Tuesday, September 13, 2022 | 4:20 p.m.

SPOTLIGHT: Vicarious Calibration

Integrating On-board and Vicarious Calibration with the Improved Radiometric Calibration of Land Imaging Systems (IRIS)

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ABSTRACT: As part of Raytheon's effort to provide innovative calibration capabilities that advance the performance of future earth imaging systems, an on-board Jones source calibrator integrated with vicarious SPecular ARray Calibration (SPARC) is introduced. The Improved Radiometric calibration of land Imaging Systems (IRIS) is a compact full-spectrum calibration system that reduces the size, weight, and power of conventional on-board radiometric sources into a single flat panel format providing high spatial illumination uniformity. Combining both carbon nanotube and LED technology within a Jones source design, IRIS offers a common assembly calibration reference covering the spectral range from 0.4 to 12 µm. On-board calibrator degradation from the effects of launch and lifetime exposure to the space environment impacts performance, making it difficult to maintain absolute knowledge of the sensor radiometry. What has been missing from past on-board lamp calibration systems is an operational capability for establishing and maintaining absolute SI traceability in the solar reflective spectral range after launch and over the sensor lifetime. Introduced in this presentation is a methodology that sustains traceability through a fusion of the on-board IRIS LED reference with Labsphere's FLARE vicarious system. In this process, the imager collects an on-board calibration source image nearly simultaneously with observations of the sun safely reflected by a FLARE array of convex mirrors on the ground. The process known as IRIS-V provides data for recalibration of the onboard VSWIR system, as needed, in-flight without affecting operational land or coastal image collection. A prototype of the IRIS on-board calibrator and IRIS-V methodology will be described. IRIS is funded by the NASA Earth Science Technology Office (ESTO) through the Sustainable Land Imaging-Technology 2019 (SLIT19) Program.

Monitoring Sentinel-2 MSI inter-calibration using Deep Convective Clouds

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ABSTRACT: The Deep Convective Cloud (DCC) method is an efficient method to estimate the relative radiometric uncertainty of Earth Observation sensors. The method has been used to monitor the inter-satellite relative uncertainty of the Copernicus Sentinel-2 constellation.

The data selection process relies on thresholds on the NIR (B08) and cirrus (B10) bands on data acquired in the inter-tropical region. More than 1000 products for each satellite are processed each month. Histograms of the reflectance values are extracted for all spectral bands and each detector module. Once enough products are collected, a skewed-Gaussian is fit to the accumulated histogram. The second inflexion point of the distribution is used as a reflectance indicator. This indicator is preferred to the more standard choice of the mode of the distribution because it is statistically more robust. The reflectance indicators of the two satellite units can then be compared and their evolution in time monitored. Thanks to the large number of available data, it is possible to estimate the statistical uncertainty of the method by repeating the evaluation over the same time period. More precisely, the collected products are randomly assigned to 5 different batches and processed independently. The mean value and standard deviation of the 5 different measurements can then be computed to evaluate the sampling uncertainty. Similarly, results can be computed on different geographic zones to analyse the sensibility to local climatology.

The method has been used operationally to follow the radiometry of Sentinel-2 MSI instrument since January 2022. One particular objective of the analysis was to estimate the efficiency of the radiometric harmonization of the VIS-NIR channels implemented at the end of January 2022. The measured inter-satellite bias is smaller than 1.1% for bands B01 to B09 with 67% confidence, while a larger bias is observed on the SWIR B12 band.

The Ground to Space CALibration Experiment (G-SCALE): SI-traceable Intercalibration of Multi-scale Earth Observation Platforms using Mirror-based Targets

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ABSTRACT: In order to deliver high quality, traceable, multi-sensor optical Earth Observation measurements and fused data products, there is a need for common reference sources and dedicated intercalibration and bias assessment activities. The goal of the Ground to Space CALibration Experiment (G-SCALE) was to demonstrate the use of convex mirrors as a radiometric and spatial calibration and validation (cal/val) technology for Earth Observation (EO) assets operating at multiple altitudes and spatial scales. Specifically, to generate a point source with NIST-traceable absolute radiance signal for simultaneous vicarious calibration of multi- and hyperspectral sensors in the VNIR/SWIR range, aboard Unmanned Aerial Vehicles (UAVs), aircraft, and satellites. The experiment was carried out at the Rochester Institute of Technology's 177-acre Tait Preserve in Penfield, NY, USA on July 23, 2021. The G-SCALE represents a unique, international collaboration between commercial, academic, and government entities for the purpose of evaluating a novel method to improve vicarious cal/val for EO, in direct comparison to traditional diffuse reflectance techniques. We will provide an overview of the experiment and acquired data sets, with an intercomparison of signature retrievals using both traditional and mirror-based calibration techniques.

Furthermore, we will present updates to the FLARE Network, an on-demand automated commercial cal/val network utilizing the mirror technology employed in G-SCALE. Extensive validation efforts have shown stable performance against commercial and agency missions, with radiometric uncertainties below 3.5% across most of the solar reflective spectrum (350 – 2500 nm). In addition to high dynamic range fixed nodes, newly developed semi-mobile stations have been developed which can be quickly and inexpensively deployed to provide targeted references suitable for cal/val. The first of these units was commissioned to validate Sentinel 2 surface reflectance products. Finally, we present the upcoming Mauna Loa node, created in partnership with the NOAA Mauna Loa Observatory. This high-altitude, atmospherically stable site provides multiple radiometric and spatial calibration points. The Mauna Loa FLARE node has the potential to achieve < 1.5% radiometric uncertainty for multi- and hyperspectral Earth Observation missions.

Vicarious Calibration of Orbiting Carbon Observatory 2 and 3

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ABSTRACT: The Orbiting Carbon Observatory 2 and 3 (OCO-2 and OCO-3) instruments, launched in 2014 and 2019 respectively, employ multiple methodologies to refine the absolute radiometric scale. One technique, vicarious calibration, uses in-situ measurements taken at Railroad Valley, USA (RRV), along with near simultaneous measurements (within 0.5 hours) from the satellite instruments. The JPL field team has conducted measurement campaigns near every summer solstice since 2009 along with colleagues from the Greenhouse gases Observing SATellite (GOSAT) project, JAXA/NIES. Since 2012, additional ground datasets have been collected in the spring and fall to support additional targets acquired throughout the year. The RRV playa is also equipped with automated sensors developed and maintained independently by JPL and the Remote Sensing Group at University of Arizona. These automated data sets include surface pressure, surface reflectance, aerosol optical depth, and the ambient meteorological condition (temperature, wind speed, and relative humidity). The automated surface reflectance data sets provide a valuable time series, although the reported values are systematically lower than the spectroradiometer measurements collected by the field team. This is because the automated sensors do not directly measure the surface reflectance. They measure the reflected radiance at the bottom of atmosphere to estimate the surface reflectance but use a radiative transfer modeling (MODTRAN and the solar irradiance data) to estimate the downwelling solar flux incident on the RRV playa. We have combined the datasets collected during the field campaigns with these automated datasets to estimate scaling factors for the analysis of OCO-2 and OCO-3 measurements taken significantly before or after the campaigns. This combination could mitigate the systematic bias in the automated datasets and improve temporal coverage for OCO-2 and OCO-3. Other recent updates to the vicarious calibration data analysis procedure include adopting the TSIS-SIM solar irradiance spectra, and reprocessing data from the entire OCO-2 and OCO-3 missions using the ACOS Build 10 retrieval algorithm, and MODIS surface bidirectional reflectance factor version 6.1 data in the off-nadir correction to nadir surface reflectance to account for the impacts of OCO2/OCO3 viewing geometry. Results from the vicarious calibration analyses are presented here,

reaching 3% accuracy of spectral radiance for the OCO collects closest to nadir, along with the estimated agreement with the satellite on-board calibrator results.

The Vicarious Radiometric Calibration of SDGSAT-1 Satellite MII Sensor Over Dunhuang, China

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ABSTRACT: The Sustainable Development Goals Satellite (SDGSAT-1) is the first Earth science satellite of the Chinese Academy of Sciences, aiming to support the achievement of the Sustainable Development Goals. The satellite carries three main sensors: Multispectral Imager for Inshore (MII), Glimmer Imager for Urbanization (GIU) and Thermal Infrared Spectrometer (TIS). At 2:19 am UTC on 5 November 2021, SDGSAT-1 satellite, manufactured by the Changchun Institute of Optics, Fine Mechanics and Physics, and Shanghai Institute of Technical Physics, Chinese Academy of Sciences, was successfully launched at the Taiyuan satellite launch center by the CZ-6 rocket. SDGSAT-1 has seven bands with spectral ranges of 380–900 nm, a swath of ~300 km, a spatial resolution of 10 m. This report will give a comprehensive introduction to the radiometric performance of the satellites and data acquiring status. The vicarious radiometric calibration coefficients were derived for MII sensor via a calibration experiment performed at the high-altitude, dry, homogeneous Dunhuang calibration site in the Gobi Desert in western China on 14 December 2021. In-situ measurements, including the ground reflectance, atmospheric parameters and radiosonde data, were also acquired during this calibration period. The entire calibration site was a 500 m × 500 m square region and the satellite overpass time was 03:45:17 UTC 14 December 2021. The surface reflectance measurement was performed in the squared region from 10:30 am to 13:30 pm Beijing time, 20 meters per point. The total measured data was exceeded 400 groups. The atmospheric parameters and the radiosonde data were provided by Dunhuang Meteorological Bureau. The reflectance-based method was used to predict the top-of atmosphere (TOA) radiance (LTOA) using MODTRAN 5.2.1 code. The SDGSAT-1 satellite MII sensor calibration coefficients are directly calculated by dividing the radiance from the 40 × 40 averaged DN values.

We focused our analysis on uncertainties caused by aerosol type assumptions, AOD measurements, water vapor content measurements, atmospheric model assumptions and radiative transfer model inherent errors. The aerosol type assumption causes the maximum uncertainty of 5.3%. The calibration uncertainties caused by the ground reflectance measurement, atmospheric model assumption, the AOD retrieval and RTM simulation is estimated to be 2%, 1.2%, 1.3%, 0.4% and 1%, respectively. The total uncertainty (root sum of squares) discussed above associated with the reflectance-based method for SDGSAT-1 satellite MII sensor is estimated to be less than 6.0%. The absolute radiation calibration results of MII sensor provided was only based on the preliminary results obtained from one imaging at the Dunhuang calibration site on 14 December 2021, and the final coefficient and uncertainty analysis are still in progress. In the future, we will conduct more calibration experiments and derive radiometric calibration coefficients of SDGSAT-1 by irradiance-based methods and present more details.