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Dr. Robert A. Iacovazzi, Jr., Editor

Along Track Scanning Radiometers (ATSR) and their potential use for inter-calibration

The Advanced Along Track Scanning Radiometer (AATSR - Smith et al., 2001) is flying on the *Envisat* platform, which is in a polar orbit with a 10:00 ascending node crossing time. AATSR's primary mission is the estimation of sea surface temperature (SST). High accuracy for SST is achieved (Corlett et al., 2006) via AATSR's (i) dual-view geometry, which gives high levels of robustness to variability in the transmission of the atmosphere, (ii) actively-cooled (to <90 K), low-noise detectors, and (iii) two-point calibration against stable, high-emissivity black body targets. Some technical data are summarized in Table 1 for the AATSR, and detailed information is available in an online user guide (http://envisat.esa.int/handbooks/aatsr/toc.htm).

Table 1. Selected technical data of AATSR.

Quantity	Typical Value
Calibration target temperatures (in normal operation)	262 K and 300 K
Noise equivalent differential temperatures at 300 K (average in flight)	3.7 µm, 0.031 K 11 µm, 0.032 K 12 µm, 0.032 K
Noise equivalent differential temperatures at 262 K	3.7 µm, 0.075 K 11 µm, 0.034 K 12 µm, 0.034 K
View angle ranges	Nadir: 0º to 22º Forward: 53º to 56º
Design stability of calibration technology (1σ of expected drift)	0.006 K yr^{-1} (Mason et al., 1996)
Expected absolute accuracy	30 mK

AATSR SSTs are used as a bias reference in different ways in operational systems at the Met Office and the Ocean and Sea-Ice Satellite Application Facility. There is also interesting potential of AATSR as a cross-reference for brightness temperatures (BTs) or radiance.

The previous sensor in the series, ATSR-2 on *ERS-2*, was used

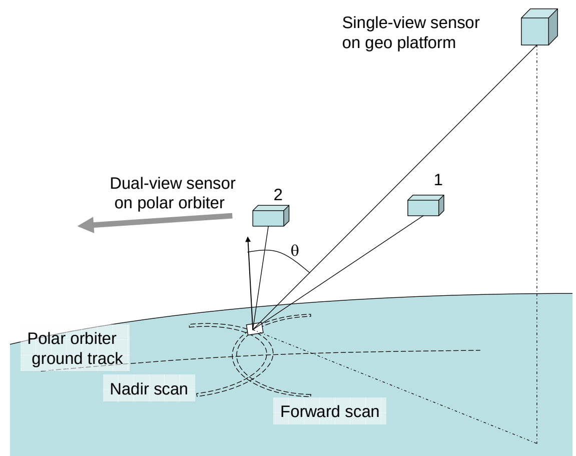

Figure 1. Schematic geometry of inter-sensor matching between a dual-view (along-track scanning) radiometer and a single-view sensor (envisaged here on a geostationary, geo, platform). The forward scan is obtained when the polar orbiter is at position 1, and the nadir scan, about 2 minutes later, at position 2. The geo sensor's satellite zenith angle can be greater than the nadir zenith angle and less than the forward zenith angle, allowing geometric interpolation of the dual-view observations to the intermediate zenith angle.

(Merchant et al., 2003) to cross-calibrate the BTs of the Visible Infrared Spin-Scan Radiometer (VISSR) observing the Indo-Pacific region from Japan's Geostationary Meteorological Satellite 5 (GMS-5). The approach was to find common clear-sky homogeneous areas over the oceans observed near-coincidently by ATSR-2 and VISSR. If comparing single view sensors, an additional constraint would be that the satellite zenith angles should also match. However, with ATSR-2, it was only required that the VISSR zenith angle, θ, be between the nadir and forward view zenith angles of the ATSR-2, allowing interpolation in sec(θ) of the dual-view BTs to the zenith angle of the VISSR (Fig. 1). Assuming azimuthal symmetry of the atmosphere, radiative transfer modeling suggested that this geometric interpolation is accurate to <0.05 K for "window" channels.

Spectral differences also exist between sensors, even for nominally similar channels; see Figure 2 for the case of ATSR-2 and GMS-5 VISSR. Simulations suggested that the BT observed by either VISSR channel at 11 or 12 µm could be estimated from the dual-view BTs of the ATSR-2, using an approach analogous to the retrieval of SST to an accuracy of 0.05 K. This assumes azimuthal symmetry in the atmosphere and perfect knowledge of the ATSR-2 spectral response functions. In practice, we could justifiably expect to be able

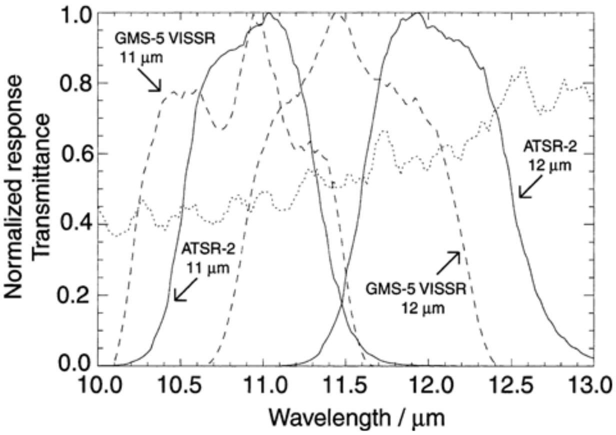

Figure 2. Normalized spectral response functions for the 11 and 12 µm channels of the VISSR on GMS5 (dashed lines) and the ATSR2 (solid lines). The dotted line shows the atmospheric transmittance for tropical atmosphere. Reproduced from (Merchant, 2003).

to retrieve such BTs with accuracy comparable to the 0.1 to 0.2 K (O'Carroll et al., 2008) obtained for SST retrieval. In fact, the actual VISSR and retrieved VISSR BTs differed by more than 0.5 K. The discrepancy was attributed to the uncertainty in VISSR calibration, and correction coefficients for VISSR BTs were derived that permitted significantly improved SST retrieval from the VISSR.

The purpose of this article has been to raise the profile of the ATSR-series sensors within GSICS, focusing on the infrared channels. This instrument series has highly specified radiometric performance. In addition, the dual-view capability of the sensors allows estimation of BTs at the view angles of other sensors, which can be useful in formulating cross-comparison strategies. In the future era of the *Sentinel* missions, the Sea and Land Surface Temperature Radiometer (SLSTR) instruments will offer comparable capability to the ATSRs, on a sustained basis.

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[by Dr. C. J. Merchant, (University of Edinburgh)]

ATSR Data Re-analysis for Climate (ARC)

The record of the Along Track Scanning Radiometer (ATSR) series sensors begins in 1991 with ATSR-1 flown on *ERS-1*, with no interruption exceeding about 1 month to the present time. The dual view capability is particularly beneficial early in the record, in dealing with the SST retrieval impacts of stratospheric volcanic aerosols following the eruption of Pinatubo in 1991. There are overlap periods of 7 months between ATSR-1 and -2, in which the satellites are 1 hour apart, and 11 months between ATSR-2 and Advanced ATSR (AATSR), in which the satellites are 30 minutes apart.

The ATSR Re-analysis for Climate (ARC) is an ongoing project that will derive a homogeneous independent record of SST from the ATSR series (Merchant et al., 2008). Part of the approach is an inter-calibration between sensors in the series using the overlap periods. For the ATSR-2/AATSR overlap, the approach is a cross-calibration of BTs rather than SST. To do this, we need to take account of the subtle spectral differences between the sensors, and of the real difference in BT that arises from the diurnal warming and cooling that occurs in the half-hour interval between overpasses. Residual differences after modeling these effects are then attributable to the relative difference in calibration of the sensors. This is ongoing work, and initial results are that "unexplained" BT differences between the sensors are of order 0.05 to 0.1 K. Correcting for these reconciles retrieved SSTs between the two sensors to <0.03 K for the main SST algorithms. Figure 1 shows the steps in this approach to cross-calibration of BTs.

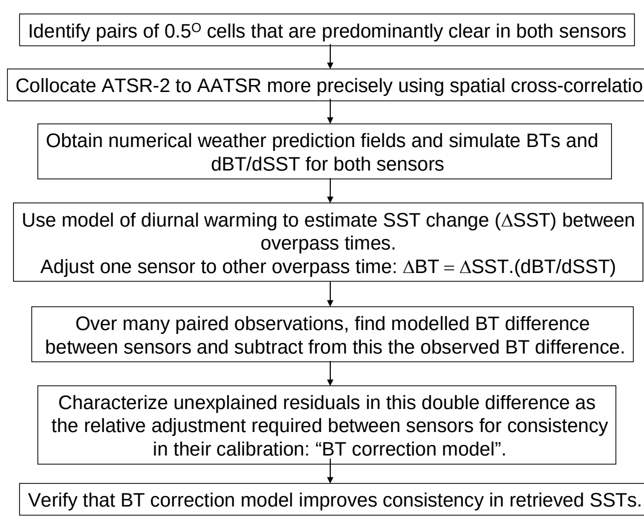

Figure 1. Approach to use overlap period between ATSR-2 and AATSR to make BTs from the sensors more mutually consistent.

An unfortunate limitation of the AATSR sensor with regard to inter-calibration of sensors is significant uncertainty in the spectral response function of the 12 µm channel. BTs in this channel are systematically cold by about 0.2 K, independently of scene temperature. This correction is applied upfront within

ARC and gives good results for SST. Hypotheses under investigation at the Rutherford Appleton Laboratory to explain the bias include out-of-band leakage and wavelength shifting of the spectral response. Work on characterizing the instruments within the ATSR series is ongoing, and interactions with the inter-calibration community on this topic are invited.

Some ATSR contacts are:

Expert support laboratory	Chris Mutlow	C.T.Mutlow@rl.ac.uk
AATSR validation scientist	Gary Corlett	gkc1@leicester.ac.uk
ATSR Re-analysis for Climate	Chris Merchant	c.merchant@ed.ac.uk

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[by Dr. C. J. Merchant, (University of Edinburgh)]

Intercomparison of AATSR and MERIS top-of-atmosphere reflectances over stable desert targets

Introduction

The Advanced Along Track Scanning Radiometer (AATSR) and the Medium Resolution Imaging Spectrometer (MERIS) instruments on ESA's *Envisat-1* mission are designed to make accurate measurements of the Earth's surface [see http://envisat.esa.int]. For AATSR the principal measurement is sea and land surface temperature and for MERIS, ocean colour and land vegetation. Data from both sensors may be combined to provide information on aerosols and clouds. In order for the data to be combined it is essential that any relative biases in their radiometric calibrations at the corresponding wavelength bands be well characterised. This paper is a summary of a comparison of top-of-atmosphere (TOA) reflectances, observed over large-area, stable desert targets, for similar AATSR and MERIS visible channels.

Desert Sites

Quasi-stable desert sites have been used for some time to monitor long-term stability of a number of sensors including AVHRR (Rao and Chen 1995), ATSR-2 (Smith et al. 2002) and AATSR (Smith and Poulsen 2008), as well as to perform intercomparsions of the calibrations of different sensors (Miesch et al. 2003). The principal assumptions of the sites are:

- Uniform reflectance over large area;
- Long-term radiometric stability of the calibration sites ensures long-term stability – including seasonal variations (if any) - of albedo or reflectance; and.
- High surface reflectance to maximise the signal-to-noise and minimise atmospheric effects on the radiation measured by the satellite.

The sites used in this comparison are primarily those well established reference targets identified by Cosnefroy et al. (1996). Although some variations do occur, such as clouds and dust, these can be screened out and any seasonal variations average out over long time scales. The test sites used are spatially uniform over a large area and are therefore suitable to compare sensors having spatial resolutions of order 1km such as AATSR and MERIS. Also the spectral variation of the test sites is smooth with no significant spectral features in the bands to be compared.

Data Extraction

AATSR L1b child products were obtained via the L1b archive at Rutherford Appleton Laboratory (RAL) and have been corrected for long-term drift as described in (Smith and Poulsen 2008). The products were screened for the presence of clouds, and the cloud-free TOA normalised radiance computed for the region of interest. For MERIS, data for the desert targets were generated by the METRIC tool where cloud-free TOA radiances for the test sites are extracted from MERIS L1b images and saved in HDF files.

Comparison

Since both AATSR and MERIS visible wavelength channels are calibrated via white tile diffusers using the Sun as reference, the parameter being compared is normalised radiance defined as

$$\begin{aligned}\text{NormalisedRadiance} &= \text{SceneRadiance}/(\text{SolarIrradiance}/\pi) \\ &= \text{SceneReflectance} * \cos(\text{SolarZenith})\end{aligned}$$

A typical result in Figure 1 for the "Sudan 1" site shows very good agreement at all wavelengths between MERIS and AATSR, with a slight bias at 870nm and 560nm. Note that only near-nadir observations are compared because of the MERIS viewing geometry. The results for all sites are consistent and have been summarised in Table 1.

Table 1: Summary of AATSR vs. MERIS comparisons over desert targets at 560nm, 670nm and 870nm for all test sites. The table gives the mean and standard deviation of the ratio of the AATSR/MERIS reflectance.

	560nm	670nm	870nm
Mean Ratio	**1.0274**	**1.0012**	**1.0246**
Std Deviation	0.0041	0.0042	0.0042

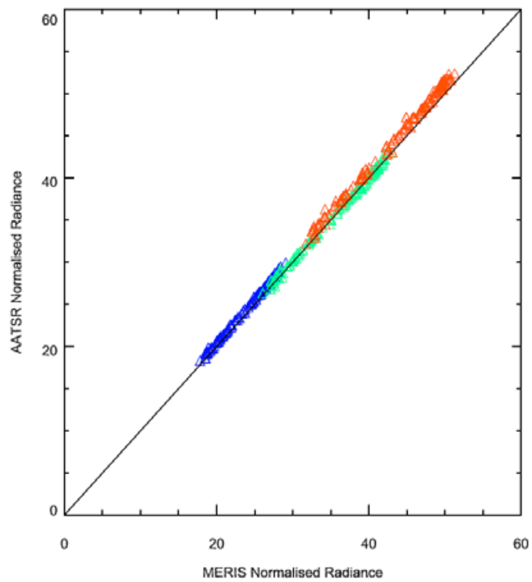

Figure 1: Comparison of AATSR vs. MERIS nadir view normalised radiances at 560nm (blue), 670nm (green) and 870nm (red) for the Sudan 1 site.

Conclusion

Using data from quasi-stable desert sites, the relative biases between the radiometric calibrations of AATSR and MERIS at 560nm, 670nm and 870nm has been established.

Acknowledgements

AATSR Data are provided courtesy of the UK Department for Environment, Food and Rural Affairs (DEFRA) and the European Space Agency (ESA). MERIS data are provided courtesy of ESA and Brockman Consult.

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[by D.L. Smith, (Rutherford Appleton Laboratory)]

News in this Quarter

Summary outcome of the first GSICS Users' Workshop

The Global Space-based Inter-Calibration System (GSICS) convened its first Users' Workshop on 22 September 2009 in Bath, UK, in conjunction with the 2009 European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Meteorological Satellite Conference. The workshop attracted 67 participants from 37 national and international organizations and universities.

In the first two hours of the workshop, participants were introduced to GSICS, its first key product (GSICS Correction), the GSICS data and products servers, and the GSICS Coordination Center. A presentation was also given on the Committee on Earth Observation Satellites (CEOS) led Quality Assurance Framework for Earth Observation (QA4EO) that proposes general data quality assurance principles and guidelines that are broadly in accordance with GSICS goals and practices. The remaining two hours of the workshop were set aside to receive feedback from a variety of users that GSICS hopes to be interacting with in the future.

In order to kick-off this part of the workshop, several users briefly presented their results of, and/or plans for, calibration, inter-calibration, and re-calibration. These topics covered reanalysis, climate trend detection, climate and seasonal forecast modeling, and numerical weather prediction (NWP) monitoring. This set the stage for in-depth discussions regarding how to determine impacts of GSICS results on user-generated products, as well as what areas users would like to see GSICS emphasize in the future.

Several users stepped forward during workshop discussions to volunteer as possible "beta testers" of the current GSICS Correction. For example, impacts of applying the GSICS Correction to Meteosat-9 IR channel data before NWP bias correction may be explored at the UK Met Office. Also, the EUMETSAT Satellite Applications Facility (SAF) on Land Surface Analysis (LSA SAF) researchers are interested in evaluating the impact of GSICS Correction for Meteosat-9 IR data on the diurnal cycle of Land Surface Temperatures. A representative from the Climate Monitoring SAF (CM SAF) offered to compare operational (non-corrected) radiance, GSICS Corrected radiance, and in-house corrected radiance (but non-GSICS) using reference RAOB, and was also interested in evaluating the impact of GSICS corrected Meteosat-9 radiance on the Upper Tropospheric Humidity products of the CM SAF. Finally, Chiba University reported positive impacts of GMS visible channel vicarious calibration on aerosols and other products, using an algorithm jointly developed with JMA.

Potential new GSICS products were also a major topic of discussion in the latter half of the GSICS Users' Workshop. Many of the attendees expressed a strong desire for GSICS to include products for the inter-calibration of microwave imagers and sounders. Throughout the conference, there was a lot of interest (*e.g.* CM SAF) in the calibration of the solar channels of GEO satellites – particularly *Meteosat*. The workshop participants also had considerable interest in extending the IR inter-calibrations to include (A)ATSR and AVHRR; as well as inter-calibration between different GEO imagers.

The workshop was well attended and the general feedback is that users have strong expectations. Several representative users expressed readiness to contribute to the evaluation of GSICS products, and encouraged GSICS to develop new products to suit their needs. Moreover, GSICS needs to enhance its communication towards, and interaction with, users. It should maintain the momentum and develop a strategy that uses the available resources and expertise to meet users' needs in an optimal way.

[by Dr. T. Hewison, (EUMETSAT)]

QA4EO Implementation Workshop

Jérôme Lafeuille and Bob Iacovazzi, Jr. from GSICS participated in a Workshop on Facilitating Implementation of the Quality Assurance Framework for Earth Observation (QA4EO). The meeting, chaired by the Group on Earth Observations (GEO) and warmly hosted by TÜBİTAK UZAY (TÜBİTAK Space Technologies Research Institute), was held from September 29th to October 1st, 2009 in Antalya, Turkey. Aslı Aytaç, Vice Director at TÜBİTAK UZAY, welcomed the participants and thanked GEO for making the workshop possible. Presentations and discussions throughout the three-day workshop spanned a cross-section of Earth Observation (EO) disciplines as the participants considered how best to take QA4EO forwards and encourage its rapid uptake by the full Global Earth Observation System of Systems (GEOSS) community.

The GEOSS community represents a wide variety of disciplines, which utilise a multitude of monitoring methodologies and procedures that require an association of a quality metric to their outputs to enable them to be reliably integrated into the various systems and services, and to support the EO needs of Society. The fundamental principle of QA4EO – "that all EO data and derived products has associated with it a documented and fully traceable quality indicator (QI)" – addresses this core requirement and is universally applicable to all disciplines. This principle is not in itself novel and is already being practised by many. QA4EO seeks to ensure it is implemented in a harmonious and consistent manner throughout the disciplines of the GEOSS community to the benefit of all stakeholders. The end-user, "customer" is the driver for any specific quality requirements and will assess if any supplied information, as characterised by its associated QI, are "fit for purpose".

The GSICS response to the call for QA4EO is the GSICS Procedure for Product Acceptance (GPPA). The Procedure describes the supporting evidence and review process needed to ensure that GSICS product quality is internally well documented and scrutinized, and can be easily interpreted by product users. The GPPA was presented during the second day of the workshop in a session devoted to application of QA4EO to space-based observations. The concept of the GPPA was well received, and questions and discussions surrounding the presentation focused on the mission of GSICS, and the roles and responsibilities of each organization to establish a robust self-compliance process that fulfills the essential qualities of QA4EO.

At the conclusion of the workshop, participants agreed to a series of steps to facilitate implementation of QA4EO into the GEOSS community:

- Augment the current QA4EO task team to include representatives from other GEO tasks and all Societal Benefit Areas (SBAs). The augmented team will not regulate but will provide a coordination role, monitor progress and provide a guidance, harmonisation and capacity building function.
- Draft a high-level implementation and action plan to facilitate the expansion of QA4EO to the wider EO community and to engage data providers and users.
- Create a one-page summary describing the key principle of QA4EO that will become the primary reference containing all pre-requisite information against which compliance can be assessed. The current QA4EO framework and key guideline documents based on best practises will be expanded as necessary to provide templates and examples to facilitate implementation of the key QA4EO principle by the GEOSS community.
- Draft a questionnaire/template that clearly states the requirements needed for QA4EO compliance, and enables data providers to compile necessary evidence to support any declared quality information implemented by product users to assess its "fit for purpose".
- Adapt the GEO dataset registration to encourage the association of a Quality Indicator to each dataset, which will be linked to the "quality questionnaire" (previous bullet).
- Develop a 'communication toolbox' – presentations, posters, brochures, etc. – to summarise the scope and benefits of QA4EO and to provide material for use in outreach throughout the EO community via the QA4EO website (http://qa4eo.org/).

This QA4EO workshop was very productive in shedding light on the current state of, and necessary steps that need to be taken, to make QA4EO principles accessible to the GEOSS community. To review the status of the QA4EO implementation, measure its impact on the Earth Observation community and coordinate future activities, a new workshop is tentatively proposed in Summer 2010.

[Dr. M.-C. Greening (Greening Consulting) and Dr. R. Iacovazzi, Jr. (NOAA)]

NASA GPM Cross-Calibration Meeting

On October 24-26, GCC Director Dr. Fuzhong Weng attended the NASA Global Precipitation Measurement (GPM) Cross Calibration (X-Cal) meeting held at University of Utah. The GPM X-Cal team members presented the latest results on the consensus calibration procedure for the GPM mission. The GPM core satellite will provide the microwave measurements from 10 to 183 GHz, and serve as a standard microwave transfer radiometer. At the team's request, Dr. Weng presented the bias monitoring technique using numerical weather prediction (NWP) analysis and background. In the future, all microwave imagers similar to GPM operated by various space agencies will be calibrated to the GPM standard so that the standard algorithms can be applied for all instruments. Currently, the proxy sensor to the GPM is the TRMM Microwave Imager (TMI). The GPM X-Cal team is tasked to work on several issues related to TMI calibration such as TMI antenna emissivity, earth incident angle (EIA) variation, and secular trends in brightness temperature. The new corrections will be included in the TMI Version 7. At the request of NASA, NESDIS/STAR will take the lead in cross-calibration of GPM water vapor channels, in collaboration with GSICS partners. An algorithm will be first developed with a pair of *NOAA/Metop-A* AMSU-B/MHS instruments, and then applied to SSMIS and ATMS water vapor channels. To learn more about GPM X-Cal efforts, the new web site link is http://www.gpm-x-cal.info/.

[Dr. F. Weng, (NOAA)]

Just Around the Bend …

GSICS-Related Meetings

- **American Meteorological Society Annual Meeting,** 17-21 January 2010, Atlanta, GA, USA, http://www.ametsoc.org/MEET/annual/.
- **Joint GSICS Research and Data Working Group Meeting**, 9-11 February (tentative), CNES, Toulouse, France.

GSICS Publications

Cao, C., E. Vermote, and X. Xiong, 2009: Using AVHRR lunar observations for NDVI long-term climate change detection. *J. Geophys. Res.*, **114**, D20105, doi:10.1029/2009JD012179, 2009.

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Wang L., C. Cao, and M. Goldberg, 2009: Inter-calibration of GOES-11 and GOES-12 water vapor channels with MetOp/IASI hyperspectral measurements. *J. Atmos. and Oceanic Tech.*, **26**, 1843–1855.

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