GSICS Global Space-based Inter-Calibration System **Quarterly** V5 No. 3 2011

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http://gsics.wmo.int *Dr. Fangfang Yu, Editor*

Cross – comparison of GOME-2, AVHRR and AASTR Reflectance

The coincidence in space and time, and spectral coverage of the instruments on Metop-A provides an excellent opportunity to gain insight into their performance and the characteristics of their data. To assist in the calibration/validation of the GOME-2 spectrometer on Metop-A, comparisons with AVHRR-3 data have been performed to establish both the accuracy of the geo-location of the GOME-2 data and ultimately to examine long-term trends between the instruments' calibration. The method can be extended to similar classes of instruments, e.g., inter-comparisons of GOME-1, SCIAMACHY, ATSR-2 and AATSR. An initial evaluation of consistency between GOME-2 and AATSR has already been carried out. This multi-mission framework will allow further analysis of the long-term consistency of each instrument dataset.

The GOME class of instruments (GOME-1, SCIAMACHY, GOME-2 on ERS-2, ENVISAT and Metop-A respectively) provide visible measurements collocated with ATSR-2, AATSR and AVHRR-3 respectively. Due to the different spectral and spatial resolutions, the spectrometer data must be spectrally averaged, using the appropriate radiometer filter function, while the radiometers must be spatially averaged with the appropriate spectrometer ground pixel footprint (40x320km, 30x120km, and 40x80km respectively).

For each ground pixel of the spectrometer, its reflectance is convolved with the Spectral Response Function (SRF) of each imager channel. For AVHRR Channel 1, a small part of the SRF is not covered by GOME-2 channel 4 (see Figure as illustration). The spectrometer reflectance is currently extrapolated at a constant value over this region, on the basis of an examination of spectra from multiple scenes, for which this seems a good approximation. Comparison of GOME-2 with AVHRR channel 2 is currently only considered indicative, due to partial spectral coverage and the presence of water vapour absorption lines across the channel.

The imager data in each band is then spatially averaged based on the latitude/longitude information provided for each instrument. Due to the sequential readout of the GOME-2 detectors, each detector pixel sees a slightly different ground scene and therefore a wavelength dependent correction to the geolocation information is required. Based on the corner values for each spectrometer ground pixel, plus some margin, the associated latitude/longitude data of the imager data is extracted.

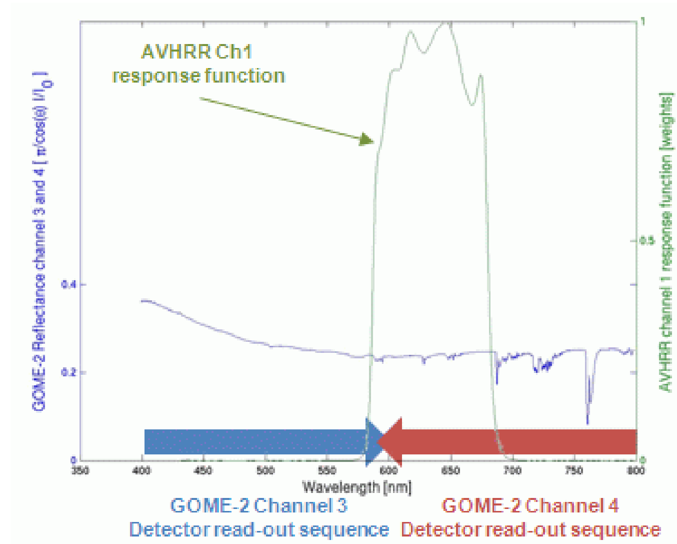


Figure 1: AVHRR-3 Channel 1 spectral response function and GOME-2 spectral bands with red arrows showing the detector readout direction.

Imager pixels within the FoV are identified, allowing for any specified misalignment correction and taking into account skew in off-nadir view, longitude varying with latitude, and earth curvature. Imager data are averaged and some scene variability statistics are stored for each spectrometer pixel (including cloud information where available).

Assuming the geolocation of the higher spatial resolution imager is correct and that scatter is due to differences in scene viewed by the two instruments, a collocation shift can be derived which produces the minimum scatter. Applying this method to GOME-2 and AVHRR data allowed an error in the GOME-2 geolocation calculation to be isolated and corrected. The UTC time per scanner position was shifted by 375 ms due an incorrect processor setting and as a consequence all latitude/longitude and geolocation parameters were shifted by 2.5 to 5% of the along-track pixel size at nadir position, i.e., by 1 to 2 km along the orbit. This was fixed in the new processor version 4.5 installed on 9th September 2010.

After implementing the bug fix, GOME-2 data were compared to both AATSR and AVHRR data to examine differences in radiometric accuracy between the instruments. In the case of AATSR the 30 minute separation of Metop-A and ENVISAT adds noise to the comparisons due to scene variability. This effect can be reduced by processing several orbits to provide a stable estimate of the bias, although systematic scene differences also need to be considered.

Comparison of GOME-2 with the AATSR 670nm channel, which is believed to be very well calibrated, showed excellent agreement for the period 2007 to September 2009 based on a selection of one orbit with near-nadir coincidence per month over a period of two years. The mean difference in Sun-normalised reflectance was <1% with some seasonal variation (assumed to be due to systematic differences in scene and surface BRDF).

By contrast, comparison of GOME-2 data with collocated Metop-A/AVHRR channel 1 data for the same period indicates an offset of ~9% in AVHRR (see Figure 1). This is consistent with the offset of ~9% reported by *Cao et al. 2008* between NOAA-16 & -17 AVHRR and MODIS 0.63µm data.

This work will be continued with a view to investigating long-term trends between the instruments and extending the method other instruments of a similar class.

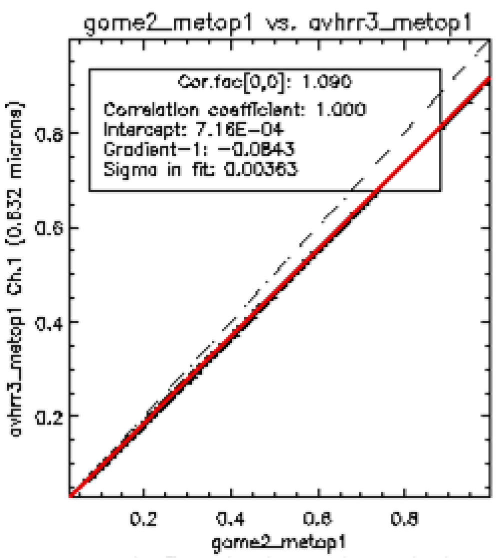


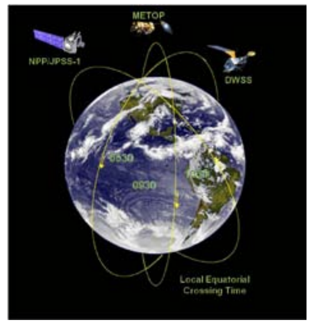
Figure 2: GOME-2 spectrally convolved reflectance versus AVHRR channel 1 (0.632) reflectance – both on Metop-A. The red line shows the fit forced through [0, 0] i.e., no offset is assumed, only a potential gain error. Dash-dot line is 1:1.

REFERENCES

Cao, C., X. Xiong, A. Wu, X. Wu, 2008. Assessing the consistency of AVHRR and MODIS L1b reflectance for generating Fundamental Climate Data Records, *J. Geophys. Res.* **113**, D09114, doi:10.1029 /2007JD009363.

(by B. Latter [Rutherford Appleton Laboratory, U.K.], R. Lang and R. Munro [EUMETSAT])

JPSS Mission



On February 1, 2010, the Executive Office of the President announced that the Joint Polar Satellite System (JPSS) would be NOAA's portion of the restructured National Polar-orbiting Operational Environmental Satellite System (NPOESS). JPSS is the next generation polar satellite system and will provide operational continuity of observations and products for NOAA's Polar-orbiting Operational Environmental Satellites (POES) and the NPOESS Preparatory Project (NPP) mission.

The NPP satellite is the pathfinder for the JPSS operational satellite series. While the Department of Defense will leverage the Defense Weather Satellite System (DWSS) to provide data from an early morning (0530) orbit, and EUMETSAT will provide data from the 0930 orbit (via METOP), NPP, successfully launched on October 28, 2011, is flying in the 1330 polar orbit. It has 2 major mission objectives: 1) Provide a continuation of the group of Earth system observations initiated by the Earth Observing System Terra, Aqua, and Aura missions, and 2) Provide the operational forecasting community with pre-operational risk reduction, demonstration, and validation for selected JPSS instruments and ground processing data systems.

A joint NOAA-NASA technical and managerial team structure has been created to ensure that the JPSS mission:

- Maintains continuity of critical environmental data and climate observations from the polar orbit
- Increases timeliness and accuracy of severe weather event forecasts
- Provides advanced imaging capability to analyze fires, volcanoes, Gulf oil tracking and other adverse incidents
- Provides advanced atmospheric temperature and moisture profiles

The NOAA-NASA JPSS team works collaboratively to align management and scientific team activities with the JPSS program requirements. As an example, the JPSS Sensor Data Record (SDR) Science Teams provide technical oversight for the instrument development, prelaunch testing, SDR algorithms and software, on-orbit verification, and long-term monitoring of all instruments on NPP and JPSS satellites. Their goal is to ensure that each instrument's performance complies with the requirements set forth in its performance and operations requirements and satisfies user needs, is referenced to recognized international standards, and conforms to "best" calibration practices. An SDR team is established for each instrument and provides technical guidance and recommendations to the JPSS Program Offices. The team is led by NOAA/NESDIS/Center for Satellite Applications and Research (STAR) and includes working level scientists and engineers at NOAA, NASA, universities, and other organizations.

To meet national requirements the JPSS will fly the following major instruments (Figure 1):

- **Visible/Infrared Imager/Radiometer Suite (VIIRS)** will have multi-band imaging capabilities to support the acquisition of high-resolution imagery of clouds and generation of a variety of applied products including visible and infrared imaging of hurricanes and detection of fires, smoke, and atmospheric aerosols.
- **Cross-track Infrared Sounder (CrIS)** will be the first in a series of advanced operational sounders that will provide more accurate, detailed atmospheric temperature and moisture observations for weather and climate applications. This information will help to significantly improve both short-term weather "nowcasting" and medium range prediction, and to enhance climate analyses and prediction.
- **Advanced Technology Microwave Sounder (ATMS)** will operate in conjunction with the CrIS to profile atmospheric temperature and moisture. Higher (spatial, temporal and spectral) resolution and more accurate sounding data from CrIS and ATMS will support continuing advances in data assimilation systems and NWP models to improve short- to medium-range weather forecasts
- **Ozone Mapping and Profiler Suite (OMPS)** will measure the concentration of ozone in the atmosphere, providing information on the total amount of ozone and how its concentration varies with altitude. Data from OMPS will continue three decades of monitoring ozone depletion, the ozone hole, and the recovery of the ozone layer with the ban on CFC emissions. The OMPS measurements also fulfill the U.S. treaty obligation to monitor global ozone concentrations with no gaps in coverage.
- **Cloud and Earth Radiant Energy System (CERES)** seeks to develop and improve weather forecast and climate model predictions by providing measurements of the space and time distribution of the Earth's Radiation Budget components. The observations from CERES are essential to understanding the effect of clouds on the energy balance (energy coming in from the sun and radiating out from the earth), which is one of the largest sources of uncertainty in our modeling of the climate.
- **Total Solar Irradiance Sensor (TSIS)** will measure the variability in the Sun's total output using two sensors. There is no operational heritage, but this instrument suite will continue the research measurements of TSIS on NASA's SORCE mission.

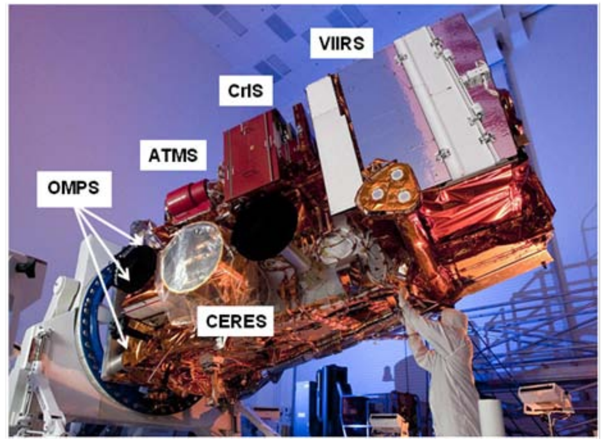


Figure 1. Arrangement of the instruments on NPP/JPSS.

(by Dr. Fuzhong Weng [NOAA])

NPP Provides a New Opportunity for GSICS

The Global Space-based Inter-Calibration System (GSICS) has established the Infrared Atmospheric Sounding Interferometer (IASI) on METOP satellites as a reference instrument, along with the Atmospheric InfraRed Sounder (AIRS) on EOS Aqua satellite. It has been shown that the difference between IASI and AIRS brightness temperatures is within 0.1 K without an apparent trend in bias during the past four years. The GSICS science team is also developing a consensus method for solar band cross calibration based on MODIS and other hyperspectral visible instruments such as GOME-2 on the METOP-A satellite.

The NPOESS Preparatory Project (NPP) satellite (see previous article) provides an additional opportunity to the GSICS community for cross-calibration. For example, a huge number of simultaneous nadir overpasses (SNO) between the NPP and Aqua satellites will be obtained, as shown in Table 1. In addition, there are protracted SNO data (NPP directly over Aqua) every 2.667 days when the two spacecrafts are within ±15 minutes for 19 hr 25 min, and the scan angle from NPP to Aqua nadir ranges up to 26° at all latitudes & many longitudes over one year (Figure 1).

Table 1. Orbit characteristics of NPP and Aqua satellites

NPP	Aqua
Sun Synchronous	Sun Synchronous
1330 Ascending Node	1330 Ascending Node
824 Km, 101.5 min orbit	705 Km, 98.9 min orbit
16 day ground-track repeat, 227 revolutions	16 day ground-track repeat, 233 revolutions

In the GSICS program, CrIS data will be compared with those from AIRS and IASI to determine the accuracy and stability of CrIS. VIIRS measurements will be compared with MODIS, MERIS, ATSR, and MERSI, and the data from the stable earth targets over the Antarctic DOME-C site and desert sites. OMPS will be intercompared with GOME-2 and other high quality ozone sensors, and ATMS will be intercompared with AMSU/MHS instruments. GSICS will assess the accuracy and stability of the NPP sensors. If appreciable biases and trends are found, GSICS will generate correction coefficients allowing users to adjust the measurements of the impacted instruments to the quality of established reference instruments.

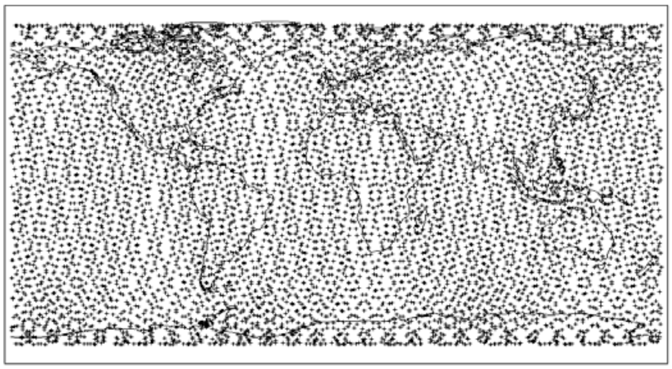


Figure 1. Location of Aqua Nadir Pixel when NPP sees the same location within ±15 minutes

(by Drs. Xiuqing "Scott" Hu [ERT/NOAA], Fuzhong Weng [NOAA] and Mitch Goldberg, [NOAA])

News in this Quarter

The 3rd GSICS Users' Workshop

The third GSICS Users Workshop resulted in excellent interactions between the GSICS program and the user community, which was represented by over 50 attendees. The external users provided very positive feedbacks on the GSICS Algorithm Theoretical Basis Documents (ATBDs) used for describing the GSICS correction products currently in the demonstration phase, and on the accessibility and usability of these GSICS correction products. Positive impacts on derived products using the GSICS corrections for geostationary infrared imagers were also reported. Examples included improved cloud detection and cloud top temperatures, sea surface temperatures and clear sky radiances. Small, but statistically significant, improvements were found in the data assimilation of clear sky MSG imager radiances by NCEP. A discussion on "common reference imager channels" has led to an action to suggest to CGMS the development of guidelines for the design of future instruments, with a view of harmonizing key specifications of at least a set of core imager channels for better interoperability. The Global Precipitation Mission Cross-Calibration Group (GPM X-Cal) project scientist attended the workshop, which led to an agreement to continue to discuss how best to enhance collaboration. The X-Cal and GSICS working groups agreed to share data, models and documentation. GSICS is willing to assist in the evaluation of X-Cal inter-calibration algorithms using the GSICS Product Acceptance Procedures (GPPA). The communities representing the WMO's Sustained, Co-Ordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM) program and the World Climate Research Program's Global Energy and Water Cycle Experiment (GEWEX) expressed needs to improve interactions with GSICS, especially understanding the role of GSICS in inter-calibration of historical satellite datasets going back to 1979. An earlier suggestion to establish a User Board might be a way to strengthen interactions with SCOPE-CM at a proper strategic level. It is still the desire of GSICS for the GEWEX International Satellite Cloud Climatology Project (ISCCP) to validate the GSICS corrections and provide feedback.

From a broader perspective, the discussion also pointed out the need to put more emphasis on explaining the scope of GSICS, its operating principles and planned deliverables, and on the development of some independent assessment of GSICS calibration results.

(By Jerome Lafeuille [WMO] and Tim Hewison [EUMETSAT])

IEEE TGRS Special Issue on "Inter-Calibration of Satellite Instruments"

Call for Papers: This special issue of the Transactions on Geoscience and Remote Sensing (TGRS) will focus on how inter-calibration and comparison between sensors can provide an effective and convenient means of verifying post-launch sensor performance and correcting the differences. The guest editors invite submissions that explore calibration methods including, but not limited to, pseudo-invariant calibration sites, instrumented sites, simultaneous nadir observations and other ray-matching comparisons, lunar and stellar observations, deep convective clouds, liquid water clouds, Rayleigh scattering and Sun glint. The inter-calibration results should focus on rigorous quantification of bias and associated sources of uncertainty from different sensors, crucial for long-term studies of the Earth. The goal of this special journal issue is to capture the state-of-the-art methodologies and results from inter-calibration of satellite instruments, including full end-to-end uncertainty analysis. Accordingly, it will become a reference anthology for the remote sensing community.

Paper submission deadline: 31 January 2012

Guest Editors: Gyanesh Chander [SGT/USGS], Tim Hewison [EUMETSAT], Nigel Fox [NPL], Xiangqian "Fred" Wu

[NOAA], Xiaoxiong "Jack" Xiong [NASA], William J. Blackwell [MIT/LL]

IEEE TGRS Special issue on the Chinese Fengying-3 Satellite Instrument Calibration and Applications

Call for Papers: In the Chinese weather satellite program, the first two research and experiment satellites FengYun-3A (FY-3A) and FengYun-3B (FY-3B) were successfully launched into orbit on May 27, 2008 and November 5, 2010, respectively, and the remaining five operational satellites will be launched once every two years. FY-3A/B satellites cover the mid-morning and afternoon orbits. The following eleven instruments are on board both FY-3A and FY-3B: (1) Visible and InfRared Radiometer (VIRR); (2) MEdium ReSolution Imager (MERSI); (3) InfRared Atmospheric Sounder (IRAS); (4) MicroWave Temperature Sounder (MWTS); (5) MicroWave Humidity Sounder (MWHS); (6) MicroWave Radiation Imager (MWRI); (7) Solar Backscatter Ultraviolet Sounder (SBUS); (8)Total Ozone Mapping Unit (TOU); (9) Earth Radiation Measurer (ERM); (10) Solar Irradiation Monitor (SIM); and (11) Space Environment Monitor (SEM).

During the first two years of FY-3A/B in orbit the focus has been on the calibration and validation of all the instruments, and applications of data in NWP models, which will be the focus of this special issue.

Hence we would like to invite contributions covering the following topics:

- Calibration and performance monitoring of the FY-3A/B instruments;
- First results of calibration and validation and scientific studies using FY-3A/B data;
- Algorithms for retrieving the environmental and geophysical parameters;
- Assimilation of FY-3 data into NWP models; and
- Other advanced applications of FY-3 data in research and operations

Submission Deadline: October 31, 2011, with final publication in the December 2012 issue.

Guest Editors: Fuzhong Weng [NOAA/NESDIS], Xiaolei Zou [Florida State University], and Joe Turk [JPL/CIT]

GSICS 11th Session of the Executive Panel (EP) Meeting

The GSICS 11th Session of the EP meeting was held at St. Petersburg, Russian Federation in the afternoon of October 2, 2011.

Just Around the Bend …

GSICS-Related Meetings

- 18th Conference on Satellite Meteorology, Oceanography and Climatology/First Joint AMS-Asia Satellite Meteorology conference, which will be held as part of the 92nd American Meteorological Society Annual Meeting, 22-26 January 2012 in New Orleans, LA, USA.

GSICS Publications

Roithmayr, C, and P. Speth, 2011. Analysis of opportunities for intercalibration between two spacecraft, in *Adv. Eng. Res.*, edited by V.M. Petrova, pp. 1-28. Nova Science Publishers, Hauppauge, NY.

Wang, L., et al. 2011. Consistency assessment of Atmospheric Infrared Sounder and Infrared Atmospheric Sounding Interferometer radiances: Double difference versus simultaneous nadir overpass. *J. Geophys. Res.* Vol. **116**, D11111, dio:10.1029/2010JD014988.

Meier, W., S. Khalsa, and M. Savoie, 2011. Intersensor calibration between F-13 SSM/I and F-17 SSMIS near-real-time sea ice estimates, *IEEE Trans. Geo. Remote Sens.* Vol. **49**, No. 9, pp 3343-3349.

Hewison, T. 2011. GSICS SEVIRI-IASI Inter-calibration uncertainty evaluation, *Proc. 2011 EUMETSAT Met. Satellite Conf.*, Olso, Norway 5-9, Sept. 2011. [online]

Please send bibliographic references of your recent GSICS-related publications to Fangfang.Yu@noaa.gov.

With Help from our Friends:

The *GSICS Quarterly* Editor would like to thank those individuals who contributed articles and information to this newsletter. The Editor would also like to thank Dr. George Ohring for the technical support and proofreading of the articles, our European Correspondent, Dr. Tim Hewison of EUMETSAT, and Asian Correspondent, Dr. Yuan Li of CMA, in helping to secure and edit articles for publication.

Submitting Articles to GSICS Quarterly: The *GSICS Quarterly* Press Crew is looking for short articles (<1 page), especially related to cal/val capabilities and how they have been used to positively impact weather and climate products. Unsolicited articles are accepted anytime, and will be published in the next available newsletter issue after approval/editing. **Please send articles to Fangfang.Yu@noaa.gov.**