GSICS Quarterly

Global Space-based Inter-Calibration System

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Vol. 2, No. 1, 2008

www.orbit.nesdis.noaa.gov/smcd/spb/calibration/icvs/GSICS/index.html

Dr. Robert A. Iacovazzi, Jr., Editor

SEVIRI/IASI Differences in 2007

König (2007) reported the use of IASI to simulate radiances observed by Meteosat Second Generation (MSG) SEVIRI instruments. This has been extended to include an error propagation analysis and now covers most of 2007. In this method, the mean and variance of the radiances in the 25 MSG pixels closest to each IASI Instantaneous Field of View (IFOV) are calculated. This is repeated for all IASI pixels within ±30° latitude/longitude of the geostationary sub-satellite point where the instruments' view angles are within 2°. No cloud mask is applied to the data, so it now includes cloudy as well as clear scenes to cover a fuller range of radiances. A weighted linear regression is then calculated between the IASI and SEVIRI radiances, accounting for the variance of the scene. This is used to estimate the mean difference between the instruments' radiances for a reference scene and finally is converted to brightness temperature (T_b). In addition, a radiance uncertainty or error propagation analysis is performed and likewise converted to T_b. The current assumptions of the error propagation are:

- Accurate timing and geolocation of IASI & SEVIRI data;
- Negligible solar and azimuthal effects arise when using night-time IASI & SEVIRI measurements with view angle differences less than 2°;
- Standard deviation of SEVIRI pixels in IASI IFOV represents spatial variability;
- Biases follow polynomial functions of the scene radiance;
- Negligible temporal variability in data when IASI & SEVIRI observation time difference is less than 15 minutes*; and
- Accurate knowledge of all spectral response functions.*
  (* These assumptions are subject to future investigation.)

The reference scene radiances have been derived for typical clear-sky scenes within the domain of the inter-comparison, as shown in Table 1. As the difference between the instruments can depend on scene radiance, the regression method has also been applied to estimate the mean difference for cloudy scenes with lower radiances (T_b=200 K). However, the results were found to be highly variable for most channels.

The statistics in Table 1 were found to be independent of the method of filtering the data – whether they are unfiltered, or include only cases with low scene variance using either absolute brightness temperatures [σT_b<0.5 K] (as König (2007)) or relative radiances [σL<0.05$B_\nu(T_{bref})$]. This validates the decision not to filter the data in this analysis.

Table 1: Brightness temperatures, T_bs, for reference scenes and mean T_b difference between Meteosat-9 (MSG2) SEVIRI and IASI during 2007.

Ch (µm)	Clear-sky Ref Scene T_{bref} (K)	Mean Bias MSG2-IASI at T_{bref} (K)	Standard Deviation (K)
3.9¶	290	0.17¶	0.10
6.2	240	0.61	0.05
7.3	260	0.25	0.04
8.7	290	0.02	0.04
9.7	270	0.00	0.07
10.8	290	0.03	0.06
12.0	290	0.05	0.06
13.4	270	-1.63	0.26

¶ IASI response is limited to 2760 cm^{-1}, which underestimates radiance of a 290 K scene in 3.9 µm channel by 0.17 K.

The range of radiances covered in this analysis allows us to investigate the linearity of the relative differences between SEVIRI and IASI. This effect is small — at most about 0.2 K at 3.9 µm for reference scenes — and no consistent pattern was found when testing the statistical significance of a quadratic term in the regression, representing any non-linearity. This variability may be due to the error bars being currently underestimated because no account has yet been taken of the temporal variability between the instruments' samples, which can be up to 15 minutes.

The results in Table 1 are consistent with König (2007) despite the different method: showing a large bias in the 13.4 µm channel of SEVIRI on MSG2, which was the operational geostationary satellite at 0° longitude for most of this period. The time series in Figure 1 show the biases in the 3.9 µm and 13.4 µm channels change during 2007, followed by a sudden recovery following the decontamination

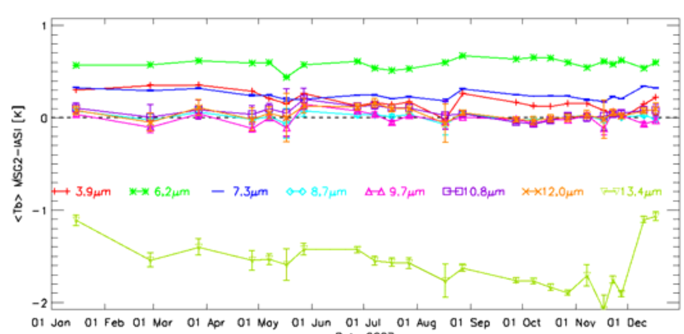


Figure 1: Time series of T_b differences between MSG2 SEVIRI/IASI for reference scene radiances as above. Each MSG2 SEVIRI infrared channel is depicted with a different color and symbol as shown in the legend. Error bars represent statistical uncertainty on each mean bias, which may be very small.

procedure of 3 to 11 December 2007. The biases in the other channels remain constant, with small standard deviations of approximately 0.05 K, and are similar to those found for Meteosat-8 (MSG1) SEVIRI. All SEVIRI biases show slow variations, which may be modeled using a Kalman Filter based on inter-calibration with IASI on a weekly basis.

Future plans are: to include temporal variability in the error propagation by interpolating between two successive geostationary images, to account for the IASI Point Spread Function by weighting the SEVIRI pixels used in each collocation, and to investigate if shifts in SEVIRI's Spectral Response Functions can explain the biases.

König, M., 2007: Inter-calibration of IASI with MSG-1/2 onboard METEOSAT-9, *GSICS Quarterly,* Vol.1, No. 2.

(by Dr. T. Hewison [EUMETSAT])

Redefining Radiances for SEVIRI

For a precise interpretation and thus inter-calibration of the MSG SEVIRI thermal channels, it is important to note that the SEVIRI data processing to Level 1.5 makes use of a very specific definition of thermal radiance. The SEVIRI radiances L^{15} are monochromatic blackbody radiances B for a channel-specific central wavelength ν:

$$L^{15} = B_\nu(T) \qquad \text{(Eq. 1)}$$

i.e. that SEVIRI data are actually temperatures, T, expressed as monochromatic Planck radiances. For inter-calibration purposes, however, the radiance should be expressed as an effective radiance, $L^{15\,eff}$, over the entire channel filter width:

$$L^{15\,eff} = \frac{\int B_\nu(T) r_\nu d\nu}{\int r_\nu d\nu}, \qquad \text{(Eq. 2)}$$

where r_ν is the spectral response and ν is wavenumber. Depending on the channel and on absolute scene temperature T, the differences between the two radiance definitions, expressed as temperatures, can amount to 0.1 to 2 K.

The MSG SEVIRI/IASI inter-comparison results presented in the previous article take this effect into account by first expressing the Level 1.5 radiances as blackbody temperatures (Eq. 1), and then converting these temperatures back to an effective radiance (Eq. 2). EUMETSAT plans to change the Level 1.5 radiance definition to an effective radiance in early 2008. Further information on this issue can be found in http://www.eumetsat.int/groups/ops/documents/document/pdf_msg_planned_change_level15.pdf.

(by Dr. M. König [EUMETSAT])

Demonstration of the GSICS GEO/LEO Inter-Calibration System

The GSICS algorithm to assess geostationary (GEO) to low-earth-orbit (LEO) inter-calibration is rapidly reaching the end of its initial stage of development. An example of the GSICS GEO-LEO Inter-Calibration System has been prepared using data from the Earth Observing System (EOS) *Aqua* Atmospheric InfraRed Sounder (AIRS) and the GOES-11 and GOES-12 Imagers. In Figure 1, the locations AIRS-convolved and GOES-12 Imager 13.3 µm band data that meet the criteria for inter-comparison are mapped for 21 February 2002.

The green dots in the figure show that most of the data are not near the nadir location of the GOES-12 satellite. Also, since there are several co-located data points, the behavior of the inter-comparison as a function of brightness temperature ($\boldsymbol{T_b}$) can be evaluated, as shown in Figure 2. In Figure 2, two sets of AIRS-convolved $\boldsymbol{T_b}$s are plotted as a function of GOES-12 13.3 µm $\boldsymbol{T_b}$. One set of AIRS-convolved data was made using the official spectral response function for the 13.3 µm GOES-12 Imager channel, while the other was made by

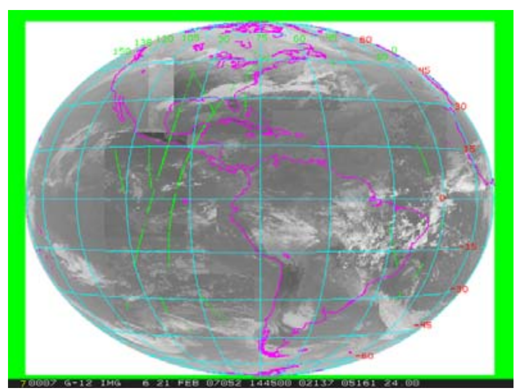


Figure 1: Green dots depict locations of AIRS-convolved and GOES-12 Imager 13.3 µm band inter-comparison data on 21 February 2002.

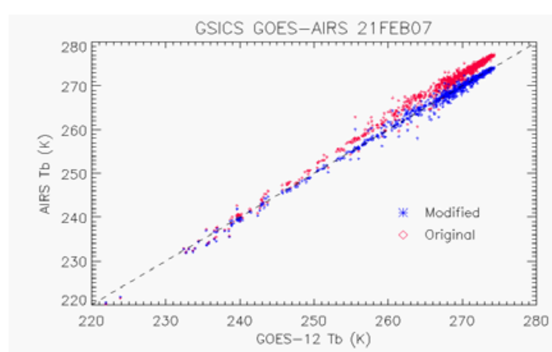


Figure 2: Plot of $\boldsymbol{T_b}$ bias as a function of $\boldsymbol{T_b}$ for the AIRS-convolved and GOES-12 Imager 13.3 µm band data.

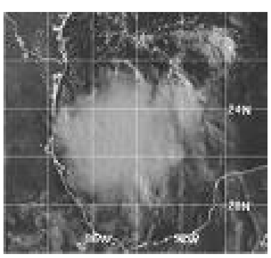
shifting the peak of this spectral response function by about +0.1 µm. This spectral response function shift compensates for the non-unity slope between AIRS and GOES-12 Imager in this channel.

In essence, the new GSICS GEO-LEO inter-calibration algorithm features flexibility in the form of off-nadir field-of-view (fov) resolution inter-comparisons. This flexibility allows GEO-LEO inter-comparisons to extend through much of the diurnal cycle bracketing the local equatorial crossing times of the LEO satellites. Also, the fov resolution of the analysis allows instrument bias estimates to be made as functions of scene radiance or T_b. These features of the new GEO-LEO inter-calibration software were not present in algorithms that focused on nadir-only, area-average instrument comparison.

In developing this new GEO-LEO inter-comparison algorithm, GSICS partners have come together to establish algorithm specifications and to develop code. For example, preliminary versions of the software code were developed at NOAA, but JMA has come up with a recent software version that has improved modularity and is independent of McIDAS. This new version produces identical results to previous versions and may help in implementing the software at some GSICS Processing and Research Centers. Thus, development of the new algorithm reveals the ability of GSICS partners to share knowledge, ideas and workloads to improve the state-of-the-art of GEO-LEO satellite inter-calibration.

(by Drs. X. Wu and R. Iacovazzi, Jr., [NOAA])

On the Use of Deep Convective Clouds to Monitor Visible Channel Degradation



Deep Convective Clouds (DCCs) are cold and bright tropopause targets near the equator. These targets provide maximum earth-view radiances in the solar reflective bands and have reflection and absorption components that are in equilibrium, thereby maintaining a constant albedo at the top of the atmosphere. Since DCCs are located at the tropopause, no apriori atmospheric profile or surface information is required. Only slight albedo variations may occur due to ozone and stratospheric aerosols. Collectively, these near isotropic and predictable albedos can be used to detect the relative gain drift of a visible sensor, although they cannot be used to provide absolute calibration. A short description of the procedure is given below, while a more comprehensive summary can be found in Minnis et al. (2007).

The DCC method relies on all visible radiances collected over the course of a month. The DCC radiances are identified by a simple IR threshold. The IR channels are usually well calibrated and therefore do not rely on satellite navigation accuracy. The DCC pixel radiances have 11µm brightness temperatures less than 205 K, are located between 30°N and 30°S, and the 8 surrounding pixels have a standard deviation in the 11µm and 0.65µm channels less than 1 K and 2%, respectively. The DCC pixel radiances are then converted to overhead sun albedo using the Clouds and the Earth's Radiant Energy System (CERES) Tropical Rainfall Measurement Mission (TRMM) Angular Distribution Models (ADM) http://asd-www.larc.nasa.gov/Inversion/ for overcast ice clouds with optical depths greater than 50 to correct for anisotropy. The ADM converts the individual pixel radiance (dependent on viewing and solar geometry) to a flux or albedo (only a function of SZA). The flux is then converted to an overhead sun flux using the CERES directional model, which describes the albedo as a function of SZA.

As an example, the DCC algorithm was applied to four months of MET-8 SEVIRI 0.86 µm channel radiances. The left panel of Figure 1 shows the monthly probability distribution functions (PDFs) of pixel counts (proportional to radiance) converted to overhead sun. The time series of the mode or the mean of the PDF are also plotted in the right panel of this figure. In this case, there are not enough months to predict a trend. Figure 2 shows GOES-8 five-year calibration trend based on DCC and on VIRS-matched gridded radiances. These calibration trends are very similar, thus verifying the DCC method effectiveness.

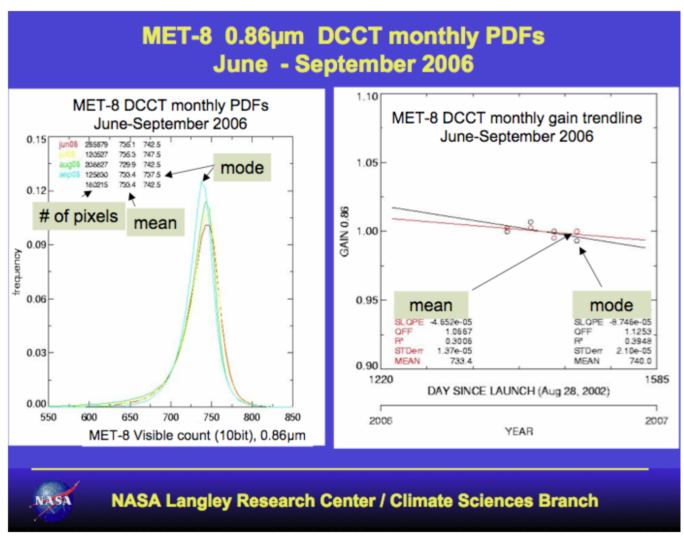


Figure 1: (left) Monthly PDF of pixel counts converted to overhead sun; and **(right)** normalized mode and mean of PDF over time. Note each month uses more than 100,000 DCC pixels. Also, the middle month in the time series is used to normalize the mean or mode radiances.

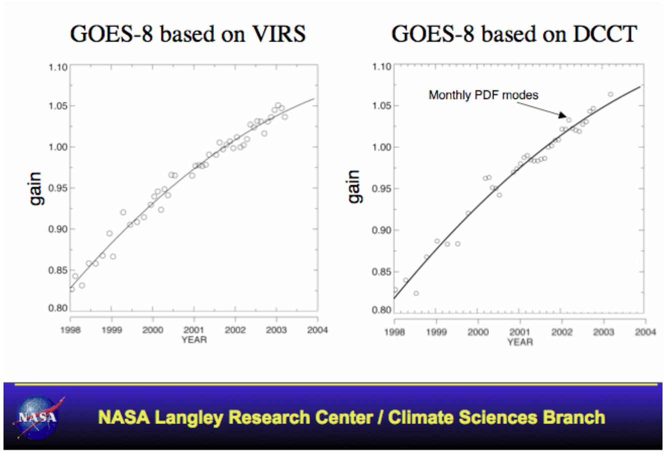


Figure 2: GOES-8 five-year calibration trend based on **(left)** VIRS and **(right)** DCC matched gridded radiances.

Minnis, P., D. R. Doelling, L. Nguyen, W. F. Miller, and V. Chakrapani, 2007: Assessment of the visible channel calibrations of the VIRS on TRMM and MODIS on Aqua and Terra. *J. Atmos. Oceanic Technol.*, **in press** (available at http://www-pm.larc.nasa.gov/calibration/pub/journal/ Minnis.etal.JTech.07.pdf.)

(by Dr. David Doelling [NASA])

GOES-12 13.3 μm Channel Bias During Decontamination

Schmit and Gunshor (2007) reported a -1.4 K cold bias between GOES-12 Imager Channel 6 (13.3 μm) and AIRS data convolved with the GOES-12 Channel 6 spectral response function (SRF). Similarly, a -2.4 K bias between GOES-13 and AIRS was found for this channel. In addition, they discovered that shifting the GOES-13 SRF by 4.7 cm^{-1} (or 0.1 μm) towards shorter wavenumbers nearly removed the GOES-13 bias.

Wu (2007) confirmed the cold bias for GOES-12 using an early version of the GSICS geostationary (GEO) to low-earth-orbit (LEO) inter-calibration algorithm and a sample set of GOES-12 and AIRS data collected on 21 February 2007. He further demonstrated that the bias is dependent on scene temperature, which lends support to the hypothesis that the bias is caused by an error in SRF. However, the magnitude of the GOES-12 bias (-2.6 K), and consequently the required shift in SRF, seemed to be consistent with those of GOES-13.

When GSICS became partially operational at NESDIS in October 2007, it was found that the GOES-12 Imager Channel 6 bias became smaller, much similar to the -1.4 K originally reported by Schmit and Gunshor. This was deemed as an issue for further investigation.

Recently, EUMETSAT reported that the Meteosat Second Generation SEVERI 13.4 μm channel had a cold bias compared with IASI, and that bias was substantially reduced after decontamination in December 2007 (see the first article of this newsletter). This prompted us to re-examine the GOES-12 Imager and AIRS inter-calibration, since the Imager went through decontamination on 2 July 2007. As Figure 1 shows, there is indeed a significant reduction of bias after decontamination, which means that part of the GOES-12 bias is caused by a contaminant deposited on the cooler window. This is consistent with an earlier analysis by the instrument vendor, and further analysis of this problem is planned.

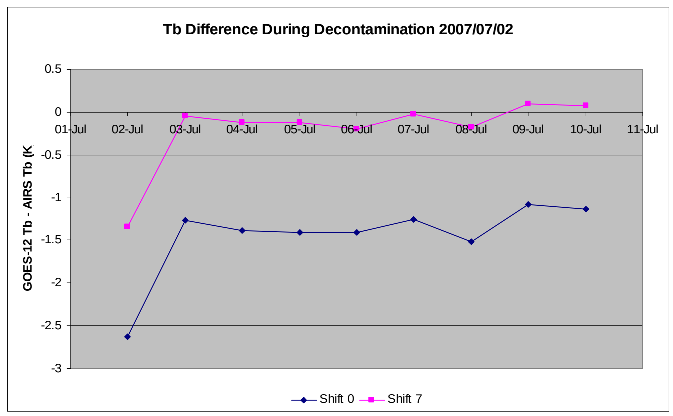


Figure 1: Time series of the difference between GOES-12 Imager Channel 6 and AIRS, expressed as brightness temperature, during the decontamination maneuver of 2 to 4 July 2007. The blue curve denotes the bias without an imposed shift of the SRF, while the purple curve denotes the bias with the SRF shift.

Schmit, T., and M. Gunshor, 2007: Apparent cold bias in the GOES-13 Imager band 6 (13.3 μm). Internal Memorandum.
Wu, X., 2007: GRWG Report to the GSICS Executive Panel. GSICS Executive Panel-III Meeting. Cocoa Beach, FL, USA.

(by Dr. X. Wu [NOAA])

SNO Analysis Captures NOAA-16 AMSU-A Channel 4 Instability

Continuous estimation of Advanced Microwave Sounding Unit-A (AMSU-A) inter-satellite calibration biases is valuable in monitoring changes in these instruments. It also is vital to the process of inter-calibrating satellite instrument constellations, which is needed to support the Global Earth Observation System of Systems (GEOSS) and GSICS initiatives. The GSICS low-earth-orbit (LEO) to LEO inter-comparison software was recently expanded to include automated processing of all simultaneous nadir overpass (SNO) events between the AMSU-A instruments on NOAA-16 to -18 and MetOP-A. From these analyses, stability degradation of NOAA-16 AMSU-A Channel 4 is clearly evident after mid-March 2007. This is shown in Figures 1A and 1B in SNO bias time series between AMSU-A Channel 4 brightness temperatures of NOAA-15 and NOAA-16, and NOAA-16 and MetOP-A, respectively. The remaining channels of NOAA-16 do not show such clear stability degradation (not shown). To view all AMSU-A SNO analyses, follow the SCIENCE PAGES link on the GSICS web site.

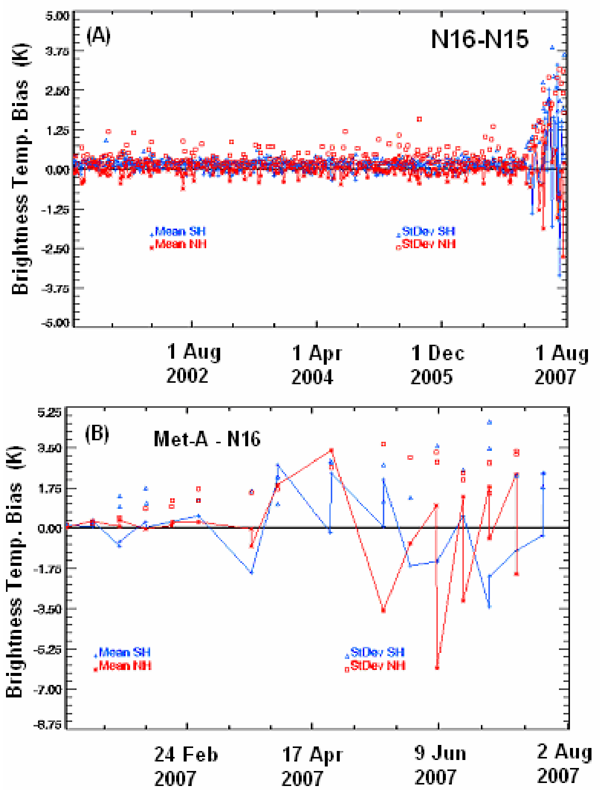


Figure 1: Time series of **A)** NOAA16 – NOAA15 and **B)** MetOp-A – NOAA16 AMSU-A Channel 4 brightness temperature bias. The mean and standard deviation are denoted respectively by lines and symbols, while Southern and North Hemispheres are denoted respectively using blue and red colors.

(by Dr. R. Iacovazzi, Jr., [NOAA])

News in this Quarter

GSICS Executive Panel III Meeting

The GSICS Executive Panel III meeting commenced at 9:00 local time on 4 November 2007 at the Hampton Inn in Cocoa Beach, Florida, USA. Reports from the Coordination Center, Processing and Research Centers, and Research and Data Working Groups of GSICS occupied the first half of the meeting. During these presentations, progress towards several GSICS Operating Plan goals was discussed. Some of the topics covered in these discussions included: low-earth-orbit (LEO)-to-LEO and geostationary (GEO)-to-LEO inter-calibration methods and results; recent expansion of the SADE (Calibration Data Repository) database; calibration of FY-2 C/D IR channels at the National Satellite Meteorology Centre of CMA; performance of IASI with respect to AIRS; the planned COMS satellite; archival strategies for GSICS data; and GSICS web site content and architecture.

In the afternoon, the panel heard presentations from NASA and NIST, the newest members of GSICS. The experience accumulated by these two agencies regarding satellite instrument calibration is a tremendous boost to GSICS capabilities. This experience includes:

- Pre- and post-launch instrument calibration;
- Relationship assessment of satellite instrument calibration to data products - e.g. cloud cover climatology; and
- Development of procedures to establish satellite instrument calibration that is traceable to international measurement standards and best practices.

In the presentations by NASA and NIST, this experience was carefully reviewed and led to lively and enlightening discussion on these topics.

The GSICS Executive Panel III meeting wrapped up with open discussions about GSICS relations with other remote sensing initiatives, such as the Regional/Specialized Satellite Centres for Climate Monitoring (R/SSM-CM), Committee on Earth Observations Working Group on Cal/Val (CEOS-WGCV), Global Precipitation Measurement (GPM) mission, and GCOS Reference Upper-Air Network (GRUAN). In addition, future priorities, expected deliverables, and guidance to the GSICS Research and Data Working Groups were extensively discussed. The meeting adjourned at 18:30 local time.

(by Drs. R. Iacovazzi, Jr. [NOAA] and Jerome Lafeuille [WMO])

Report of the First International IASI Conference

The First International Infrared Atmospheric Sounding Interferometer (IASI) Conference, organized by CNES and EUMETSAT, took place in Anglet, France from 13 to 16 November 2007, only one year after the successful launch of IASI on the MetOP-A platform. Around 130 participants, mainly from Europe and USA, attended the conference. It is a credit to CNES and EUMETSAT, and to the manufacturers of IASI, that so soon after launch users are already making significant use of IASI data and were able to present exciting first results.

The performance of IASI has been assessed by the IASI Technical Center in CNES, and validated against NWP model output and airborne and balloon coincidence flights. Results during the conference showed that the specified 0.5 K radiometric performance of IASI has clearly been met. The Joint Airborne IASI Validation Experiment (JAIVEX) demonstrated that the achieved calibration is within 0.2K accuracy. Comparisons between AIRS and IASI showed comparable radiometric biases of 0.1 K to 0.2 K.

A key role of IASI is to support numerical weather prediction (NWP). The European Centre for Medium-range Weather Forecasting (ECMWF) started to assimilate IASI data in June 2007, and the UK Met Office in November 2007. A number of other centres are in the pre-operational testing phase. IASI is already being seen to have a significant impact on NWP – the largest single impact of any instrument. No centre reported any problems in the real-time availability of IASI data, which is a significant endorsement of the Eumetcast distribution service. The speed at which NWP centres have established viable assimilation systems is, to a large extent, due to the valuable experience gained with the Atmospheric InfraRed Sounder (AIRS) instrument.

The high spectral resolution of IASI is revealing further benefits. Several users at the conference described techniques to use the IASI hyperspectral information to retrieve surface and cloud properties – paving the way for even greater use of IASI data in NWP. Other sessions during the conference concentrated on retrieval of cloud and aerosol properties and on the growing number of trace gases that can be detected in IASI data. This highlights another critical role of IASI in the monitoring of the Earth's climate over a long time period.

(by Drs. T. Phulpin [CNES] and D. Klaes [EUMETSAT])

GSICS-Related Publications

Iacovazzi Jr., R. and C. Cao, 2007: Quantifying EOS-Aqua and NOAA POES AMSU-A Brightness Temperature Biases for Weather and Climate Applications Utilizing the SNO Method. *J. Atmos. and Ocn. Tech.*, **24**, 1895-1909.

Rong, Z., Y., Zhang, and F. Jia, 2007: On-orbit radiometric calibration of FENGYUN geostationary meteorological satellite's infrared channels based on sea-surface measurements in the South China Sea. *J. of Infrared and Millimeter Waves*, **26**, 97-101.

Wang, L., C. Cao, and P. Ciren, 2007: Assessing NOAA-16 HIRS Radiance Accuracy Using Simultaneous Nadir Overpass Observations from AIRS. *J. Atmos. and Ocn. Tech.*, **24**, 1546–1561.

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

Just Around the Bend ...

GSICS-Related Meeting

- **GSICS GRWG-III and GDWG-II, 19-21 February 2008, Washington, DC, USA.**
- **IGARSS, 6-11 July 2008, Boston, MA, USA:** Sessions on radiometer instruments and calibration, passive optical and hyperspectral sensors, and data management and systems.
- **SPIE Optics and Photonics, 10-14 August 2008, San Diego, CA, USA:** Conference on Atmospheric and Environmental Remote Sensing Data Processing and Utilization IV: Readiness for GEOSS II.
- **CALCON Technical Conference, 25-28 August 2008, Logan, UT, USA.**

GSICS Classifieds

Are you looking to establish a GSICS-related collaboration, or do you have GSICS-related internships, exchange programs, and/or available data and services to offer? *GSICS Quarterly* includes a classified advertisements section on an as-needed basis to enhance communication amongst GSICS members and partners. If you wish to place a classified advertisement in the newsletter, please send a two to four sentence advertisement that includes your contact information to Bob.Iacovazzi@noaa.gov.

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. **Please submit contributions at least two weeks prior to the end of each quarter to Bob.Iacovazzi@noaa.gov, GSICS Quarterly Editor.**

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 Ms. Regina Bellina for her help in proofreading this publication.