

GSICS Quarterly

Global Space-based Inter-Calibration System

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Dr. Robert A. Iacovazzi, Jr., Editor

MetOp-A IASI Level 1 Cal/Val at IASI TEC

From January to July 2007, Infrared Atmospheric Sounding Interferometer (IASI) Level 1 (L1) Calibration and Validation (Cal/Val) was performed by scientists and data analysts of the IASI Technical Expertise Center (IASI TEC) located at CNES Toulouse. This effort was made in close cooperation with, and supported by, the EUMETSAT teams responsible for control and processing in Darmstadt. During this phase, IASI was calibrated, and the quality of the instrument data and the L1 data (radiances) were verified with respect to performance requirements and validated against independent measurements.

The main drivers for the definition of the L1 Cal/Val activities were the innovative design of the instrument, and the large amount of processing that is performed on-board IASI (see Figure 1 and Tournier et al., 2007). Therefore, L1 Cal/Val was split into the following three distinct sub phases:

- Phase A: Instrument evaluation and system technical validation;
- Phase B: Early validation of the L1 products; and
- Phase C: In-depth validation of the L1 products.

The scheduled and effective time periods given for these activities are shown in Figure 2. Note that the accuracy of the IASI validations, and the diversity of the conditions under which they were performed, increased with time during these activities.

Radiometric noise — verified regularly using measurements from views of the internal black body and space — was found to be very close to that measured in the laboratory, and to meet

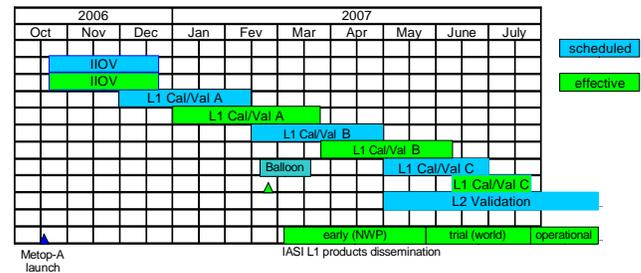


Figure 2: IASI L1 Cal/Val Schedule

instrument specifications. IASI was also shown to be very stable, so a decontamination of the instrument has been necessary only recently (end of March 2008). Short-term radiometric calibration stability was also verified with black body and space view measurements. In this stability assessment, these measurements were taken continuously over a dozen successive orbits using the External Calibration Mode of IASI. This has been done on two occasions, and the results are well below the requirement that orbital variation is to be less than 0.15 K at 280K.

For validation of absolute accuracy, there was the Joint Airborne IASI Validation Experiment (JAIVEx, 2007), but the IASI TEC also performed inter-calibration with the Advanced Very High Resolution Radiometer (AVHRR) instrument on-board *MetOp-A*, and with the Atmospheric InfraRed Sounder (AIRS) instrument on-board *Aqua*. We identified a small bias between IASI and AVHRR (0.35K) that has a dependency on the viewing direction. With respect to AIRS, only three simultaneous nadir overpass (SNO) comparisons have been done, using earth targets carefully selected for their relatively high spatial uniformity. For the three cases, the differences were lower than 0.1K (at 280K reference temperature) for nine computed boxcar pseudo-channels. Monitoring with respect to the HIRS instrument on *MetOp-A*, performed by our partners from METEO FRANCE (CMS Lannion), also shows very good results.

Assuring the spectral calibration of IASI involves the TEC determining parameters describing the state of the interferometer. These parameters include shear and interferometric axis position, as well as the sounder pixel point spread function (PSF) (see later example). They have been estimated regularly and found to be very stable. For example, shear has been found to change less than 0.5 μm over the first seven months. This stability later was reconfirmed for the last 15 months in orbit.

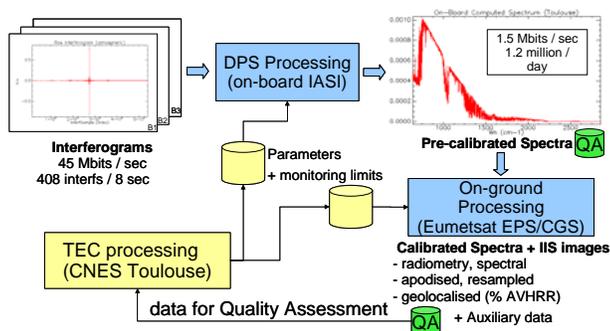


Figure 1: IASI Processing Overview

Spectral performance has also been validated by comparing measured spectra with simulated spectra using the Automatized Atmospheric Absorption Atlas [4A-OP] radiative transfer model and Management and Study of Atmospheric Spectroscopic Information (GEISA) spectroscopic database. The earth targets for these comparisons have been selected for uniformity near the instrument nadir view. The results have been found to conform to the very stringent requirement, which is relative error less than 2×10^{-6} (see Blumstein et al., 2007 and Tournier et al., 2007).

The main requirement for geolocation performance is that the one standard deviation displacement between IASI and AVHRR pixels is less than one-third the size of an AVHRR pixel. This has been achieved by IASI with some margin to spare. Moreover, during the calibration phase, a lot of effort was put into validating the pixel sounder PSF using scenes with high thermal contrast, such as clouds and coastlines. This validation was a very important input for accurate spectral calibration of the instrument. Finally, verification of straylight was done using views of the moon when it came into the cold space calibration view. This verification showed lower perturbation than measured during ground tests.

Following these calibration activities, updates of the following processing parameters have been delivered to EUMETSAT:

- Set 1 operational 15th of January 2007 (*on-board parameters*: monitoring limits and spectra coding tables);
- Set 2 operational 2nd of April 2007 (*on-board parameters/on-ground parameters*: spectral database, optimized filtering parameters);
- Set 3 operational 27th of June 2007 (*on-board*: coding tables and monitoring limits), 5th of July (*on-ground*: radiometric post-calibration); and
- Set 4 operational 11th of July 2007 (*on-ground*: spectral database).

More detailed presentations can be found in the following references.

Blumstein, D., B. Tournier, F-R. Cayla, T. Phulpin, R. Fjortoft, C. Buil, and G. Ponce, 2007: In-flight performance of the Infrared Atmospheric Sounding Interferometer (IASI) on *MetOp-A*. Proceedings of the SPIE, Vol. 6684, paper 6684-17.

Blumstein D. and Co-Authors, 2007: IASI FM2 commissioning on *MetOp-A* – Level 1 cal/val description. First IASI Conference, Anglet, France, 13-16 November, <http://smc.cnes.fr/IASI>

Jacquinet-Husson, N. and Co-Authors, 1999: The 1997 spectroscopic GEISA data bank. *J. Quant. Spectrosc. Radiat. Transfer*, **62**, 205-254.

JAIVEx, 2008: <http://cimss.ssec.wisc.edu/jaivex/>

Scott, N. A. and A. Chédin, 1981: A fast line by line method for atmospheric absorption computations: The Automatized Atmospheric Absorption Atlas. *J. Appl. Meteor.*, **20**, 556-564.

Tournier, B., F-R. Cayla, D. Blumstein, 2007: IASI on-board processing. ASSFTS13, Toulouse, 7-9 November.

Tournier B. and Co-Authors, 2007: IASI on *MetOp-A* – Radiometric and spectral performances measured during commissioning. First IASI Conference, Anglet, France, 13-16 November, <http://smc.cnes.fr/IASI>

(by Dr. D. Blumstein [CNES])

An AIRS-IASI Inter-Comparison



The Earth Observing System (EOS) *Aqua* Atmospheric InfraRed Sounder (AIRS) and *MetOp-A* Infrared Atmospheric Sounding Interferometer (IASI) are

carefully designed and engineered hyperspectral infrared satellite instruments. They can be readily used to transfer calibration between most broadband infrared radiometers. In addition, they can be used to estimate the portion of broadband instrument inter-satellite radiance bias due to spectral response function differences. This in turn helps to isolate calibration related infrared instrument biases. Since both AIRS and IASI are essential to inter-calibrate low-earth-orbit and geostationary infrared instruments within the global satellite observing network, inter-comparing AIRS and IASI radiance measurements becomes critical to GSICS.

For the purpose of such inter-comparison, measurements from AIRS and IASI, taken at simultaneous nadir overpass (SNO) events, have been convolved to 33 pseudo-channels utilizing boxcar-shaped spectral response functions (see Figure 1). A SNO event is considered to occur in this analysis when AIRS and IASI view the same nadir earth scene within 30 seconds. Furthermore, bilinear interpolation is used to collocate the SNO scene measurements of the two satellite instruments. SNO brightness temperature (T_b) bias statistics from the 33 AIRS and IASI pseudo-channels are now routinely being generated, and are summarized in plots and tables available from the GSICS website.

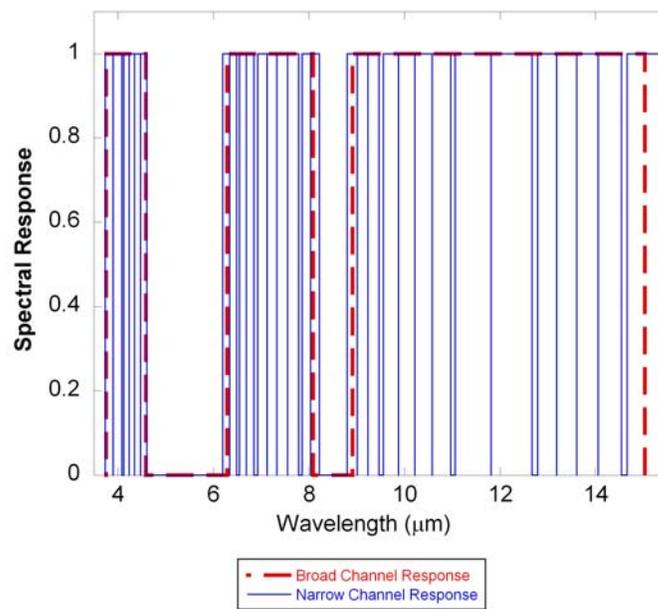


Figure 1: Spectral response as a function of wavelength for 33 AIRS and IASI pseudo-channels. Note that the 33 pseudo-channels consist of 30 narrow (blue) and 3 broad (red) bands.

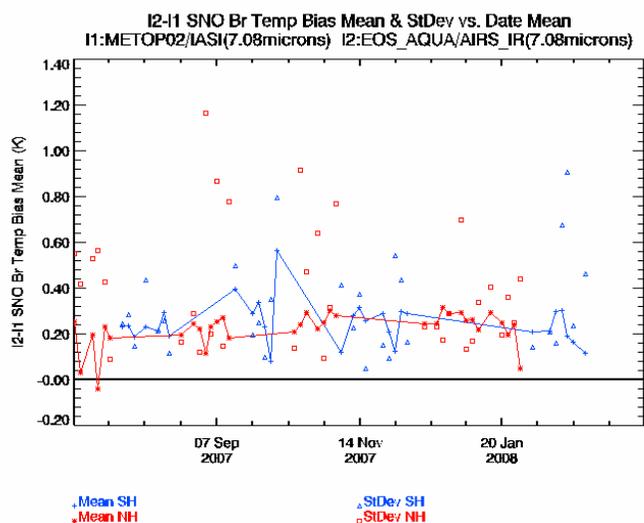


Figure 2: A time series of AIRS minus IASI T_b bias mean (symbols with lines) and standard deviation (symbols without lines) computed from individual SNO events. In the plot, blue (red) represents the Southern (Northern) Hemisphere.

To exemplify the results found on the website, time series of Broadband 2 (7.08 μm) AIRS minus IASI T_b bias statistics computed from individual SNO events are shown in Figure 2. This figure reveals SNO-event mean T_b bias values that range from about -0.05 K to 0.6 K, while T_b bias standard deviation fluctuates between 0.05 K and 1.2 K. This variability in standard deviation is associated with the magnitude of earth scene inhomogeneity and instrument field-of-view mismatch changing from one SNO to another. The SNO-ensemble mean T_b bias computed from all the data in Figure 2 is 0.22 ± 0.08 K (0.24 ± 0.10 K) for the Northern (Southern) Hemisphere. In Table 1, these values can be found along with those computed for Broadbands 1 and 3.

In Table 1, it is found that SNO-ensemble mean T_b bias and its standard deviation are about 0.25 K or less, except for Broadband 1 in the Southern Hemisphere. In this band, individual SNO mean biases can be -1 K or larger in scenes that are colder than 235 K (not shown). Since the Southern Hemisphere records the coldest temperatures and the largest temperature fluctuation, it reflects the largest SNO-ensemble mean T_b biases and uncertainties. The source of this relatively-large bias is in need of further investigation.

As mentioned at the opening of this article, routine inter-comparisons between AIRS and IASI is critical to the process

Table 1: AIRS minus IASI SNO-ensemble mean T_b bias and its standard deviation for the three broadband channels.

Channel	Central λ (μm)	NH Bias / STD Bias (K)	SH Bias / STD Bias (K)
Broadband 1	4.13	-0.16 / 0.21	-0.88 / 1.35
Broadband 2	7.08	0.22 / 0.08	0.24 / 0.10
Broadband 3	11.19	0.03 / 0.18	0.31 / 0.213

of inter-calibrating low-earth-orbit and geostationary infrared instruments within the global satellite observing network. The SNO analysis between these two instruments, preliminarily performed at CNES and now routinely generated at the GCC and EUMETSAT, represents an important link in this process.

(by Drs. R. Iacovazzi, Jr. and C. Cao, [NOAA])

Using IASI to Assess GOES-11 Imager Water Vapor Channel Calibration Accuracy

Given its hyperspectral attribute and good data quality, *MetOp-A* IASI measurements allow more accurate comparisons of measured radiances with other broadband instruments sharing the same spectral regions, which can provide an accurate evaluation for on-board calibration. As a pilot study, we explore the use of IASI spectra to evaluate the radiances from the GOES-11 water vapor channel (6.8 μm).

MetOp-A passes the GOES-11 satellite sub-point (135°W, 0°N) at around 18:30 and 06:30 UTC a few times each month. When this happens, the IASI and GOES Imager satellite instruments view Earth and its atmosphere at nadir at the same place nearly simultaneously. The nadir observations of homogeneous scenes from the two sensors are selected and spatially collocated. The four IASI pixels within each IASI footprint are averaged to compare against the mean of the GOES pixels that correspond to the IASI footprint. The IASI spectra are convolved with the GOES Imager spectral response function to compare with GOES-11 observations. The specific constrains for data processing are:

- Observational time difference < 15 minutes;
- Both sensor's satellite zenith angle < 10°;
- Two sensor's solar zenith angle difference < 1°; and
- Uniform constraint: $\text{StDev}(\text{BT}_{\text{GOES11}})/\text{Mean}(\text{BT}_{\text{GOES11}}) < 0.001$ K, where BT is the brightness temperature.

We analyzed nearly eight months of data from March to November 2007 and found a total of 282 samples. Figure 1 gives the time series of BT difference between IASI and the water vapor channel of the GOES-11 Imager. Each dot represents one sample that meets the above criteria. The black dots indicate the nighttime data, while the red ones are for the daytime observations. The mean of IASI minus GOES-11 BT difference is -0.292 K with a standard deviation 0.206 K. It also indicates that IASI minus GOES BT difference is smaller during nighttime than daytime. Compared with the existing methods that use the High Resolution Infrared Radiation Sounder (HIRS) and Atmospheric Infrared Sounders (AIRS), the IASI measurements eliminate the problem of the spectral gaps and difference in spectral response functions. We are now extending this method to GOES-12 to use the IASI hyperspectral radiance as a reference to link GOES-11 and 12 water vapor channels to resolve their spectral differences.

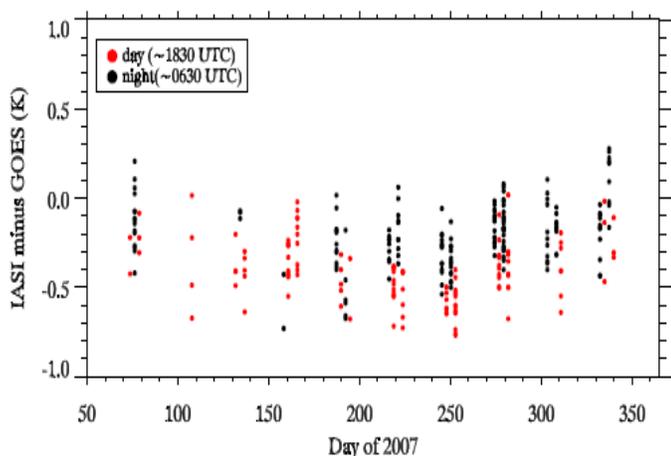


Figure 1: Time series of BT difference between IASI and the water vapor channel of the GOES-11 imager.

(Drs. L. Wang and C. Cao [NOAA])

News in this Quarter

Joint GRWG-III and GDWG-II Meeting



The GSICS Research Working Group (GRWG) held their third meeting (GRWG-III) in conjunction with the second meeting of the GSICS Data Working Group (GDWG-II). This joint meeting was hosted by

NOAA at the NOAA Science Center, Camp Springs, MD, USA, on 19-21 February 2008. The first day was devoted to a joint session to address implementation and operational issues. On the second day, parallel sessions were held to discuss issues of interest only to the respective working groups. The meeting concluded on the third day with a half-day joint session comprised of a summary and recommendations. The agenda, list of participants, and presentations to the meeting are available on the GSICS website. In this article, each session of the meeting is individually summarized below.

1.0. 19 February 2008 Joint Session

GSICS Executive Panel Chairman, Mitch Goldberg, welcomed all participants, and introduced Drs. Jim Butler and Raju Datla to the group respectively as the GSICS representatives from NASA and NIST, our newest members. Mitch presented the low-earth-orbit (LEO) to LEO inter-calibration activities and results – the centerpiece of the GSICS 2007 activities – and reported that the other 2007 GSICS goals have all been met, including the annual operating plan, GRWG and GDWG meetings, and AIRS-IASI inter-comparison. He mentioned that the core task of the 2008

GSICS activities is the commissioning of geostationary-earth-orbiting (GEO) to LEO inter-calibration, i.e., the routine inter-calibration of GEO instruments with AIRS and IASI at GSICS Processing and Research Centers (GPRCs), with results delivered to the GSICS Coordination Center (GCC) and then disseminated to the community.

Dr. Jerome Lafeuille, the WMO Executive Panel Representative, reported on the Executive Panel (EP) Meeting of November 2007. The EP asked for advice and clarifications on a number of issues, particularly related to the transition to operations phase of GSICS. Drs. Fred Wu, Volker Gärtner, and Bob Iacovazzi, Jr. (representing Fuzhong Weng) delivered Chair Reports on recent activities of GRWG, GDWG, and GCC, respectively.

A significant development since the last meeting in June 2007 is the delivery of a GSICS algorithm in October 2007 for inter-calibration between GEO instruments and AIRS, which has been implemented at NESDIS and JMA. Initial results generated from this algorithm have had positive impacts on satellite operations. A similar algorithm was developed and implemented at EUMETSAT for inter-calibration between GEO instruments and IASI, which has also led to excellent results. These developments represent major steps towards this year's GSICS goals.

GSICS participants were pleased in this session, not only with the great progress that has been made since the last joint meeting, but also with the collaborative manner by which it has been made. One example is that JMA has improved the delivered GEO-LEO software. This benefits all GPRCs, especially those using Man computer Interactive Data Access System (McIDAS). Another example is the investigation of the GOES-13 Imager 13.3 μm channel cold bias by scientists from CNES, EUMETSAT, NESDIS, and University of Wisconsin. This investigation began in March 2007, and is still continuing, using data from GOES, POES, MSG, as well as data from AIRS and IASI. Such collaboration is the key to the success of GSICS.

2.0. 20 February 2008 GDWG Session

At this meeting, the GDWG was tasked to identify goals achievable in the next one or two years regarding the operational aspects of GSICS data management. The main objectives of the meeting included:

- Discuss the GSICS collaborative data management server design;
- Discuss filename, metadata, and data format conventions;
- Establish a generic GSICS data flow diagram;
- Create a list of required types of operational documents;
- Share ideas about GSICS website organization and updates; and
- Initiate the creation of a GSICS service specification (GSS) brochure.

The synopsis of the breakout session of this productive meeting is provided below.

A cornerstone of future GSICS success is the ability to collectively store and share data and information. An important step towards this goal is to build and maintain collaborative data management servers. At GDWG-II, Peter Miu of EUMETSAT unveiled a plan illustrating the hardware and software elements, and their interrelationships, necessary to run a collaborative data management server for GSICS. After the presentation, the EUMETSAT representatives were strongly encouraged by the group to implement a server by the fourth quarter of 2008. In addition, plans are now in the works at NOAA to implement a similar server at the GSICS Coordination Center (GCC), and Dr. Koji Kato expressed the interest of JMA to use the servers to deposit their MTSAT data sets in the source data format. Dr. Kato also underscored the need for collaborative data management servers when he spoke of the difficulties that JMA personnel were having in getting IASI data from EUMETSAT. The problem was resolved, but future problems of this type can be minimized with collaborative data management servers.

During GDWG-II, participants recognized that common file naming, metadata, and data format conventions need to be created as soon as possible for data users to efficiently share and utilize GSICS data. The group was informed of a variety of existing standards, but Jerome Lafeuille encouraged the members to consider the WMO metadata profile defined within the ISO 19115 standard, and the WMO Information Systems (WIS) filename convention, as the overall framework. These conventions have been defined by WMO members, and can be adopted with the understanding that GSICS could propose amendments to accommodate particular needs. Meanwhile, the group readily adopted NetCDF-4 as the official data format of GSICS.

In an effort to identify the types and volumes of data that GSICS computers will host, the GDWG invested time in creating a generic data flow definition. The generic data flow outlines all the actions associated with data processing – e.g., making satellite orbital predictions; defining collocation criteria; and collocating, transforming, filtering, and analyzing inter-comparison data. It also includes storage components, such as raw data and auxiliary product feeds, as well as collocated and analysis inter-comparison data. From this exercise, it was recommended that the members of the GDWG create data format templates in accordance with the generic data flow diagram, and the GSICS partners should use these formats in generating their data and products. The GCC staff is currently in the process of posting the generic data flow diagram on the GSICS website, along with a description of its elements and processes.

The GDWG recognized the need to store and share data products that are of particular use to the weather and climate communities. For this reason, an important recommendation of the meeting was for the GCC to create a draft GSS brochure, including a list of deliverables. During the brochure

development process, GSICS should seek feedback from the user communities (e.g., RSSC and NWP) regarding the deliverables defined in the service specification brochure. This brochure is planned for review by the GSICS members and for approval by the GSICS Executive Panel.

Finally, the GDWG stressed the importance of a web-based document archive as a vehicle to communicate with data users and to enhance the institutional memory of processes. Several recommendations in this direction were made by the GDWG. For example, it was recommended that a GSICS Wiki be installed on the GCC server that would allow GSICS partners to regularly provide input to and archive documents. In addition, GSICS Processing and Research Centers (GPRCs) could create Algorithm Theoretical Basis Documents (ATBDs) explaining the processes and algorithms applied in creating their products. Furthermore, it was recommended to upgrade the central GSICS website at the GCC into a web portal by the end of 2009. All GSICS partners were invited to support GCC to keep the central GSICS web pages up to date. GSICS members were also encouraged to host GSICS-specific pages on their websites, and these pages will be linked to the GCC central website.

3.0. 20 February 2008 GRWG Session

Members of the GRWG exchanged research results at its breakout session. Drs. Tim Hewison and Fred Wu detailed the EUMETSAT and NESDIS algorithms. Matt Gunshor reported recent results of GEO-AIRS inter-calibration activities taking place at University of Wisconsin, and some anomalies found in METEOSAT-8 and FY-2C data. Dr. Dave Doelling of NASA Langley gave a thorough overview of visible channel vicarious calibration based on the deep convective cloud (DCC) technique, as well as several other methods. Dr. Louis Nguyen demonstrated the calibration server and website at NASA Langley, using GEO visible channel calibration as an example. Dr. Arata Okuyama presented JMA re-calibration of GMS-5 visible channel using a radiative transfer model and sea, land, and cloud targets. Dr. Claire Tinel provided a status report of the SADE database and related activities, while Dr. Denis Blumstein reviewed plans and methods for AIRS-IASI inter-calibration at CNES and the Laboratory of Dynamic Meteorology (LMD). Dr. Nikita Pougatchev briefly discussed the nature and modeling of error propagation in the context of validation.

During the discussion after the presentations, an important outcome was a roadmap for GEO solar band inter-calibration. Members reviewed the available techniques and volunteered to apply selected techniques to satellites of interest. In reviewing the pending Actions, members were pleased to note that of the 11 Actions assigned at the last meeting, five had been completed and closed and five were on track with minor modifications. Only one Action was seriously delayed and needed major revisions. This breakout session concluded with members proposing seven Recommendations and 10 Actions, including those carried over from the previous meeting.

4.0. 21 February 2008 Joint Session

The final half-day of the meeting was dedicated to a joint session designed to foster communication between GDWG and GRWG members. In this session, a summary of the breakout sessions of the previous day were given from each working group, as well as a list of Recommendations and Actions. At the conclusion of this joint GDWG-II and GRWG-III meeting, many participants expressed a sense of accomplishment and a clearer vision of the direction of GSICS. It was agreed that the report from the meeting would be presented at the next GSICS Executive Panel meeting in July 2008. Meanwhile, the date and place of the joint GDWG-III and GRWG-IV meeting is to be decided at this EP meeting, but a preferred date at present is January 2009.

(by Drs. V. Gärtner [EUMETSAT] and X. Wu [NOAA])

GSICS-Related Publications

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

Just Around the Bend ...

GSICS-Related Meetings

- **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.** Session on inter-calibration and validation of operational sensors.

GSICS Classifieds

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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.

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.

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 Bob.Iacovazzi@noaa.gov, GSICS Quarterly Editor.**

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