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Newsletter–Summer 2017 Issue

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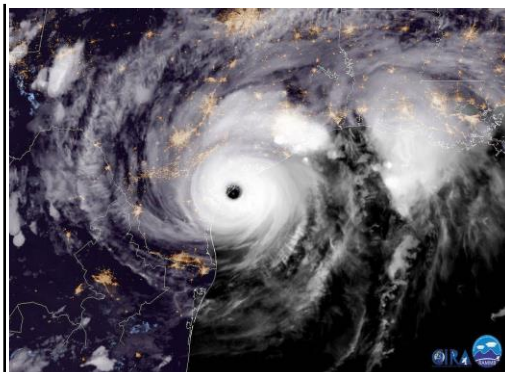
Special Issue on Re-Processing



Detailed images of Hurricane Harvey (L) and Solar Eclipse (R) of 21 Aug 2017, taken by GOES-16

Rethinking the release of imager calibrated radiances

by David R. Doelling (NASA)

The GSICS community will be radiometrically scaling GEO imager reflected solar channels using VIIRS as a calibration reference. The new GEO and VIIRS imagers will be concurrent on multiple satellites for many years to come. Unlike MODIS, both NOAA and NASA are retrieving and archiving environmental parameters. VIIRS does not have just one official calibration. There are versions from the NOAA Interface Data Processing Segment (IDPS), NOAA-VIIRS ocean color, NASA Ocean Biology Processing Group, NASA-Land Product Evaluation and Analysis Tool Element (PEATE) to name a few. The NASA Land PEATE dataset uses the NASA-GSFC VIIRS Characterization Support Team (VCST) onboard calibration methodologies, which is already in its 5th version. Each calibrated dataset has been optimized for the objectives of the calibration group. Some groups require inter-channel inconsistency, others require continuity between MODIS and VIIRS retrievals, and others require stability. For weather and assimilation applications, accurate calibration is required. If each VIIRS retrieval team requires releasing a Level 1B (L1B) data product, it will amount to petabytes of storage and associated archival costs. Climate modelers validate their models using observational data products, but are confronted with the many VIIRS data products offering the same retrieved parameters.

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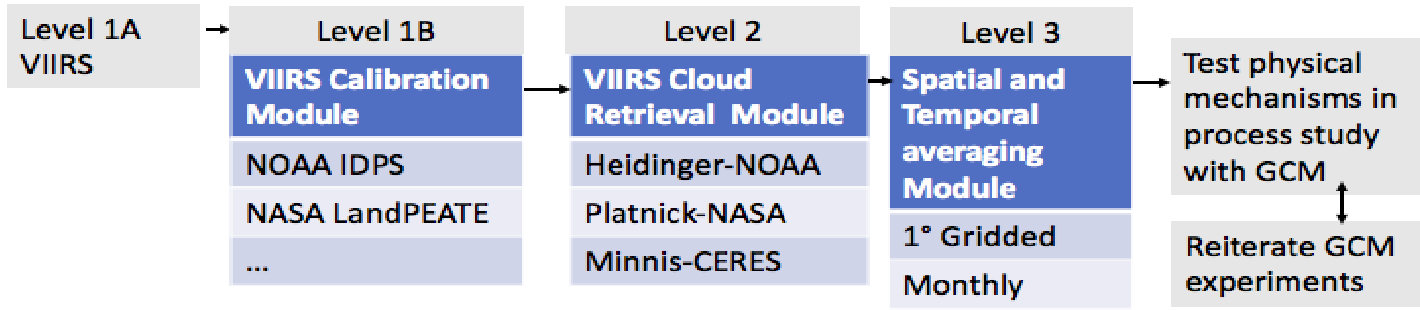

Figure 1. Example schematic of a processing flow starting from VIIRS level 1A for the purpose of yielding cloud properties applicable to a certain user's GCM studies.

Ideally, the well-informed user would be able to select the sensor (for example, VIIRS), calibration module, retrieval algorithm, and spatial/temporal averaging techniques that are best suited for their application. Figure 1 illustrates a possible scenario of how a GCM user may test their model results using VIIRS cloud properties. Flexibility comes in the form of users being able to choose the calibration source, cloud property retrieval algorithm, and spatial and temporal scales best suited for their application. The data starts processing from the L1A, once the user has entered in their selections. No intermediate datasets (for example, L1B) are created or utilized. For most calibration modules and retrieval algorithms, the I/O time, not CPU, sets the pace of the processing. By eliminating the I/O steps will make the processing more efficient. Communication between modules would need to be standardized. MODIS Collection 6.1 data are currently being processed (September 2017). This release provides critical cross-track corrections to bands 27 through 30, caused by the Terra safe-hold anomaly during February 2016. The MODIS Characterization Support Team (MCST) quickly found a solution. Due to the coordination of the C6.1 release among MODIS retrieval teams and more importantly the processing of another Terra and Aqua combined 32 year L1B dataset, the public release of the L1B C6.1 cross-track adjustments are delayed. Calibration modules would substantially reduce the latency to correct any onboard instrument anomalies.

Historically, satellite imagery was transmitted to antennas in a cryptic binary format in order to facilitate near real time analysis. Super users with access to expensive computers and antennas were the only ones that could analyze the data for science applications. It was left to the user to read the binary data, calibrate, and perform environmental retrievals. Experts were required in every step of the process. The ISCCP project was one of the first projects to standardize the satellite data format and archive to tapes. Similar to ISCCP the AVHRR community worked together to share read codes and calibration updates and thereby expanding the number of users.

NASA's directive of making calibrated MODIS data available in HDF format within two years and funding a dedicated calibration group along with releasing cloud, land-use, aerosol, ocean color and other environmental products, dramatically increased the number of MODIS users. Users could now concentrate on MODIS science.

This arrangement created two groups, retrieval scientists and processing centers, who are at odds with each other. In a very broad sense, the scientists are constantly modifying code, seeking perfection, and holding the release of a dataset (perhaps for years) that is 99% correct for that last 1% improvement. Meanwhile users who are only expecting 90% perfection are denied their dataset. The processing center, however wants to make sure that each execution and output is identical to the last. This sometimes involves rewriting the code based on science documents, rather than utilizing the scientist's code. Each version of the data product must be preserved in perpetuity, requiring massive amounts of digital storage. By producing only modules, incremental improvements in calibration and retrievals can quickly be released and the processing centers need only to be concerned with module fidelity.

I suggest to maintain only a level 1A product that incorporates all the pertinent on-orbit measurements needed for calibration. The level 1A product is then processed using calibration modules, which are version-controlled with carefully documented calibration objectives. The user can select the calibration module that is best suited for their application. With this approach, the user, or processing

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center, only needs to download or store the level 1A data. The processing latency has been eliminated, and onboard calibration anomalies can be corrected as soon as solutions are found. Such a framework would allow GSICS to not only monitor overall temporal calibration drift, but also enable the capability to use the onboard calibration factors to mitigate response versus scan angle features, detector to detector striping, and other instrument related issues. This approach also has the advantage of allowing future researchers to re-calibrate when new information is discovered, or as absolute calibration references emerge, such as CLARREO. Keep in mind that a key aspect of this approach is to define the best practices for producing calibration modules. For example, that the calibration module has been properly implemented and documented. This should help facilitate converting the L1A datasets into future data formats (see PyGAC article) and translating modules into future programming languages (see CALCON discussion article).

Discuss the Article

PyGAC: An open-source, community-driven Python interface to preprocess nearly 40-year AVHRR Global Area Coverage (GAC) data record

by Abhay Devasthale (SMHI), Martin Raspaud (SMHI), Cornelia Schlundt (DWD), Timo Hanschmann (DWD), Stefan Finkensieper (DWD), Adam Dybbroe (SMHI), Sara Hörnquist (SMHI), Nina Håkansson (SMHI), Martin Stengel (DWD) and Karl-Göran Karlsson (SMHI)

Nearly four decades of Global Area Coverage (GAC) data available since 1978 from the Advanced Very High Resolution Radiometers (AVHRR) onboard a series of NOAA satellites offer opportunity to derive Fundamental Climate Data Records (FCDRs) and Thematic Climate Data Records (TCDRs) of the Essential Climate Variables (ECVs) listed by the Global Climate Observing System (GCOS) to provide support for the United Nations Framework Convention on Climate Change (UNFCCC). The first important step in deriving FCDR/TCDR is to read, decode, quality control and (inter)calibrate packed 10-bit Level 1b GAC data. Although this preprocessing step is essential in all applications of GAC data, there is no clear traceability and uniform agreement on preprocessing Level 1b data in an internationally agreed convention.

To address this issue has been the starting point for the development of PyGAC, a python based open source, community driven interface to preprocess AVHRR GAC data. PyGAC is developed under the framework of ESA's Cloud Climate Change Initiative Phase II (ESA Cloud_cci) (Hollmann et al. 2013) with user feedback from EUMETSAT's Satellite Application Facility on Climate Monitoring (CM SAF) (Schulz et al. 2009). PyGAC takes an advantage of modular and object oriented philosophy of Python and its vast cache of public utilities. The schematic representation of PyGAC processing flow is shown in Fig. 1. The main data input to PyGAC is a level 1b GAC orbit and Two-Line Elements (TLEs) of a satellite. The installation instructions and usage are explained at GitHub website (https://github.com/pytroll/pygac/tree/feature-clock).

The interface first determines whether the GAC data is from the first or second (POD family of satellites) or the third generation (KLM family of satellites) AVHRR instrument. Accordingly, it calls POD or KLM GAC reader to unpack and read 10-bit GAC data, along with header and a host of other metadata related to calibration, navigation and quality. The POD and KLM data user guides (Kidwell, 2000) are taken as the reference source for the design of the corresponding GAC readers and calibrators in PyGAC. , navigation and quality. The POD and KLM data user guides (Kidwell, 2000) are taken as the reference source for the design of the corresponding GAC readers and calibrators in PyGAC. The next processing step involves improving geolocation information.

There are at least two known problem areas while geo-locating AVHRR GAC

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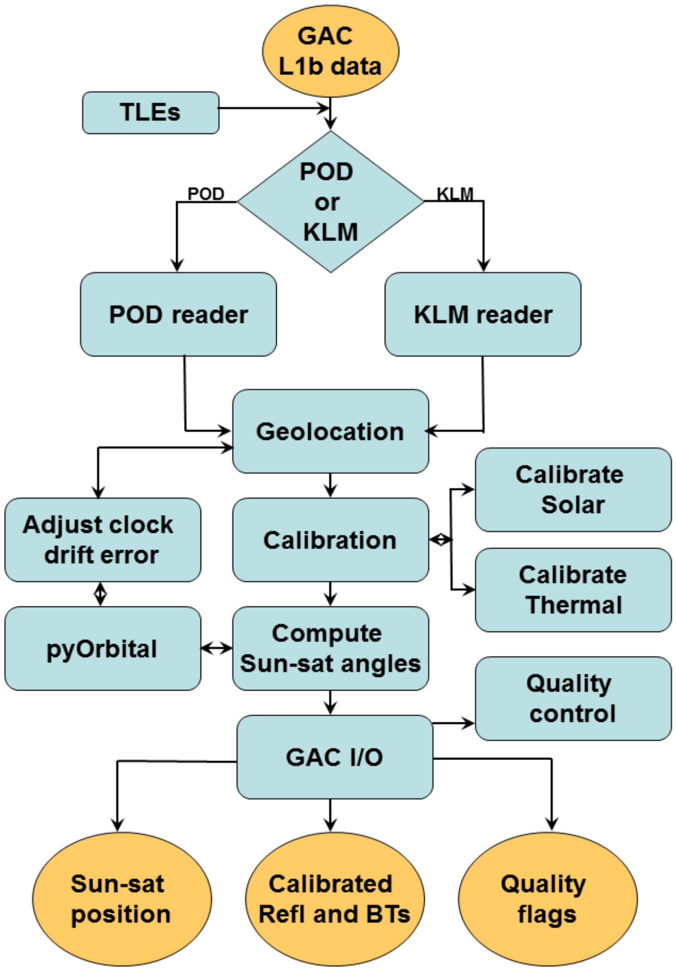

Figure 1: Schematic representation of the components of PyGAC interface. POD represents satellite family that carried second generation AVHRR instruments (i.e., up till and including NOAA-14), while KLM represents satellite family carrying the third generation instruments (from NOAA-15 onwards). PyOrbital is a part of PyTroll family of Python interfaces designed to process meteorological satellite data.

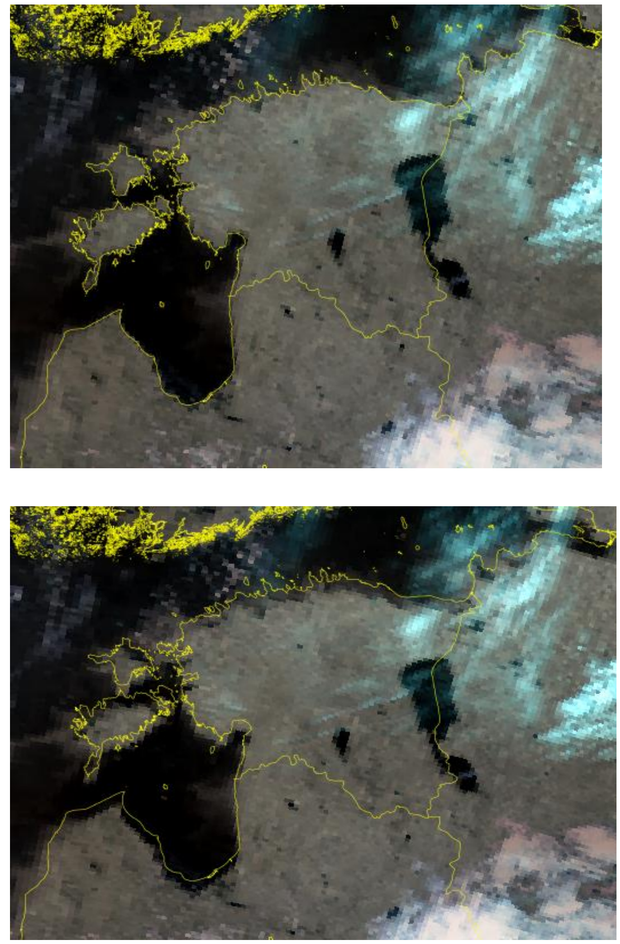

Figure 2: An example of a GAC/NOAA-14 scene (97196T0042Z) showing improved geolocation after clock drift corrections (top). The bottom panel shows original, uncorrected scene.

data: (1) drift in spacecraft clock causing errors in the estimated along-track position, and (2) uncertainty errors in spacecraft and sensor attitude. If the GAC data belongs to POD family, then clock drift errors (obtained from University of Miami, Pathfinder AVHRR Oceans project) are used to adjust existing Lat-Lon information for afternoon satellites (http://www.rsmas.miami.edu/groups/rrsl/pathfinder/Processing/proc_app_a.html). Here, PyGAC makes use of PyOrbital package, which is a part of PyTroll suite of Python interfaces developed to process meteorological satellite data (http://www.pytroll.org/). PyOrbital computes spacecraft position from the TLEs, yielding positions accurate to the model with 3.5 m. Figure 2 shows an example of improved navigation for the NOAA 14 satellite. It can be seen that the spatial misplacement of up to 25-30 km can occasionally occur in a GAC scene without navigation corrections. Such incorrect geolocation has profound impact on the retrievals of climate variables. The next processing step involves computing calibrated reflectances and brightness temperatures. At present, updated climate quality calibration coefficients provided by Dr. Andrew Heidinger (NOAA) under the SCOPE- CM framework are applied for all NOAA satellites (http://www.scope-cm.org/). The solar channel calibration (Channels 1 and 2, and Channel 3a if available) takes into account inter-satellite differences and is derived using amalgamation of different calibration

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references including the most recent MODIS Collection 6 data, in-situ targets, and simultaneous nadir observations. The original methodology for obtaining calibration coefficients was presented by Heidinger et al (2010). The calibration corrections can be accessed at the GSICS website (https://www.star.nesdis.noaa.gov/smcd/GCC/ProductCatalog.php). The thermal channel calibration is done from scratch, starting from obtaining Platinum Resistance Thermometer (PRT), space and Internal Calibration Target (ICT, blackbody) counts. For each thermal channel, a smoothing window of 51 successive PRT, ICT and space counts is used to obtain robust gain values and to dampen undue high frequency fluctuations in the count data. The decision to choose this window size was based on evaluation of a number of cases where fluctuations occurred. In some cases, it was found that the PRT numbers and corresponding counts could be inconsistent. This inconsistency is treated in PyGAC by redetecting PRT reset values and correspondingly assigning numbers to each PRT reading. With regard to quality control, at present three scanline quality flags are applied to the output files to mask out potentially corrupt data. These flags, that are common for POD and KLM families and available in the GAC data stream, are set to true if a) fatal error occurs in the orbit pre-processing, or b) calibration information is missing, or c) navigation information is missing. If any of the three flags is true, then those scan lines are masked out as missing data. Among all 559258 GAC L1b orbits from all NOAA and MetOp satellites covering time period from 1978 to 2015, about 32116 orbits (5.74%) were deemed un-processable (http://www.esa-cloud-cci.org/sites/default/files/documents/public/Cloud_cci_RAFCDR_v1.0.pdf). Finally, the output from PyGAC is organized into three HDF5 files. The first file contains calibrated reflectances and brightness temperatures and geolocation. The second file contains sun-satellite angles. The third output file provides scan line quality flags. It also provides flags to warn about potential contamination of thermal channels by solar light impinging on detectors. Scan line number, total number of data records, and the last scan line number are also provided.

PyGAC has already been used to preprocess 30+ years of AVHRR GAC data in the frameworks of EUMETSAT's CM SAF and ESA Cloud CCI (Karlsson et al., 2017; Stengel et al., 2017). While primarily designed to process GAC data, PyGAC is also able to process 1-km Local Area Coverage (LAC) data from AVHRRs. It can also be used as an independent library that can be plugged into existing software architectures. Improvements in near future include clock drift estimation for morning satellites, handling of solar blackbody contamination and implementation of improved thermal channel inter-calibration. In the future, the nearly 50-year GAC data record can be preprocessed using PyGAC once the EUMETSAT's MetOp-C comes into the operation.

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Discuss the Article

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A decade of IIR/CALIPSO Level 1 assessment against MODIS/Aqua

by Noëlle A. Scott (LMD), Anne Garnier (SSAI/NASA), Jacques Pelon (LATMOS) and Raymond Armante (LMD)

Introduction

The Version 1 Level 1 calibrated radiances of the Imaging Infrared Radiometer (IIR) on-board the NASA / CNES CALIPSO satellite, part of the A-train constellation, have been quantitatively evaluated since launch in June 2006. Two complementary approaches, "relative" and "stand-alone", have been used to monitor the IIR observations against "reference" observations of MODIS / Aqua Collection 5 (C5) and SEVIRI / Meteosat (not shown). Collocated IIR, MODIS, and SEVIRI observations are from the "REMAP'' product available at the AERIS/ICARE Data and Services Center (http://www.icare.univ-lille1.fr). MODIS viewing angles for pixels collocated with IIR quasi-nadir observations decrease from 20° at the equator to a few degrees near the poles. IIR and MODIS observations are quasi-simultaneous. As a result of pre-launch simulations, IIR channels 1 (8.65 µm), 2 (10.6 µm), and 3 (12.05 µm) are paired with MODIS / Aqua channels 29, 31, and 32, respectively. Also, the impact of spectral, geometric and GEO/LEO inherent mismatches have been characterized. For several air mass types and viewing angles conditions, the simulated brightness temperature (BT) of the IIR and MODIS paired channels differ from -1 K to +0.3 K (standard deviations from 0.33 to 0.02K).

The two approaches and initial results covering 2.5 years in orbit were presented by Scott et al. (2009). A refined assessment is presented in Garnier et al. (2017), which is based on a detailed analysis of nearly a decade of collocated IIR Version 1 and MODIS/Aqua C5 data using the complementary relative and stand-alone approaches. So far, the analysis is limited to global day and/or night sea cases for which surface emissivity is more stable than over land.

Long term stability analysis using concomitant relative and stand-alone approaches

Using the relative approach, time series of daily-averaged IIR-MODIS BTDs have been analyzed for several ranges of BTs and latitude. A slight trend of the IIR1-MODIS29 BTDs, equal to -0.02 K/year on average, is visible at all latitudes and temperatures ranges, whereas no trend is seen in the IIR2-MODIS31 and IIR3-MODIS32 BTDs. This is illustrated in Fig. 1, for, e.g. 30°S-30°N and warm temperature (290-300 K) conditions. Such a specific behavior of MODIS29 was independently noticed by Wu et al. (Proc. of SPIE, doi: 10.1117/12.2069246, 2014).

The concomitant analysis of time series of simulations-minus-observations BTDs (residuals) generated by our stand-alone approach allows identifying which channel

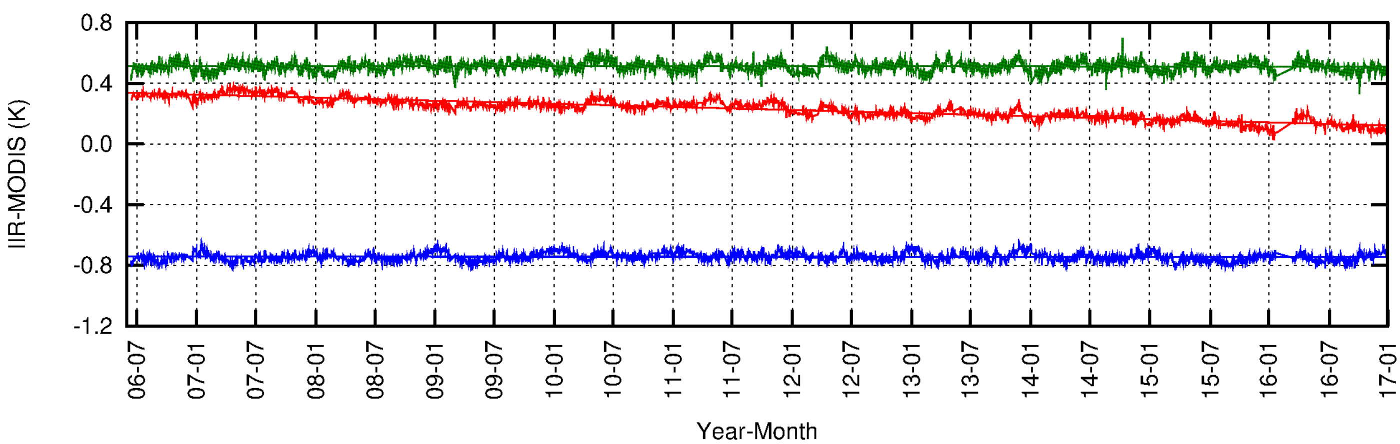

Figure 1. Time series of IIR-MODIS daily average BTDs for IIR1-MODIS29 (red), IIR2-MODIS31 (green) and IIR3-MODIS32 (blue). Latitude range: 30°S-30°N. Temperature range: 290-300 K. Sea only.

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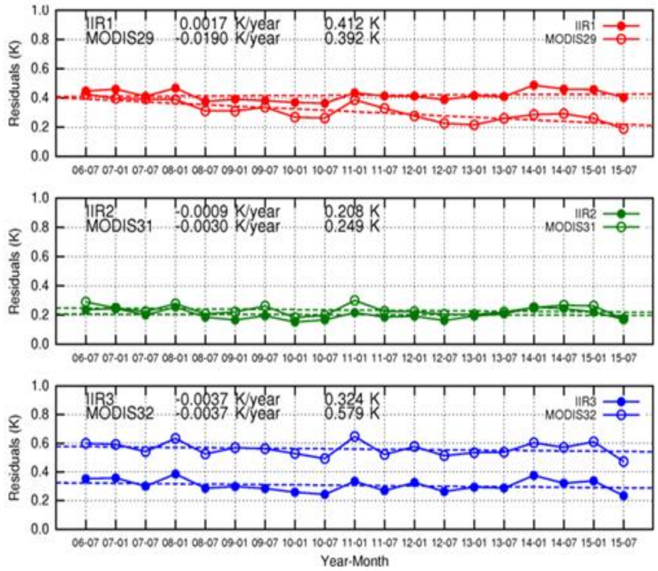

Figure 2. Time series of the IIR and MODIS residuals from the stand-alone approach. Latitude range: 30°S-30°N. Sea only.

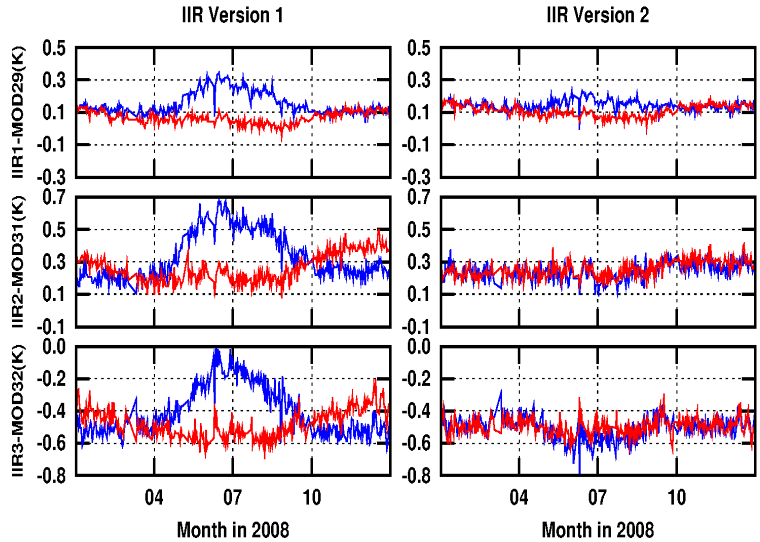

Figure 3. Nighttime (blue) and daytime (red) time series of IIR-MODIS daily average BTDs for IIR1-MODIS29 (top), IIR2-MODIS31 (middle) and IIR3-MODIS32 (bottom). Latitude range: 30°N-60°N. Temperature range: 280-290 K. Sea only. Left: IIR Version1; right: IIR Version 2.

deviates from the other. Within the same observing conditions, observed BTs of each IIR and MODIS channel are compared to simulations performed using the 4A/OP model and the spectroscopic GEISA database (http://ara.lmd.polytechnique.fr). Atmospheric and surface inputs to 4A/OP are from a 3h/5km collocation with ECMWF ERA-INTERIM products. The clear sky mask is based on co-aligned observations from the CALIPSO lidar and IIR, and is further extended to the IIR 69-km swath.

As seen in Fig. 2 (top), the MODIS29 residuals exhibit a trend of -0.019 K / year when the IIR1 residuals are stable, indicating that this trend originates from MODIS29. No trend (less than ± 0.004 K/year) is detected for any of the other channels.
Due to this drift, IIR1 and MODIS29 residuals agree within 0.02 K at the beginning of the mission and ~0.2 K nine years later. (Fig. 2, top). IIR2 and MODIS31 residuals stably agree within 0.04 K (Fig. 2, middle). This reveals an excellent accuracy of the IIR calibration with respect to MODIS for these pairs of channels. However, IIR3 residuals are smaller than MODIS32 ones by 0.26 K, (Fig. 2, bottom), which suggests a calibration bias (under study).

IIR Version 1 calibration biases in the Northern hemisphere at day-to-night transitions

Unexpected, moreover seasonal, IIR-MODIS BTDs day/night differences are seen since launch in the 30°N-60°N latitude band, but not south of 30°N. In July, the nighttime BTDs in the descending portion of each orbit are larger than the daytime BTDs by up to 0.2 K to 0.4 K on average (Fig. 3, left as an example for year 2008). Concurrently, the stand-alone approach shows a decrease of nighttime IIR2 and IIR3 residuals from 25°N to 45°N not seen in MODIS companion channels (Garnier et al., 2017): this unambiguously reveals that the larger IIR-MODIS observed BTDs at night at 30°N-60°N in July are due to IIR warm biases. In parallel, it was found that these calibration biases are well correlated with the occurrence of a striping effect seen in images of IIR inter-channel BTDs over homogeneous scenes (Scott, 2009). These findings have guided parallel investigations conducted at CNES towards a refined calibration during the day-to-night transitions at mid- and high latitudes in the Northern Hemisphere. With this refined Version 2 calibration (Fig. 3, right), the day/night differences are substantially reduced.

Concluding remarks

The relative and the stand-alone approaches are complementary and mutually reinforcing. Our findings have impacted and guided part of the calibration revisions carried out at CNES, thus contributing to the Version 2 IIR level 1 products publicly released in July 2017. Version 2 is the first major release since Version 1 in 2006. We plan a new evaluation using IIR Version 2 and MODIS/Aqua C6 data. The stand-alone approach will benefit from the 2016 updated version of the 4A/OP model, a newly released version of the spectroscopic database (GEISA-2015), a better handling of surface emissivity, and an improved clear sky mask from the CALIPSO lidar and IIR

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Discuss the Article

Overview of version 2.5 ozone profile products from the Suomi NPP OMPS Limb Profiler

by Natalya Kramarova, P.K. Bhartia , Philippe Xu, Matthew Deland, Zhong Chen, Glen Jaross and Leslie Moy, NASA

The Ozone Mapping and Profiler Suite (OMPS) on board of the Suomi National Polar-orbiting Partnership (NPP) satellite combines three ozone sensors that operate in the UV/VIS spectral ranges and scan the same air masses within 10 minutes [1, 6] to measure vertical and spatial ozone distributions. Suomi NPP OMPS serves as a bridge mission connecting BUV global ozone measurements pioneered in the 1970s with the next-generation of NASA / NOAA sensors on board the Joint Polar Satellite System (JPSS).

The OMPS Limb Profiler (LP) is a newly designed research sensor aimed to continue high vertical resolution profile records from SAGE and MLS instruments. In a first of its kind design, the LP employs Charge Coupled Device (CCD) detector that simultaneously measures solar radiances scattered from atmospheric limb from altitudes between 0 and 80 km over wavelengths from 290 to1000 nm, significantly reducing the cost and improving the reliability of the instrument. The UV measurements provide information to retrieve ozone concentrations in the upper and middle stratosphere (29.5-52.5 km) and visible measurements are used to retrieve ozone in the lower stratosphere (12.5-35.5 km) [2]. With 14 orbits per day and roughly 160-180 measurements per orbit (~1^0 latitude sampling) the LP provides a full global coverage every three to four days.

In summer 2017, all LP measurements starting from April 2012 have been processed with the new version 2.5 algorithm. Key changes implemented in this new version are summarized in Table 1.

Key changes	Version 2.5
Cloud Height Detection	New algorithm to better discriminate between clouds and aerosol [5]
Altitude Registration	-Refined static altitude correction (~190m); -Latitude and seasonally dependent correction (0-400 m) [*4*]; -Two 100 m steps, one in April 2013 and another in September 2014
Stray Light Correction	Empirical correction applied for VIS wavelengths
Wavelength Selection	**UV:** 302 nm, 312 nm and 322 nm paired with 353 nm (3 pairs) **VIS:** 600 nm combined with 510 and 675 nm to form a single triplet
Radiance Normalization Altitude	**UV:** 55 km **VIS:** 40 km
Aerosol Correction	Use aerosol extinction coefficient profiles retrieved from LP measurements at 675 nm
Measurement Noise	**UV:** diagonal matrix with 1% noise; **VIS:** diagonal matrix with 0.5% noise.
Vertical Smoothing	-Define a priori covariance matrices assuming 25% ozone variability above 20 km, 50% ozone variability below 16 km and inter-level correlation decaying exponentially with 5 km correlation lengths; -Remove 2nd order Twomey-Tikhonov regularization term

Table 1. Summary of key changes implemented in version 2.5 relative to version 1 described in [2].

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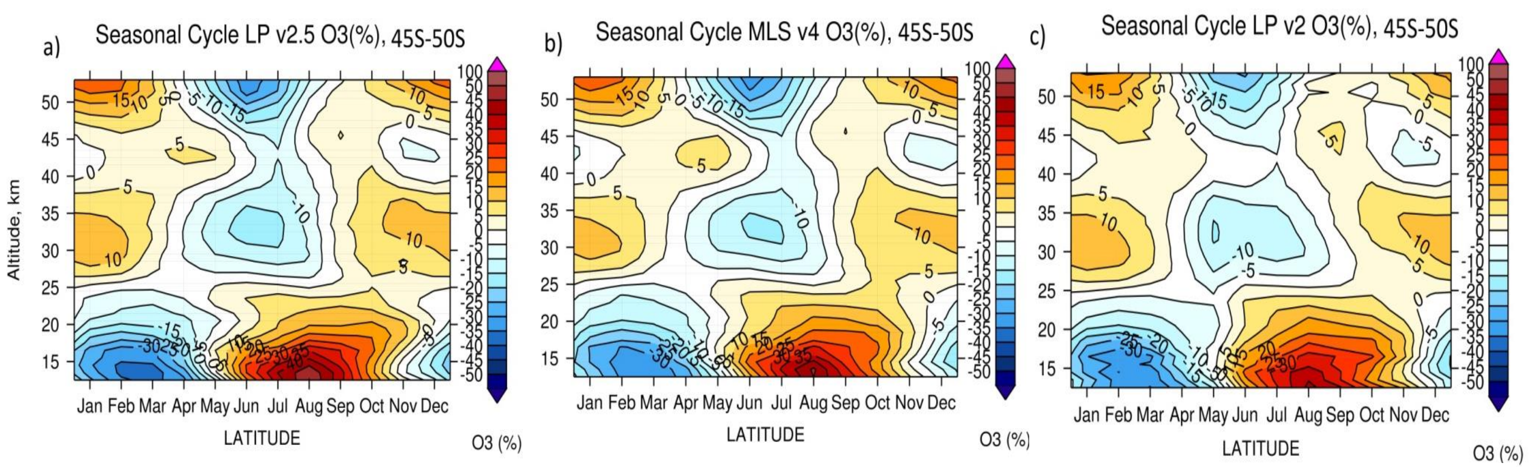

Figure 1. Ozone seasonal cycle derived from OMPS LP version 2.5 (a), version 2 (c) and MLS (b) observations expressed in (%) from the instrumental mean.

Limb scatter measurements typically suffer from altitude registration and stray light errors, and OMPS LP is no exception [*3*]. A large fraction of the effort has been invested in development and implementation of two methods to resolve LP pointing independent of the star tracker [*4*]. These methods can resolve a pointing altitude with the combined accuracy of ±200 m. After version 2.5 processing was completed, one of our altitude resolving methods detected an 80-meter drift in sensor pointing over 5.5 years. Despite significant progress in estimating and correcting radiometric errors [3], small systematic radiance errors (~±1%) still remain in LP measurements, causing ~3% persistent structures in ozone. In addition, in the northern hemisphere an unexpected thermal sensitivity of the instrument itself was discovered, causing vertical and spectral shifts in the measurements [*3*].

In order to facilitate error analysis and attribution, the original LP ozone retrieval algorithm [2] was simplified in the version 2.5 processing by reducing the number of wavelengths used in the algorithm and, therefore, increasing the sensitivity of retrieved ozone to errors in measured radiances at specific wavelengths and altitudes.

To verify the implemented calibrations and sensor pointing corrections the LP version 2.5 ozone retrievals are compared against satellite Aura Microwave Limb Sounder (MLS) version 4 [7] and ground-based sonde observations. Our analysis shows that LP retrievals accurately characterize vertical ozone distribution in different atmospheric regions most sensitive to changes in the stratospheric composition and dynamics. LP measurements agree well with MLS in reproducing ozone natural variability associated with the seasonal cycle, Quasi Biennial Oscillations in tropics and winter vortex in polar latitudes in terms of amplitude, phase and vertical structure (Fig. 1).

Our analysis indicates that the mean differences between LP and correlative measurements are mostly within ±5% between 18-42 km. In the upper stratosphere and lower mesosphere (>43 km), LP tends to have a negative bias (-6–12%), which is within combined systematic uncertainties for LP and MLS. We find larger biases in the lower stratosphere and upper troposphere, but we see significant improvements in version 2.5 compared to version 2 because of the implemented aerosol correction. In the northern high latitudes we observe larger biases between 20-32 km due to remaining thermal sensitivity issue. Our comparisons confirm that the absolute LP altitude registration is well within ±200 m. We found a small positive drift ~0.5%/yr. between LP and MLS that is more pronounced at altitudes above 35 km. Such a pattern is consistent with the 80-meter drift in sensor pointing detected by one of our altitude resolving methods.

The attribution of observed errors to a specific cause is challenging process, as errors in ozone produced by various causes tend to interfere and produce complex patterns. Both external (comparisons with independent observations) and internal (analysis of LP radiances) validation results are critical for evaluating LP altitude registration and calibrations. We expect this work to continue throughout the life of the instrument. The OMPS LP data are available at: https://disc.gsfc.nasa.gov/datasets/OMPS_NPP_LP_L2_O3_DAILY_2/summary

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Discuss the Article

Reprocessing of Suomi NPP CrIS Sensor Data Records and Impacts on Radiometric and Spectral Long-term Accuracy and Stability

by Yong Chen, Likun Wang, Fuzhong Weng and Changyong Cao (NOAA)

The Cross-Track Infrared Sounder (CrIS) is a Fourier Transform Spectrometer on board the Suomi National Polar-Orbiting Partnership (S-NPP) satellite, which was launched on October 28, 2011. Since April 19, 2012, the Joint Polar Satellite System (JPSS) ground processing system called the Interface Data Processing Segment (IDPS) has continuously generated the CrIS Sensor Data Records (SDRs) and delivered them to user communities.

CrIS, the Infrared Atmospheric Sounding Interferometer (IASI), and the Atmospheric Infrared Sounder (AIRS) are all hyperspectral infrared sounders. These instruments provide high-vertical resolution of temperature and water vapor information critically important for improving numerical weather prediction (NWP) assimilation and forecast results, supply extensive information about trace gases, cloud properties, and surface properties for climate applications, and can be used as relative space reference sensors to calibrate and validate other IR sounders [1-3]. All these applications require the hyperspectral infrared radiances with high and stable calibration accuracy.

However, the operational CrIS SDR data quality has been continuously improved due to the algorithm and software changes especially during the intensive calibration and validation (ICV) period (before Feb 20, 2014). Therefore, the operational SDR are not suitable for deriving the long-term climate trending and other climate applications due to their inconsistency during the life-time mission. Currently, CrIS provides both truncated spectral resolution (TSR) and full spectral resolution (FSR) (after December 4, 2014) SDR data products. The CrIS SDRs are being reprocessed in a NOAA reprocessing project with fine-tuned calibration coefficients to provide an improved and consistent new data set.

In this study, we only present the

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results from the reprocessed TSR data which are available from February 20, 2012 to August 31, 2016. There are several major improvements in the CrIS reprocessing SDR quality as follows: (a) Calibration algorithm improvement: the current operational calibration approach does the radiometric calibration first, and then applies the correction matrix operator (CMO) for spectral calibration, while the new approach first applies the spectral calibration to the raw spectra and at the same time takes into account the instrument responsivity, and then performs the radiometric calibration. This new calibration algorithm can effectively reduce the ringing artifacts observed in IDPS SDR [4]. (b) Spectral calibration improvement: while the CrIS spectral calibration system measures the laser wavelength periodically roughly once per orbit, the current spectral calibration algorithm does not update the resampling matrix as often as the Neon measurements (it is only updated when the cumulative variation of the metrology wavelength exceeds 2 ppm to the initial metrology laser wavelength). In order to take the laser wavelength variation into account, the resampling matrix needs to be frequently updated to reflect the changes in sensor spectral grid. In the CrIS SDR reprocessing algorithm, the resampling matrix is recalculated whenever the metrology laser wavelength is updated, which effectively eliminates the sampling error in the spectral calibration [5]. (c) Non-linearity coefficients update: the non-linearity (NL) coefficients were initially estimated during the thermal vacuum testing (TVAC) by performing analysis of out-of-band signals in complex spectra and self-consistency in calibrated External Calibration Target (ECT) view data, and refined by performing analysis of in-orbit Earth view data to determine better

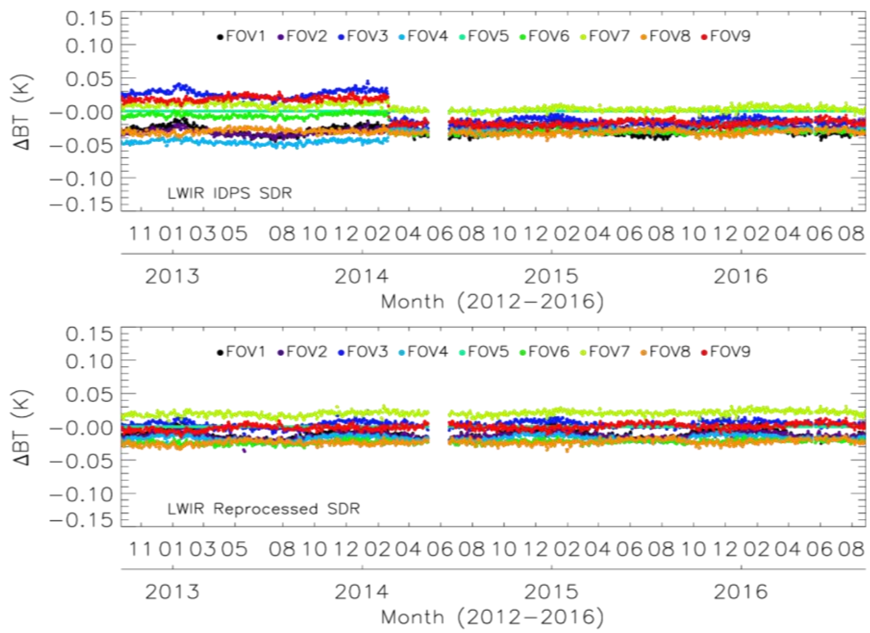

Figure 1. Time series of the longwave daily mean FOV to FOV difference (16 channels averaged from 672 to 682 cm-1) with respect to the center FOV 5 for clear sky over ocean for IDPS (top) and reprocessed (bottom) SDRs from September 22, 2012 to August 31, 2016.

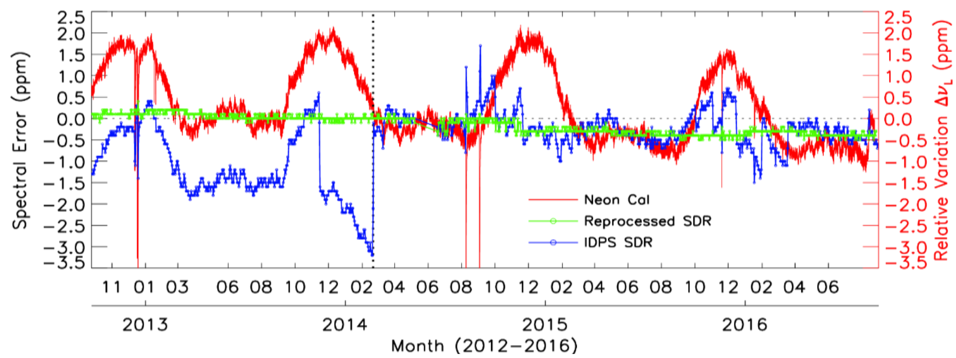

Figure 2. Comparison of the Neon subsystem spectral calibration versus calibration using the upwelling radiances for IDPS and reprocessed SDRs from September 22, 2012 to August 31, 2016.

nonlinearity coefficients for the other FOVs using one detector with negligible nonlinearity effects [6]. (d) Geolocation mapping angle parameters update: the post-launch on-orbit geometric calibration can be assessed by performing perturbation of the CrIS line-of-sight vectors along the in-track and cross-track directions to find a position where CrIS and the Visible Infrared Imaging Radiometer Suite (VIIRS) image band I5 (which has high spatial resolution and accurate geolocation) radiances match most closely. Based on the assessment results, the mapping angle parameters are optimized [7]. There are several methods to assess the CrIS SDR radiometric accuracy, such as biases between CrIS Model) simulations using ECMWF forecast / reanalysis fields as input, double difference between CrIS and IASI on MetOp-A/B (converted to observations and forward model CRTM (Community Radiative Transfer CrIS) using CRTM simulation as a transfer tool, and simultaneous nadir overpasses (SNO) difference between CrIS and IASI.

The longwave time series FOV-to-FOV

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difference is showed in Figure 1. The consistency is significantly improved in the reprocessed SDRs.

There are two basic spectral assessment methods to evaluation the hyper-spectral satellite sensors [5, 8, 9], such as IASI and CrIS. The first one is the absolute method which requires an accurate forward model such as CRTM to simulate the top of atmosphere (TOA) radiance under clear conditions. It then correlates the observed radiance to the simulated radiance by shifting the spectra at a certain range either from the observation or the simulation to find the maximum correlation. The second method is the relative method. It doesn't need a forward model, it only requires two uniform observations to determine frequency offsets relative to each other. Following [4], the absolute spectral accuracy results are showed in Figure 2. It is shown that CrIS metrology laser wavelength varies within 3 ppm as measured by the Neon calibration subsystem. The reprocessed SDR have spectral errors less than 0.5 ppm, is much better than the operational SDR with about 4 ppm. Note that the upwelling calibration has been offset by -0.6 ppm, and the Neon zero shift time is determined by the CMO update on December 19, 2012.

As shown in this paper, the S-NPP CrIS mission-long reprocessing is necessary not only to improve SDR products but also to benefit GSICS inter-calibration capabilities and climate applications, in terms of better radiometric and spectral calibration accuracy, and consistent calibration stability based on the same software and calibration coefficients.

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Discuss the Article

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Robust reflective solar bands calibration for S-NPP VIIRS science-quality mission-long SDR reprocessing

by Junqiang Sun (GST/NOAA)

The Suomi National Polar-orbiting Partnership (SNPP) Visible Infrared Imaging Radiometer Suite (VIIRS) has been on orbit for more than five years. Through independent efforts by the NOAA Ocean Color (OC) Team, the radiometric calibration of reflective solar bands (RSBs) recently has achieved robust result [1]. Numerous improvements have been made in the standard RSB calibration methodology for the sensor data records (SDR), which is the starting point for the higher-level environmental data records (EDR) and science products [2]. These improvements have helped the OC EDR products that demand stringent accuracy to reach validated maturity [2]. The success of the OC EDR performance has led to the institutional decision to implement the calibration results generated by the OC Team, in the form of look-up-tables (LUTs), as an official input for the operational SDR reprocessing to be released to all users, as stated in reference [3]. The OC LUTs delivered for the operational SDR reprocessing are the latest updates containing further improvements over the current LUTs used for the OC reprocessing and forward processing [4]. The component-by-component investigations by Sun and Wang [1, 2] have resulted in significant improvements in the RSB calibration of SNPP VIIRS. Key efforts include the careful reanalysis of the bidirectional reflectance factor (BRF) of the solar diffuser (SD) and the vignetting functions (VFs) of the attenuation screens placed in the front of the SD port and the SD stability monitor (SDSM) Sun view port, the new and better selection procedure for “sweet spots” to improve the characterization of the SD reflectance (H-factor) and RSB calibration coefficient (F-factor), and further refined data processing procedures to reduce noise and artificial features in the derived H-Factors and F-factors [1,2]. However, Sun et al. have also found that despite optimal calibration analysis in the standard procedure, the SD degrades non-uniformly with respect to both incident and outgoing directions, and thus invalidates the key assumption in the SD/SDSM calibration methodology that the SD degradation in the outgoing direction towards the SDSM can be used interchangeably with the result for the outgoing direction towards the RTA [5]. This discrepancy results in a worsening long-term error in the calibration coefficients derived using the SD, and the error is especially pronounced at shorter wavelengths [1, 2]. Sun and Wang have developed a hybrid approach combining SD-based and lunar-based calibration coefficients to generate a set of hybrid calibration coefficients that lead to overall stable short- and long-term calibrated VIIRS RSB SDR [1]

Figure 1. Normalized water-leaving radiance $nL_w(551)$ (SNPP VIIRS M4) derived from the reprocessed SDR with the hybrid F-factors (Green line) and IDPS SDR (Red line).

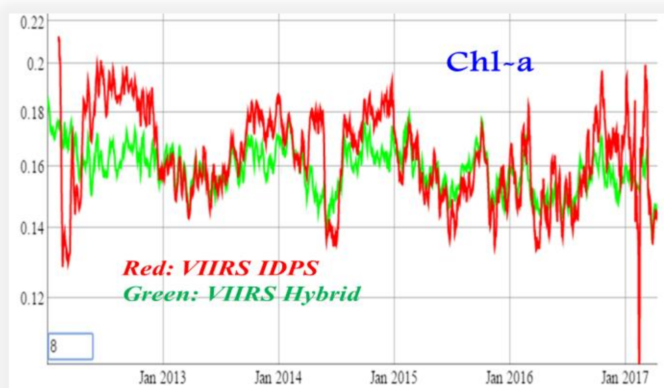

Figure 2. VIIRS Chl-α derived from the reprocessed SDR with the hybrid F-factors (Green line) and IDPS SDR (Red line).

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Significant long-term drifts and unexpected features have been found in the VIIRS-derived normalized water-leaving radiances and the chlorophyll-α calculated using the NOAA Interface Data Processing Segment (IDPS) SDR [2], which are the current official operational SDR products produced using the SD F-factors. The application of the reprocessed SDR with our improved hybrid SD F-factors significantly improves the quality of the OC EDR [2]. Figure 1 shows the time series of VIIRS-derived $nL_w(\lambda)$ at wavelength of 551 nm (M4) over the deep water region. The $nL_w(\lambda)$ spectra derived with the IDPS SDR, which are processed with standard operational SD F-factors, are represented in Fig. 1 as a red curve. The $nL_w(\lambda)$ derived using the SDR reprocessed with our hybrid F-factors are also shown in Fig. 1 as a green curve. Figure 1 shows that $nL_w(\lambda)$ data derived with the IDPS SDR have a long-term drift of ~25% while that the $nL_w(\lambda)$ spectra derived with our OC hybrid F-factors are without observable long-term drift. This is also true for other wavelengths (bands). Figure 2 shows VIIRS Chl-α derived, mainly dependent of M2 and M4, from the newly reprocessed SDR with the hybrid F-factors and those from IDPS SDR in the same region. Chl-α data based on IDPS SDR (red line) show a clear long-term drift of about 20%, while the Chl-α results based on OC SDR show a clearly reduced long-term trend (green line).

The VIIRS SDR team is working on the institutional VIIRS SDR reprocessing for all users and all EDRs [3] for the coming official NOAA release. The baseline VIIRS reprocessing is performed using the RSBAutoCal LUTs with an option of using OC calibration LUTs [4] to generate a different set of SDRs with the high-quality result for users to generate EDRs of science quality. RSBAutoCal LUTs are SD-based F-factors, which are in principle the same as the LUTs used in current forward IDPS SDR but with corrections of the forward processing in the current forward IDPS SDR products. As shown in our previous studies, the SDR products generated with the SD-based F-factor LUTs including the RSBAutoCal LUTs have significant long-term drifts and the drifts will be inherited and even amplified in the associated EDR products generated with the SDR. These drawbacks are mitigated by the OC LUTs generated from the hybrid-approach provide to produce high quality SDR for users to generate EDRs of science quality [2, 4]. It is worth to note again that the OC LUTs are completely based on calibration principles without any input of OC products or their property.

The OC LUTs are adopted into the SDR reprocessing as an available option for users to generate science quality SDRs. It is the SDR version, free of issues including artificial seasonal oscillations, anomalous features and long-term drifting error, recommended for use.

Author of this article can be contacted for information on obtaining re-processed data.

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Discuss the Article

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News in this Quarter

GSICS Eighteenth Executive Panel (EP-18) Meeting held in Jeju, Korea

by Mitch Goldberg (NOAA), Kenneth Holmlund (EUMETSAT), Lawrence Flynn (NOAA), Manik Bali (NOAA), Dohyeong Kim (KMA) and Masaya Takahashi (JMA)

The GSICS Executive Panel (EP) held its eighteenth meeting on 8-9 June in Jeju, Korea. The meeting was hosted by KMA in the picturesque island of Jeju in Korea. This two day meeting was attended by GSICS Executive Panel representatives of CMA (Remotely), EUMETSAT, ROSHYDROMET, ROSCOSMOS, ISRO (Remotely), JAXA, JMA, KMA, NASA, NOAA and WMO.

The EP meeting began with the executive panel welcoming Toshiyuki Kurino as the WMO secretariat representative on the GSICS Executive Panel. Toshi replaced Jerome Lafeuille who served the secretariat for eleven years. Toshi has previously served in the GSICS EP as a member of Japan Meteorological Agency (JMA) and brings with him vital experience needed to drive the GSICS consortium. This year also marked three years of Peng Zhang's (CMA) Executive Panel Chairmanship. Upon the end of Peng's tenure, the panel elected Mitch Goldberg (NOAA) as the Executive Panel Chair. Mitch has served the GSICS Executive Panel as a member, for over ten years now and has also served as its Chair for a number of years. He is currently the Chief Scientist of the JPSS mission at NOAA. Following his election, he chaired the rest of the meeting.

The meeting began with presentations from the GSICS Coordination Centre (GCC) Director, GSICS Research Working Group (GRWG) Chair and GSICS Data Working Group (GDWG) Co-Chairs.

GCC Director, Lawrence Flynn (NOAA), gave an overview of the progress made by the GSICS coordination center in meeting the needs of the GSICS community. Among the highlights were 1) GCC facilitated the acceptance of nine new products into the GSICS Product Catalog. He thanked the reviewers of the products, Chairs, Co-Chairs of Groups and the EP for their role in the acceptance process. 2) He also reported on the development of a new tool to track GSICS Actions at GCC. This tool is built on the google cloud and can be scaled to the needs of the WIGOS system. 3) Larry also initiated discussion on the format of the GSICS Users Workshop.

GSICS Research Working Group (GRWG) Chair, Dohyeong Kim

Participants of the GSICS Executive Panel Members (EP-18) meeting in Jeju, Korea

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(KMA), provided an overview of the activities in GRWG. Dohyeong informed the panel of the successful GSICS Annual Meeting organized at Madison, Wisconsin in March 2017. This participants in the meeting made a strong pitch to connect with users of GSICS algorithms and products and to support the development and launch of the CLARREO IR mission through a letter from WMO to the CLARREO project and inclusion. He then provided a breakdown of advances in each subgroup (IR, VIS/NIR, MW, UV). The IR subgroup Chaired by Tim Hewison (Eumetsat) has made progress in developing components for the GEO Ring and GEO-GEO comparison of COMS versus Himawari 8. SRF retrieval and Spectral Corrections are vital topics in the coming future.

Dohyeong reviewed the progress made by the Visible and Near Infrared Subgroup, chaired by Dave Doelling (NASA). The subgroup has made advances in developing techniques that use Lunar and Deep Convective Clouds as transfer references. Plans are progressing for Second Joint GSICS / IVOS Lunar Calibration Workshop to be held in China 13-16 November 2017. The Microwave subgroup led by Ralph Ferraro (NOAA) is spearheading working on three major areas 1) to develop candidate satellite/sensor (inventory) as in-orbit references for specific channels, 2) to provide a draft uncertainty analysis describing the comparison of example (microwave) instruments to GRUAN, and 3) To develop RTM approaches as a calibration transfer tool.

The UV subgroup lead by Rosemary Munro (Eumetsat) has made strong pitch to work on topics to develop consensus and lead on many topics. These include the following: 1) A Reference Solar Spectrum project to compare solar measurements, 2) A White paper on ground-based characterization, 3) A direct match-ups and target sites project to compare reflective channel performance, and 4) A project for cross-calibration below 300 nm by using forward models and climatology as transfer methods.

Peter Miu (EUMETSAT) provided an overview of the GSICS Data Working Group activities. The GSICS Data working made strong progress in development of GSICS products. The development of collaboration server in storing products and the migration of GSICS Wiki from NOAA to University of Maryland was highlighted. Peter also encouraged member agencies to increase their participation in the GSICS Data Working Group. At the end of the GDWG discussion, the EP gave the responsibility of chairing the GDWG to Masaya Takahashi with an invitation to Ashim Mitra from IMD to be Vice-Chair.

The GRWG and GDWG presentations were followed by agency reports from NOAA, NASA, KMA, CMA, JMA, JAXA, IMD, ROSHYDROMET, and ROSCOSMOS. Dohyeong Kim then drew the attention of the EP towards the need for On-Orbit SI-traceable Hyperspectral Reference Instruments for Satellite Inter-Calibration. He recommended that the EP supports the CLARREO mission to meet monitoring requirements of agencies by supporting letter to the CLARREO project.

WMO OSCAR

Toshi drew the attention of the EP to the upgrades in the OSCAR webpage developed and maintained by WMO. He presented the Implementation of Sustainable Maintenance Scheme for OSCAR/Space Database. He identified the implementation of the use of a direct link from OSCAR/Space for providing calibration / validation status and instrument anomaly information. Toshi also encouraged GSICS members to participate more in the future development of OSCAR. He added that GSICS will be a member of OSCAR / Space Science and Technical Advisory Team to help review assessments, functions, rules and interfaces. The EUMETSAT Satellite Conference in Rome (10/2017) will include discussions on the role and content of OSCAR.

The EP then discussed outreach to the inter-calibration community. The EP deliberated on the formulation of vital components of the outreach which include the Quarterly Newsletter and the Users' Workshops.

Into the Future

Overall, the EP was highly appreciative of the progress made by the GSICS Research and Data Working Group and also appreciated the efforts of the GSICS Coordination Center in meeting the goals of GSICS community.

With the subgroups making advances, the GSICS Executive Panel stressed strengthening the interaction of GSICS with GNSS, Space Weather, GHRSST, CEOS, GRUAN and other components of the WMO Integrated Observing System (WIGOS). The benefits of reciprocal attendance among these groups were discussed. Several actions were generated to drive the GSICS community further towards meeting the goals set by the agencies. Detailed discussions are available at

http://www.wmo.int/pages/prog/sat/meetings/GSICS-EP-18/GSICS-EP-18.html

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Achieving calibrated data of Earth remote sensing systems today and beyond

by David R. Doelling (NASA)

This article is a summary of a panel discussion during the CALCON calibration meeting, held at Logan Utah, USA, on August 24, 2017. The panelist include; Martin Mylnczak, from NASA-Langely and a member of SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) and CLARREO projects; Alan Thurgood, the Director of the Systems Calibration & Testing Division at Space Dynamics Laboratory; David Doelling, from NASA-Langley and a member of the NASA-CERES (Clouds and the Earth's Radiant Energy System) project. The discussion was moderated by Kurt Thome, from NASA-Goddard. He is the Terra project scientist. The discussion was greatly enhanced by contributions from audience members.

Is the remote sensing community better served by building several instruments or by building one perfect instrument? One will never know the true uncertainty and limitations of the perfect instrument and associated retrieval, unless there were other instruments to compare against. For example, the SABER project retrieves ozone abundance. After comparing the ozone retrieval with other independent ozone datasets, it was found that the SABER retrieval was out of family with the other retrievals. This prompted an investigation of the instrument and algorithms. A light leak was discovered in the SABER instrument. Potentially, the retrieval code could have contained a bug, which may not be discovered, unless prompted to do so. The community is best served, if every component of the instrument and retrieval algorithm were independently designed from the previous build. Also, all instruments, should be built to observe invariant Earth, lunar, and solar targets. This will allow a calibration expert to objectively verify the onboard calibration.

How do we archive data to be useful for future generations? Usually, the program managers spend all of the money before the end of mission. Therefor the funding will not be available to incorporate all of the calibration knowledge for the final reprocessing. The end of mission recalibration objective, must be written in the program directives to dedicate this funding. We must take part of the blame. We would like to work on new missions with the latest capabilities, rather than work on the end of mission calibration activities. New instrument proposal objectives should emphasize end of mission re-calibration, data, and knowledge preservation with the same priority as promoting new instruments. The scientific community would greatly benefit by permanently archiving all remotely sensed data, along with the documented calibration accuracy. In order to transfer the calibration knowledge to future generations, we need to incorporate young scientists to be part of instrument and calibration teams. Also, new scientists have a different way of thinking about the issues and we need to be open to these ideas. To make the data useful for new generations, both the data and the codes must be converted to the latest data formats and coding languages. For example, the AVHRR read software has been converted to python. See the PyGAC article in this issue. The codes must be well documented and calibration knowledge must be placed into peer reviewed journal articles. Also, all intermediate or internal documents, such as conference presentations should be archived. For example, the aeronautics research industry, which wanted to migrate all of the paper drawings into electronic form, invented CAD/CAM. It was expensive at the time, but CAD/CAM increased the efficiency in the aeronautics industry, thus benefiting future efforts. We need to communicate to users to properly reference remotely sensed datasets used in their publications. This includes the dataset provider, product name, version number and archive center. So that the results can be tied to a particular calibration state. When researchers are required to cite data products in papers, the tendency to use non-official datasets is dramatically reduced.

How do we change the calibration paradigm, especially now that there are so many new sensors being flown? Cube satellites and the miniaturization of sensors seem to be the way of the future, in order to lower the cost.

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Further cost reductions may include trimming onboard calibration systems. How can these new constellations be uniformly calibrated? This can easily be solved if there was a concurrent sensor dedicated to calibrating other sensors, for example, CLARREO or TRUTHS. If the miniature sensor could save money by not incorporating high quality onboard calibration systems, could some of that money be dedicated for CLARREO or GSICS activities? Ultimately, we need to satisfy user requirements, such as latency. We need to have calibration systems that are flexible enough to account for onboard calibration issues in order to get the corrected data users in short order. Also, we need to produce data products designed with the user in mind. We should not allow processing to dictate the product structure, but should include extra processing, to optimize the data structure, to easily facilitate visualization, spatial, temporal, and parameter sub-setting. Designing the data products to allow for post-launch calibration validation, will allow calibration experts to quickly validate the onboard calibration. In the end, by providing more user-friendly data products, will increase the number users, which in the end results in more funding.

Announcements

Improvements of Himawari-8/AHI level-1 data quality and updates of its format

by Kenji Date and Masaya Takahashi (JMA)

The Japan Meteorological Agency (JMA) updated Himawari-8 ground processing system at 04:00 UTC on 25 July 2017 in order to improve the quality of Himawari-8/AHI level-1 data. The updates include 1) reduction of banding and stripe noise of AHI visible and near infrared (VNIR) bands, 2) improvement of quantization noise in the Himawari Standard Data (HSD), and 3) updating of HSD header block to add the latest VNIR calibration coefficients in consideration of sensor sensitivity change. The details of the updates can be found the following documents provided at the JMA Meteorological Satellite Center's website:

http://www.data.jma.go.jp/mscweb/en/operation8/eventlog/Improvement_of_Himawari-8_data_quality.pdf

http://www.data.jma.go.jp/mscweb/en/operation/calibration/hm8/CorrectionOfSensitivityTrend.pdf

Mitch Goldberg accepts GSICS Executive Panel Chair

by Manik Bali (NOAA)

In the GSICS Executive Panel meeting held in Korea, Dr. Mitch Goldberg was elected as the Chair. Mitch replaces Peng Zhang, Deputy Director General NSMC, CMA. Dr. Zhang served as the GSICS Executive Panel Chair from 2014-2017.

In the last three years, under Peng's leadership, the GSICS community has grown rapidly and satellite agencies participation in GSICS has picked up strongly. We now have thriving new UV and Microwave subgroups. New methods of inter-calibration have been introduced, WMO has come up with a new version of the OSCAR, and for the first time GSICS products became operational.

In his first stint as its chairman, Dr. Goldberg's, vision of GSICS provided the GSICS with a very strong foundation. Algorithms and best practices developed collaboratively helped agencies such as ISRO, KMA, NOAA, EUMETSAT and JMA employ GSICS methods to monitor their instruments on a daily basis, document and correct any anomaly detected.

Moving ahead, Under the GSICS umbrella, Dr. Goldberg aims to work closely with his European partners to complement their GMES / Copernicus missions (Morning/Evening orbit) with the JPSS (Afternoon Midnight instruments) and provide reference accurate measurements to the entire GSICS community. It is hoped that such a combination would be able to reveal the full scale of biases (diurnal, temporal, scan angle and geographic) in monitored instruments and help re-calibrate them to a high level of stability and accuracy. Facilitating, use of state of the art GEO instruments, such as those on GOES-16 and Himawari 8/9 in achieving GSICS goals, is another vital task in the years to come.

A goal under Dr. Goldberg's leadership is to facilitate the integration of GSICS into the WMO Integrated Observing System (WIGOS). It is envisaged that the WIGOS system would be able to bring all earth observations under a single platform and integrate GSICS corrections directly with users thereby improving the quality of downstream services (e.g., Flood Forecasting, Retrievals and Weather/Climate Forecasts). Dr. Goldberg's support to the GSICS Coordination Center will play a vital role in developing tools for this integration and help bring down the overheads required in its function.

GSICS-Related Publications

Chen, R., H. Ebrahimi, and W.L. Jones. 2017. 'Creating a Multidecadal Ocean Microwave Brightness Dataset: Three-Way Intersatellite Radiometric Calibration among GMI, TMI, and WindSat'. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 10 (6): 2623–30. doi:10.1109/JSTARS.2017.2712786.

Chen, X.; Xing, J.; Liu, L.; Li, Z.; Mei, X.; Fu, Q.; Xie, Y.; Ge, B.; Li, K.; Xu, H. In-Flight Calibration of GF-1/WFV Visible Channels Using Rayleigh Scattering. *Remote Sens.* **2017**, *9*, 513. doi:10.3390/rs9060513

Gorroño, J., A.C. Banks, N.P. Fox, and C. Underwood. 2017. 'Radiometric Inter-Sensor Cross-Calibration Uncertainty Using a Traceable High Accuracy Reference Hyperspectral Imager'. *ISPRS Journal of Photogrammetry and Remote Sensing* 130: 393–417. doi:10.1016/j.isprsjprs.2017.07.002.

Schwerdt, M.; Schmidt, K.; Tous Ramon, N.; Klenk, P.; Yague-Martinez, N.; Prats-Iraola, P.; Zink, M.; Geudtner, D. Independent System Calibration of Sentinel-1B. *Remote Sens.* **2017**, *9*, 511. doi:10.3390/rs9060511

Yeom, J.-M.; Hwang, J.; Jung, J.-H.; Lee, K.-H.; Lee, C.-S. Initial Radiometric Characteristics of KOMPSAT-3A Multispectral Imagery Using the 6S Radiative Transfer Model, Well-Known Radiometric Tarps, and MFRSR Measurements. *Remote Sens.* **2017**, *9*, 130. doi:10.3390/rs9020130

Yang, A.; Zhong, B.; Wu, S.; Liu, Q. Radiometric Cross-Calibration of GF-4 in Multispectral Bands. *Remote Sens.* **2017**, *9*, 232.doi:10.3390/rs9030232

Submitting Articles to 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 cal/val 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. Note the upcoming fall issue will be a general issue. Please send articles to manik.bali@noaa.gov.

With Help from our friends:

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