval algorithm to compare the calibration of sensors in the UV for three channels (318 nm, 331 nm and 372 nm) for OMPS, GOME-2, TropoMI and GEMS.

IR Breakout Session

Held on Wednesday March 1, 2023, the IR breakout session had a total of five sessions with 18 talks (6 remotely). The topics covers 1) sensor calibration inter-calibration status, 2) inter-calibration algorithms, 3) climate data records, 4) GEO-GEO inter-calibration, and 5) other related inter-calibration research. The presentations and meeting minutes can be accessed from the GSICS wiki page.

During the meeting, two group discussions were organized. The first one was focused on the GEO-LEO IR inter-calibration algorithm improvements. Several issues were identified in the current algorithm that was used in the IR group for many years, such as the correction formula and performance at cold end and over hot land. The team concurred that improving the algorithm will be the focus of FY23, and thus several actions were formed. Another discussion was followed by the session of GEO-GEO inter-calibration (three presentations). The team recognized the potentials of the GEO-GEO inter-calibration method in support of sensor calibration and validations and encouraged each agency to continue exploring its applications. Finally, LEO-LEO inter-calibration, issues with 3.8µm channels and the application of lunar calibration in the thermal infrared were discussed.

MW Breakout Session

The MW Subgroup presentations focused on MW instrument CAL/VAL activity status development of SI traceable standard blackbodies and generation of MW intercalibration products.

CMA, NOAA and ESA provided calibration/validation activity status reports. Juyang Hu and Mei Yuan from CMA gave briefings about the calibration improvement of the Microwave Temperature Sounder (MWTS) on FY-3D and FY-3E, and the FY-3E WindRAD instrument status and calibration accuracy evaluation, respectively. The NOAA reports covered a wide range of topics. Atmospheric humidity and temperature sounding from the Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats (TROPICS) mission was presented by John Yang (Univ. of MD), and a NOAA-21 ATMS performance summary was given by Ninghai Sun (NOAA). Juliana Chew (MIT-Lincoln Labs) provided a briefing on efforts to process TROPICS lunar data. Raffaele Crapolicchio from ESA offered a glimpse into the ESA microwave activities, which included information on the SMOS mission, CIMR mission and DOMEX experiment status, radio frequency interference activities and reporting, and the development of TriHex. Beijing Institute of Radio Metrology and Measurement (BIRMM) scientist Chunyue Cheng provided a detailed presentation about the institute's efforts to develop SI traceable brightness temperature targets.

GSICS MW Product discussions:
There was a consensus that the group should build an uncertainty framework for instrument intercomparisons. Members also agreed that a diagnosis of MW sensor uncertainties is needed to carefully choose reference sensors and generate any products that stem from needing established reference sensors. The path-forward towards creating GSICS products for the MW spectrum lies in

- Establishing a common terminology by which subgroup members can communicate about MW sensor calibration/validation and its evaluation;
- Adopting an uncertainty framework by which all MW sensors can be characterized; and
- Adopting and/or developing methods to quantify and characterize MW sensor uncertainty contributions
- Identified the need to consider the potential for generating GSICS corrections that are based on examples of current GSICS products.

VIS/NIR Breakout Session
The VIS/NIR subgroup focused on both calibration and environmental parameter retrieval continuity between multiple sensor records. These included MODIS to VIIRS aerosol and cloud retrieval continuity, ISCCP NG concurrent geostationary common channel retrieval, VGT series consistent surface reflectances, OCO intercalibration, Himawari-8/9 intercalibration, historical GOES recovery and recalibration effort, and radiometric scaling approaches between sensor records.

The VIS/NIR group is looking forward to the CLARREO, TRUTHS, and Libra, SI traceable visible reference in space missions. The CLARREO launch will be delayed until 2025, whereas the TRUTHS will launch in 2030, where the hope is that the sensors will overlap.

The group discussed promoting the GSICS VIS/NIR deep convective cloud (DCC) calibration as a GISCS operational product and noted that the DCC identified pixel-size impact on the

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PDF mode has not been fully investigated.

The NOAA-20 VIIRS sensor, the GSICS VIS/NIR reference in space, continues to have optimal performance and the newly launched NOAA-21 VIIRS seems to have consistent performance with NOAA-20 VIIRS.

This year the VIS/NIR group will compile ray-matching inter-calibration best practices collectively with the IR group. The VIS/NIR group monthly web meetings will continue in the usual format facilitating in depth discussions.

Lunar Session

The lunar part of the Vis/NIR session had several reports on recent efforts to apply lunar calibration to sensors in orbit, including Sentinel-3 OLCI, Meteosat-8 SEVIRI, MODIS, VIIRS, and Landsat-8 OLI. NOAA reported on using the new SLIMED lunar model for calibration of GOES-16 and 17 ABI, with comparing results to GIRO. This work shows better consistency is achieved using SLIMED. The session participants also agreed to advance development of lunar calibration reference models, including an update on the ESA LIME model. Reports on efforts to acquire new, high-accuracy lunar irradiance measurements included the recent campaign conducted by air-LUSI using the NASA ER-2 high-altitude aircraft, and an update on the ARCSTONE cubesat project currently in development for a planned Fall 2024 launch. The session concluded with a continuing discussion on developing a new GSICS lunar calibration system to replace the GIRO. Tom Stone and Hugh

Kieffer proposed a framework for implementing the SLIMED lunar model using a modular software approach that would allow to distribute the programming task among agencies. NOAA expressed interest in potentially supporting studies of this proposed effort.

GSICS Data Working Group Breakout Session

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, JMA, IMD, ISRO, KMA and NOAA. Arata Okuyama from JMA gave members a brief overview of the JMA GPRC and their production of the MTSAT and Himawari-8 and Himawari-9 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 plans to create high quality FCDR. Nitant Dube informed that ISRO maintained their thredds server and integrated a GSICS product plotting tool in their GPRC. Paolo Castracane from ESA elaborated on the ESA EVDC website, their PI-MED website and salinity website to help the 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, Action Tracker, Alert System, User Platform developed at NOAA to help users use GSICS products and deliverables. Discussions in the data working group lead to ten actions and a recommendation to share reprocessing plans.

Cross cutting discussions

The cross cutting session 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 future hosting of the GSICS Annual Meetings. GRWG, GDWG groups and subgroups, GIR, GMW, GUV, GSW and GVIS/NIR presented overviews of discussions they had in the breakout sessions in addition the GCC and GDWG reports were presented. The GCC report indicated the growing trend in GSICS memberships and gave an update on upcoming products and new tools developed by GCC/GDWG to help users use GSICS products.

Manik Bali, gave an overview of the recent OSCAR Workshop organized by WMO. He also demonstrated a Colab notebook that can be used to extract satellite information from the OSCAR website.

Some of the key decisions during this session were.

1. GCC reported that EUMETSAT has offered to host next year's annual meeting.
2. It was agreed to continue holding the GSICS Web Meetings on designated Thursdays of each month.
3. GCC will examine approaches, including surveys, to better understand the user expectations from GSICS.
4. Mounir Lekura to take over as Chair GRWG
5. EUMETSAT to host 2024 GSICS Annual Meeting

Presentations, Minutes and Actions can be found on the meeting page on GSICS Wiki at http://gsics.atmos.umd.edu/bin/view/Development/Gsicsannualmeeting2023

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Announcements

Characterization and Radiometric Calibration for Remote Sensing (CALCON) annual meeting to be held June 12-15, 2023 in Logan, UT

By Stephanie Halton (SDL) and Xiaoxiong (Jack) Xiong (NASA)

The 32nd Characterization and Radiometric Calibration for Remote Sensing Annual Meeting (CALCON) will be held June 12 – 15, 2023 in Logan, UT. CALCON provides a forum for scientists, engineers, managers, and mission leads to discuss challenges and solutions. Discussion topics include calibration, characterization, image enhancement, remote sensing, and radiometric issues within the UV, VIS, IR, microwave, and SAR spectral ranges. Abstracts are due March 31, 2023. For more details, please visit: https://calcon.sdl.usu.edu/.

SPIE Optics and Photonics Earth Observing Systems XXVIII conference to be held in San Diego August 20-24, 2023

By Xiaoxiong (Jack) Xiong (NASA), Xingfa Gu (CAS) and Jeffrey S. Czapla-Myers (University of Arizona)

The annual SPIE Optics and Photonics' Earth Observing Systems XXVIII conference will be held August 20-24, 2023 at the San Diego Convention Center, San Diego, CA.
The Earth Observing Systems XXVIII conference welcomes the submission of papers over a wide range of remote sensing topics. Papers are being 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 Earth Observing Systems XXVIII .
Conference abstracts are due 8 March 2023. Proceedings manuscripts are due 2 August 2023.

GSICS-Related Publications

Battaglia, A., In orbit cross-calibration of millimeter conically scanning spaceborne radars, https://webthesis.biblio.polito.it/23336/

Jianguo Niu, Lawrence. E. Flynn, C. Trevor. Beck, Zhan Zhang, Eric Beach, Zhihua Zhang & Manik Bali (2023) Enterprise version 8 total column ozone algorithm (EV8TOz) development and applications on multiple sensors, Remote Sensing Letters, 14:3, 231-242, DOI: 10.1080/2150704X.2023.2185111.

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Lee, Y., Ahn, M.-H., Kang, M., and Eo, M.: Spectral replacement using machine learning methods for continuous mapping of the Geostationary Environment Monitoring Spectrometer (GEMS), Atmos. Meas. Tech., 16, 153–168, https://doi.org/10.5194/amt-16-153-2023, 2023.

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Suto, H., Kataoka, F., Knuteson, R. O., Shiomi, K., Kikuchi, N., and Kuze, A.: Updated spectral radiance calibration on TIR bands for TANSO-FTS-2 onboard GOSAT-2, Atmos. Meas. Tech., 15, 5399–5413, https://doi.org/10.5194/amt-15-5399-2022, 2022.

Xu, Z.; Lu, P.; Cai, Y.; Li, J.; Yang, T.; Wu, Y.; Wang, R. An Efficient Channel Imbalance Estimation Method Based on Subadditivity of Linear Normed Space of Sub-Band Spectrum for Azimuth Multichannel SAR. *Remote Sens.* **2023**, *15*, 1561. https://doi.org/10.3390/rs15061561.

Yang, Le, Lei Shi, Weidong Sun, Jie Yang, Pingxiang Li, Deren Li, Shanwei Liu, and Lingli Zhao. 2023. "Radiometric and Polarimetric Quality Validation of Gaofen-3 over a Five-Year Operation Period" *Remote Sensing* 15, no. 6: 1605. https://doi.org/10.3390/rs15061605.

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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