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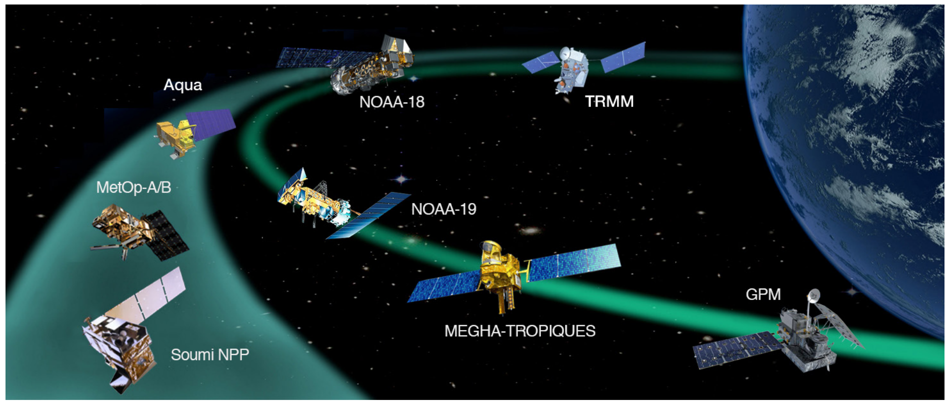

Inter-calibration of Microwave Satellite Data: An Ongoing Challenge

by Isaac Moradi ESSIC/CICS, University of Maryland and Ralph Ferraro, NOAA

Passive microwave (MW) satellite measurements and derived products play a very important role in weather forecasting, data assimilation, and also in climate monitoring and assessment. MSU was the first operational MW radiometer flown on the TIROS-N satellite and subsequently on NOAA-6 to -14 from 1978 to 2007.

AMSU-A/-B and MHS flown on NOAA-15 through NOAA-19 and EUMETSAT MetOp (-A and –B) satellites since 1998 formed the next generation of operational MW instruments. Most recently, ATMS combined the capabilities of both AMSU and MHS and was initially flown on Soumi-NPP in 2011, and is planned to be flown on JPSS-1 and -2. DMSP also operated a series of operational MW radiometers including SSM/T initially flown in 1979 onboard DMSP F04 to F15, SSM/I onboard F08 to F15, SSM/T-2 onboard F11 to F15, and currently, SSMI/S onboard F16 to F19. Finally, many MW instruments have been in recent years flown on different research satellites (WMO, 2013).

Spaceborne MW measurements, like any other physical measurements, are subject to errors and uncertainties. The errors can be classified into radiometric and geometric errors. Radiometric errors are caused by several sources including drift in sensor calibration, imperfect antenna and local electronics, Radio Frequency Interference (RFI), uncertainty temperatures of hot and cold (space-view) targets, and non-linearity in the calibration. Due to the lack of reference datasets, alternative methods are used to quantify the radiometric errors. These methods include validation using airborne observations; inter-calibration with similar spaceborne instruments, inter-comparison with brightness tem-

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peratures simulated using a radiative transfer model and atmospheric profiles from radiosonde data, NWP model fields, or GPS-RO profiles (Moradi and Ferraro, 2014; Moradi et al., 2010).

Inter-calibrating similar spaceborne instruments is one of the methods that has been extensively used, especially to develop long-term Climate Data Records (CDR). In this case, one instrument that is stable over time in terms of its performance and minimal orbital drift is chosen as the reference and other (target) instruments are inter-calibrated with respect to the reference instrument. Inter-calibration requires that both target and reference instruments observe the same location as close in time as possible (Moradi and Ferraro, 2014). Inter-satellite differences are normally scene dependent, but most of the coincident observations from sun-synchronous polar-orbiting satellites occur at high latitudes. However, several research satellites are flown in non-synchronous orbits, offering more opportunities for direct time and space collocations with the operational satellites.

There are methods to circumvent the lack of global coincident observations that are used for inter-calibrating instruments onboard sun-synchronous polar-orbiting satellites. These alternative methods rely on regions where the diurnal variation of satellite Tb's are negligible, so the time constraint can be relaxed substantially. Theoretically due to the motion of air, there is no region on the Earth where the atmospheric parameters are stable and stationary throughout the day. But, there are regions where these variations are small and can be neglected. For instance, the diurnal variations of most observations are very small over tropical oceans, thus the daily averages over tropical oceans can be used for inter-calibration. Since inter-satellite differences are scene dependent, several efforts have been made to identify other regions or methods for inter-calibration to cover a wide range of Tb's, e.g. using data averaged over Antarctica during polar nights, using Amazonian region, or vicarious cold reference (Ruf, 2003).

One of the methods that has been widely employed is referred to as "double difference" and is based on difference of differences. It is especially useful when it is not possible to directly compare observations from reference and target instruments, for instance due to frequency difference or when the overpasses do not yield coincidence observations. In this case a third sensor or radiative transfer simulations are used to transfer the calibration from reference to target instrument (Moradi and Ferraro, 2014).

This issue of GSICS Newsletter includes a variety of papers describing different aspects of inter-calibration of MW measurements which yield different goals of GSICS including: monitoring instrument performances, operational inter-calibration of satellite instruments, and re-calibration of archived data in order to develop long term homogenized CDR's. Weng explains the use of Allan Deviation for calculating NEDT for ATMS observations; Fennig et al. discuss developing CDR from SSMI observations; Kroodsma addresses inter-calibration of GPM MW radiometer using vicarious cold calibration; Yang describes a correction method for moon contamination for ATMS observations; Alsweiss et al. employ a double difference technique to evaluate the calibration biases in AMSR2 measurements; Moradi and Ferraro show the results for inter-calibration of the SAPHIR and ATMS observations; Wentz discusses inter-calibration of MW observations using RT calculations for ocean climate research; Yang et al. explain inter-calibration of AMSU-A window channels; and John and Chung discuss inter-calibrating SSM-T2 observations.

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Use of Allan Deviation for ATMS Noise Characterization

by Fuzhong Weng, NOAA

NEDT stands for Noise Equivalent Delta Temperature and describes the "radiometric resolution" of measured radiances or brightness temperatures at an observing frequency. It is computed as a ratio of the standard deviation of the warm calibration counts ($C_{ch}^{w}(i)$) to the calibration gain.

$$NEDT_{ch} = \left[\frac{1}{MN} \sum_{i=1}^{N} \sum_{j=1}^{M} \left(\frac{C_{ch}^{w}(i,j) - \overline{C_{ch}^{w}}(i)}{\overline{G_{ch}}(i)} \right)^2 \right]^{1/2} \quad (1)$$

where $\overline{C_{ch}^{w}}(i)$ and $\overline{G_{ch}^{w}}(i)$ are the averaged warm load count and gain function from the *M* recorded multiple readings of radiometric warm count and the gain function at the i^{th} scan line, respectively, and *N* is the sample size which is the total number of scan lines used in obtaining values of *NEDT*. For ATMS, a total of four recorded readings of warm load count (*M*=4) is employed in calculating NEDT in (1).

The standard deviation quantifies the spread of the statistical distribution of the measuring values around the mean. However, it is not always an appropriate parameter for describing a spread of the statistical distribution of the measured values around a mean that is non-stationary. The warm calibration counts are subject to considerable long-term variations due largely to temperature-dependent instrument gain variations;

these variations are removed by on-orbit calibration, and therefore do not contribute to actual radiometric sensitivity (i.e., *NEDT*). Therefore, a more proper statistical parameter reflecting the radiometric resolution of ATMS observations is the so-called Allan deviation (Allan, 1987; Allan et al., 1997), which is calculated from the differences of warm counts between measurements separated by a variable interval (m) between the data samples. Mathematically, it is defined as follows:

$$\sigma^{Allan}(m) = \sqrt{\frac{1}{2m^2(N-2m)} \sum_{k=1}^{N-2m} \left(\sum_{i=k}^{k+m-1} \left(C_{ch}^{w}(i+m) - C_{ch}^{w}(i) \right) \right)^2} \quad (2)$$

where $C_{ch}^{w}(i)$ and $C_{ch}^{w}(i+m)$ are the warm counts at the i^{th} and $(i+m)^{th}$ scan lines separated by the Allan interval m, respectively, and (N-m+1) is the total number of scan lines employed in the calculation of Allan variance using (2). *Note that* $C_{ch}^{w}(i)$ *in (2) can be one of M warm counts or the average value of M warm counts in each scan line.*

Figure 1 presents the mean, the standard deviation and the Allan deviation of the warm counts at channel 1 from an ATMS orbit data on February 24. The mean is not stationary and it decreases as the sample size increases. The standard deviation is also not stationary but it increases as the sample size increases. However, it is clear that the Allan deviation is much more stable over the whole range of sample size, which makes the Allan deviation a more appropriate measure to the ATMS radiometric resolution channel at a given Allan interval.

Figure 2 compares the *NEDT* values from Eq. (1) and the Allan deviation from Eq. (2). Both equations average data over 17 scan lines. It is noticed that the *NEDT* values (blue) for all ATMS channels are about 3-5 times larger than the Allan deviations (red). This further confirms that the standard deviation overestimates the variance of non-stationary time series, which is the case for ATMS warm counts. . While this overestimated *NEDT* is well within the instrument specification however the downside is that it is sensitive to sample size (N).

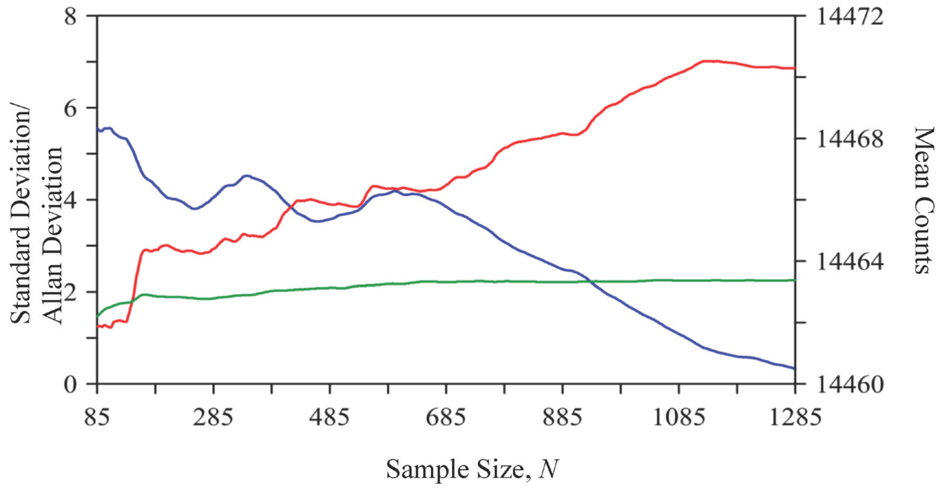

Figure. 1: The traditional NEDT (red, y-axis on the left, not gain normalized) and the Allan deviation (green, y-axis on the left, not gain normalized) and the average warm count (blue, y-axis on the right) for ATMS channel 1 on February 24, 2012. The Allan interval (*m*) is 17.

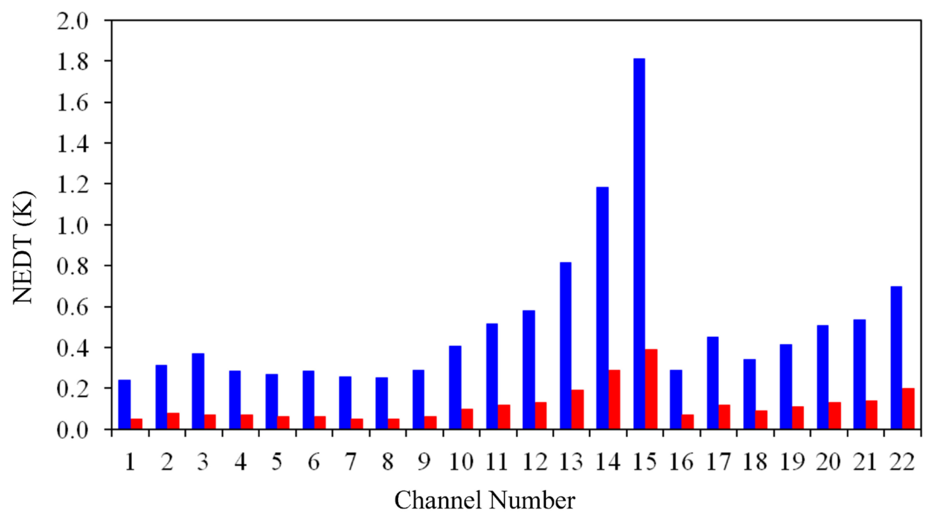

Figure 2: The traditional NEDT (blue) and Allan deviation (red) for ATMS channels 1-22. Here, Allan deviation is converted to NEDT through normalizing Eq. (2) by gain.

Since the launch of SNPP, ATMS *NEDT* is under monitoring, and is very stable and within specification. The ATMS *NEDT* values are generally higher than the corresponding AMSU-A values mainly because the ATMS integration time is much shorter than that of AMSU-A. Specifically, the ATMS integration time for all ATMS channels is about 18 ms while that for AMSU-A channels 1-2 and 3-15 is 165 ms and 158 ms, respectively.

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The Fundamental Climate Data Record of SSM/I Brightness Temperatures from CM SAF

by Karsten Fennig, Marc Schröder and Axel Andersson, Deutscher Wetterdienst

Data from the SSM/I (Special Sensor Microwave/Imager) sensor family are used for a variety of applications, such as analyses of the hydrological cycle and related atmospheric and surface parameters, as well as remote sensing of sea ice. One example is the satellite-based HOAPS (Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data; http://www.hoaps.org/) climatology, which provides climate data records of precipitation, evaporation and the resulting freshwater flux over the global ice-free ocean between 1987 and 2008. The HOAPS climate data records are primarily based on passive microwave measurements from the SSM/I. In order to provide reliable estimates of the global water cycle parameters for climate applications it is strictly necessary to carefully correct for all known problems and deficiencies of the SSM/I radiometers as well as to inter-calibrate and homogenize the different instruments. Moreover, all applied corrections need to be documented to provide a complete calibration traceability as a major requirement for a Fundamental Climate Data Record (FCDR). Following these recommendations, EUMETSAT's CM SAF has released the first version of the FCDR of SSM/I brightness temperatures, available from the CM SAF web user interface (http://dx.doi.org/10.5676/EUM_SAF_CM/FCDR_SSMI/V001) and referenced under DOI:10.5676/EUM_SAF_CM/FCDR_SSMI/V001.

All available raw data records have been reprocessed to a common standard, starting with the calibration of measured raw Earth counts. The new inter-calibration model incorporates a scene dependent inter-satellite bias correction and a non-linearity correction to the instrument calibration. Furthermore, the data processing accounts for several known issues with the SSM/I instruments and corrects calibration anomalies due to along scan inhomogeneity, moonlight intrusions, and sunlight intrusions.

The inter-sensor calibration procedure is based on the radiometer on DMSP F11, which is selected as the reference for a relative inter-calibration because this radiometer exhibits good long-term sensitivity stability and small non-linearity. The SSM/Is aboard F08 and F15, which do not have a temporal overlap with F11, are calibrated to the corrected F10 and F13 radiometers, which are used as transfer standards, respectively.

The largest expected systematic uncertainties are caused by the non-linearity of the radiometer and imperfect Antenna Pattern Corrections (APCs). In order to account for these variations, the new inter-calibration model accounts not only for scene dependency, but also for non-linearity, and cross polarization

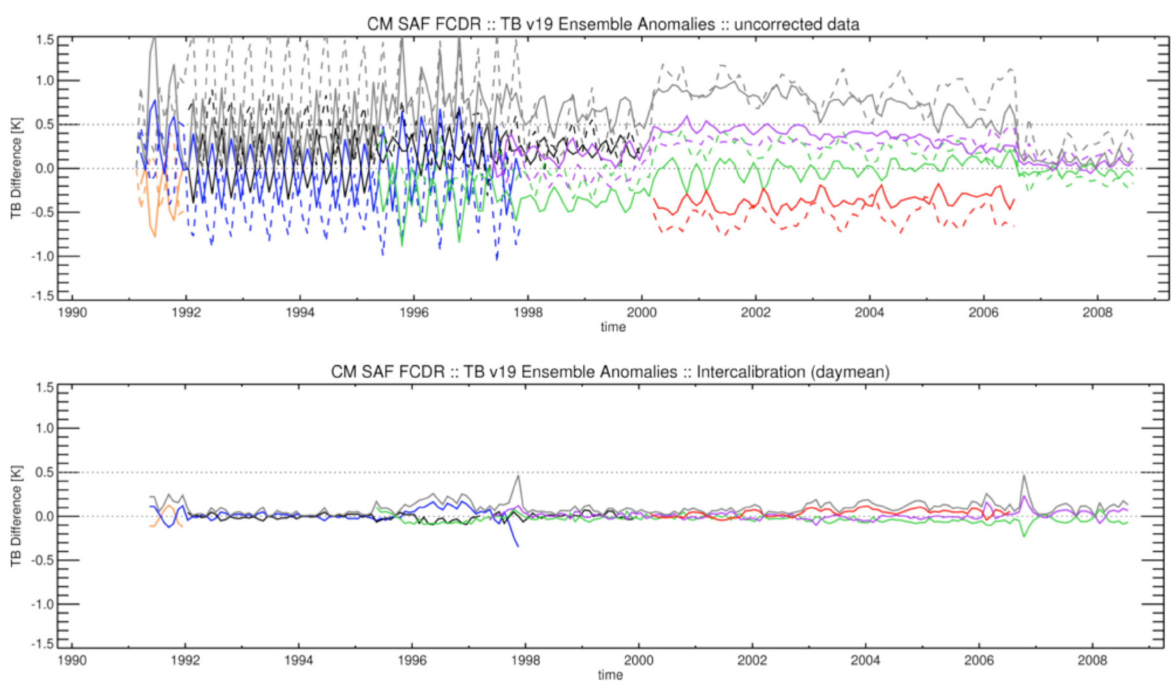

Figure 1: Time series of ensemble anomalies for SSM/I channel 19v GHz. In the upper image the solid lines are PM orbits and the dashed lines are AM orbits. The lower image depicts means of AM and PM orbits. The gray lines show the ensemble spread. Colors are as follows: F08 orange, F10 blue, F11 black, F13 green, F14 violet, and F15 red.

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coupling. The inter-sensor calibration coefficients are determined over ocean, sea-ice and cold scenes over land.
All brightness temperatures (TBs) are normalized to a constant Earth Incidence Angle (EIA) and overpass time prior to the inter-calibration. These normalized TBs are then binned into global 1x1 degree maps, separately for ascending and descending orbits, and match-up datasets are compiled to fit the individual inter-calibration model coefficients.

A validation of the TBs is a challenging task as there are no ground-truth reference measurements available for the microwave band. Hence, the homogeneity of the FCDR is evaluated by an analysis of the relative biases between the different instruments before and after the inter-calibration offsets are applied. An example of this evaluation is shown in Figure 1 for the channel at 19v GHz. The top image shows the observed global monthly mean differences between the individual instruments and the ensemble mean prior to TB normalization. The large variation for the F10 is caused by a strong variation in the EIA due to a high orbit eccentricity. Also a time dependent bias in the F14 time series is clearly visible, caused by a change in overpass time. The mean observed instrument differences can reach about 1 K. The bottom image of Figure 1 shows the differences after the application of normalization and inter-calibration corrections. The mean absolute deviation between the instruments is now reduced to below 0.1 K and no significant trend can be observed.

A comprehensive description of the developed methods, the evaluation results and a technical description of the FCDR can be found in the Algorithm Theoretical Basis Document (ATBD), Validation Report, and Product User Manual (PUM), which are available from the FCDR web page http://dx.doi.org/10.5676/EUM_SAF_CM/FCDR_SSMI/V001.

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GPM Microwave Radiometer Inter-Calibration using Vicarious Cold Calibration

by Rachael Kroodsma, NASA

The Global Precipitation Measurement (GPM) mission successfully launched the GPM Core Observatory on February 27, 2014. Onboard GPM Core is the GPM Microwave Imager (GMI), part of a group of spaceborne microwave radiometers referred to as the GPM constellation. These radiometers are used to provide global coverage of precipitation measurements. Inter-calibration of the radiometers is a key aspect of the mission, intended to ensure that consistent precipitation measurements are made among the constellation radiometers. The GPM Inter-Calibration Working Group (X-Cal) is responsible for developing algorithms to inter-calibrate the radiometers included in GPM (Wilheit et al. 2011). One of the methods being used as part of the X-Cal algorithm is the vicarious cold calibration double difference (VDD) method (Kroodsma 2014). This article will briefly describe the VDD method and show its contribution to the X-Cal algorithm.

The VDD method uses histograms of brightness temperature (TB) data from over-ocean scenes to derive a stable cold reference TB, referred to as the "cold cal TB." The cold cal TB is derived from the lower bound of the TB histograms, which consists of those TBs associated with minimal atmospheric water vapor and low surface wind speeds. Figure 1 shows an example of where these TBs occur for 18.7 GHz vertical polarization (V-pol). Each colored point represents a TB that is part of the lower bound of the TB histogram used to derive the cold cal TB. As expected, these TBs occur close to the poles where water vapor is at a minimum.

To estimate the VDD between two radiometers, the single differences (SD) for each radiometer are first computed. The SD is found by taking the difference between the cold cal TB observed by the radiometer and the cold cal TB simulated using a radiative transfer model. The simulations are an important part of the inter-calibration, since they are able to significantly reduce the dependence of the cold cal TB on geophysical variability and account for differences in instrument characteristics between two radiometers such as earth incidence angle and frequency. Given the SDs for two radiometers, the double difference (DD) can be computed from the differ-

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ence of the two SDs. This is considered the inter-calibration offset between two radiometers at a specific scene temperature.

One advantage to using the VDD method over other inter-calibration algorithms is that it does not require coincident or near-coincident cross-over points between two radiometers. For each radiometer, all over-ocean TBs for a given time period (e.g. a month) are binned into histograms. The idea behind vicarious cold calibration is that it derives a stable reference TB regardless of temporal or spatial variability, so it is not necessary to match the data when comparing one radiometer to another with the VDD method.

The VDD method is used as part of the University of Michigan's (UM) contribution to the inter-calibration algorithm for GPM. The other members of X-Cal who contribute to the inter-calibration algorithm for the GPM microwave imagers are Colorado State University (CSU), the University of Central Florida (UCF), and Texas A&M University (TAMU). The X-Cal algorithm consists of inter-calibration offsets derived at cold and warm TBs so that a calibration difference as a function of scene brightness temperature can be derived. The current algorithm adjusts the radiometers in the GPM constellation to the Tropical Rainfall Measuring Mission Microwave Imager (TMI), which is referred to as the reference radiometer. Each group has developed individual methods to calculate inter-calibration offsets at the cold end which are then combined together, along with the warm end inter-calibration offsets, into the GPM inter-calibration algorithm.

The Advanced Microwave Scanning Radiometer 2 (AMSR2) is one of the radiometers that is part of the GPM constellation. Figure 2 gives an example of derived inter-calibration offsets between AMSR2 and TMI from all four X-Cal members for the 19V channel (AMSR2 18.7 GHz V-pol and TMI 19.35 GHz V-pol). The inter-calibration results show a significant scene-dependent bias between AMSR2 and TMI. AMSR2 19V TBs are approximately 4 K warmer than TMI 19V TBs at the coldest observed temperatures, while at warm TBs AMSR2 and TMI show good agreement. Even though the X-Cal members have varying algorithms, the inter-calibration results are fairly consistent. X-Cal derives its credibility from this consistency.

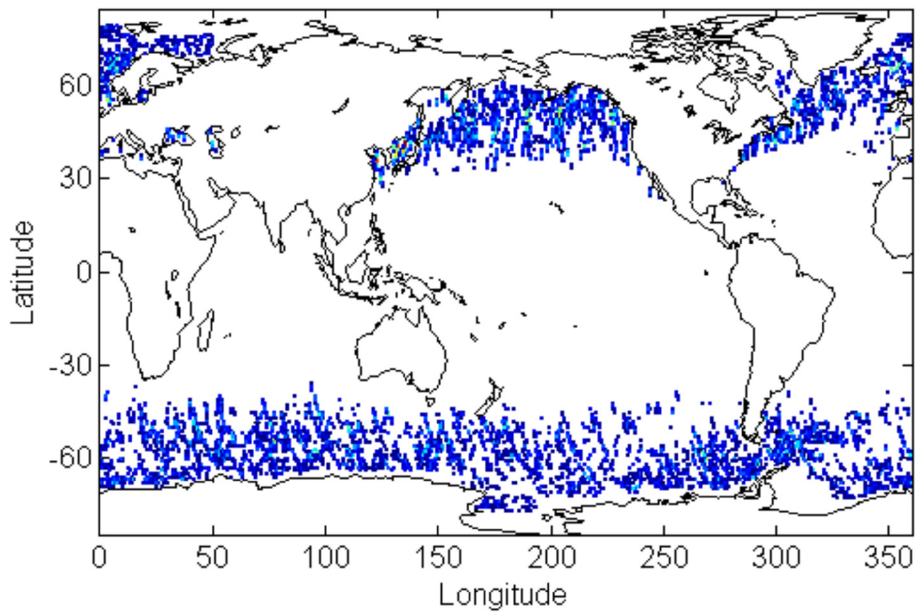

Figure 1: Locations of the coldest over-ocean TBs at 18.7 GHz V-pol for one month of data. These TBs make up the lower bound of the TB histogram that is used to derive the cold cal TB.

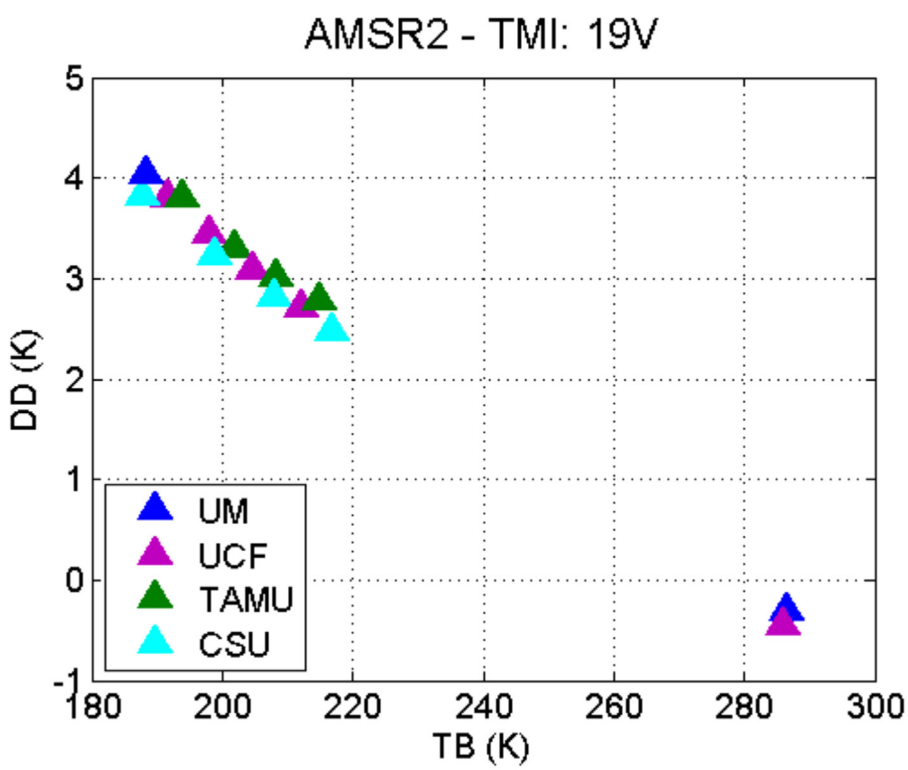

Figure 2: AMSR2 inter-calibration offsets at cold and warm scene temperatures, referenced to TMI as calculated by the four members of the GPM X-Cal team.

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The X-Cal team is currently hard at work analyzing the calibration of GMI. Once there are sufficient data from GMI, the inter-calibration offsets will be re-derived for the radiometers in the GPM constellation using GMI as the reference.

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On-Orbit ATMS Lunar Contamination Corrections

by Hu Yang, ESSIC/CICS, University of Maryland, and Fuzhong Weng, NOAA

1. Introduction

Lunar contamination on the ATMS space view counts occurs when the Moon appears in its FOV. After the launch of Suomi National Polar-orbiting Partnership (NPP) satellite into orbit, it is observed that the lunar intrusion happened several times a year with several consecutive orbits. Since the lunar surface brightness temperature can vary from 120 to 380 K and is much higher than the cosmic background temperature of 2.73 K, which is a default value used in the calibration, the lunar radiation can seriously impact the calibration accuracy if it is not corrected. The lunar contamination has produced a maximum jump of 40 counts and can produce an error of 1.5 K for a brightness temperature of 150 K at channels 1 and 2 over the ocean. The increments of space view counts at ATMS V and W/G bands arising from lunar intrusion (LI) are 200 and 400 counts, respectively. Therefore, a LI identification / correction model is needed for ATMS on-orbit calibration.

2. Methods and Results

A metric for LI detection can be defined as below:

$$\beta' = \beta - \alpha_l \leq 1.25 \cdot \theta_{3dB}$$

where β is the separation angle between Moon vector and space view vector, θ_{3dB} is the main beam width, α_l is the apparent angle of the Moon and is calculated as

$$\alpha_l = \frac{2 \cdot r_{moon}}{d_{moon}}$$

Where r_{moon} = 1737.92 km and d_{moon} is the radius of the Moon, and is the distance between satellite and the Moon, which varies with satellite position in orbit.

For ATMS space view, the brightness temperaure increment arising from lunar contamination can be expressed as:

$$\Delta T_{moon} = G \cdot \Omega_{moon} \cdot T_{moon} \quad (1)$$

In Eq. (1), T_{moon} is the microwave brightness temperature of the full Moon disk, and can be computed from the separation angle Θ between the Moon and the Sun. From the ATMS antenna pattern measurements, it is known that the azimuthal asymmetry is small and can be ignored.

The antenna response within the mean beam range can then be accurately simulated by one dimension Gaussian function:

$$G(\beta') = e^{-(\beta'-\alpha_0)^2 / 2\cdot\sigma^2} \quad (2)$$

The normalized solid angle of the Moon in Eq. (1), Ω_{moon}, is defined as an area ratio of full disk of the Moon and antenna response.

In Eqs (1)~(2), α_0 is an angle adjusted for offset in ATMS beam alignment

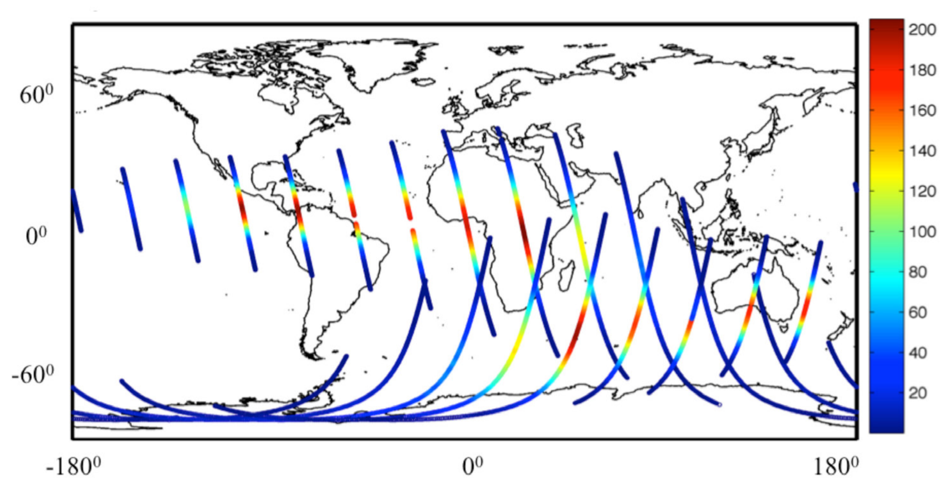

Figure 1: Global distribution and magnitude in cold calibration count from lunar contamination at ATMS channels 3-15. Color bar represents the cold calibration count anomaly.

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$$\sigma = \frac{0.5 \cdot \theta_{3dB}}{\sqrt{2 \cdot log2}}.$$

To make our model more fitted to ATMS measurement characteristics, the parameters, are determined by using a least square fitting algorithm. The best fitting parameters α_0, σ and Ω_{moon} are listed in Table 1. To validate the retrieved parameters, the observed ΔC_{moon} from 0100 UTC to 2359 UTC, December 05, 2011, are compared with the model prediction. As shown in Figure 2, the model predictions of ΔC_{moon} agree well with observations at all channels.

In reality, it is also very interesting for users to know the impact of LI to calibration accuracy of ATMS antenna temperature data records (TDR). From the two-point calibration equation, without considering the nonlinearity of receiver, the TDR calibration error arising from lunar contamination can be expressed as the equation below:

$$\Delta T \quad = T_s' - T_s = \Delta T_{moon} - \Delta T_{moon} \cdot \left(\frac{C_s - C_c}{C_w - C_c}\right) \quad (3)$$

where T_s and T_s' are the antenna temperature before and after lunar contamination correction. The term ΔT_{moon} are the increments of space view brightness temperature arising from lunar intrusion. Parameters C_s, C_w, and C_c are the receiver output counts for scene, warm load, cold space view, respectively. Figure 3 shows the TDR error for ATMS channel 8. The impact of lunar contamination to antenna temperature is channel and scene temperature dependent. As expected by Eq. (3), the calibration error increases as scene temperature decreases. For example, at K-band, the maximum brightness temperature bias is 0.9K over ocean, and 0.3 K over land. The bias increases to 3 K at V/W bands, and can be as large as 4 K at G band due to the increased magnitude of lunar intrusion at these channels.

3. Conclusions

In this study, data with lunar contamination information were collected since ATMS launch on October 28, 2011. A correction model is therefore developed for mitigating the impacts of

Table 1. Best fit parameters for ATMS lunar contamination correction model

Channel	α_0	δ	Ω_{moon}
1	-0.22	2.23	0.0050
2	-0.38	2.31	0.0053
3	-0.11	0.96	0.0257
4	-0.09	0.95	0.0255
5	-0.10	0.95	0.0258
6	-0.10	0.94	0.0259
7	-0.10	0.93	0.0261
8	-0.11	0.94	0.0262
9	-0.10	0.93	0.0263
10	-0.12	0.92	0.0275
11	-0.14	0.93	0.0277
12	-0.14	0.93	0.0277
13	-0.15	0.94	0.0276
14	-0.16	0.94	0.0277
15	-0.18	0.96	0.0281
16	-0.16	0.90	0.0287
17	-0.25	0.54	0.0913
18	-0.22	0.51	0.0900
19	-0.22	0.51	0.0897
20	-0.22	0.51	0.0894
21	-0.22	0.51	0.0898
22	-0.22	0.50	0.0895

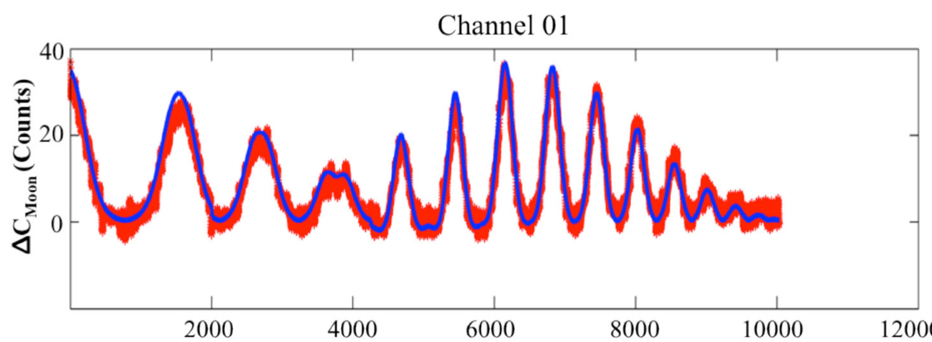

Figure 2: Comparison of the cold calibration count anomaly (ΔC_{moon}) predicted from lunar model (blue) and observed (red) at ATMS channel 1

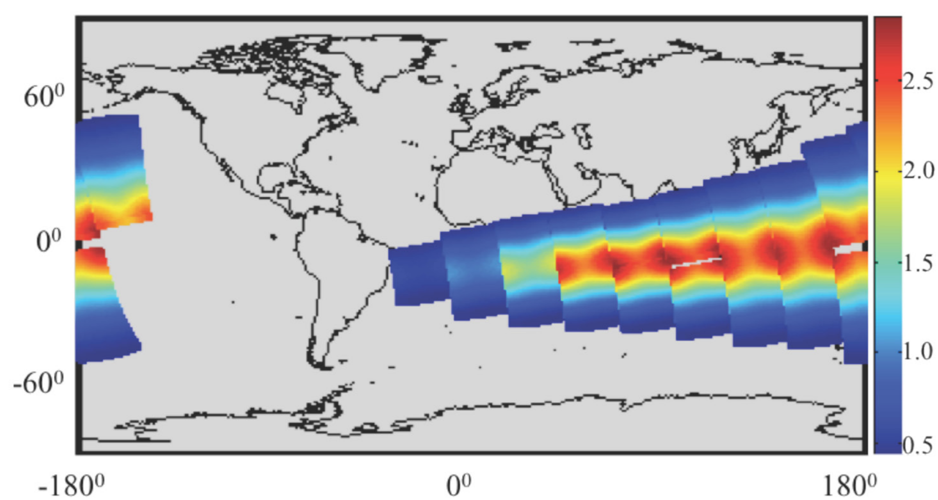

Figure 3: Scene antenna temperature difference before and after the lunar contamination corrections for ATMS channels 8 during 36 hours period of lunar intrusion.

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ATMS lunar intrusion on calibration. The algorithm is applied in ATMS on-orbit calibration and can eliminate all the radiation from lunar intrusion in the earth-scene brightness temperature.

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Identifying AMSR2 Oceanic Calibration Biases

by Suleiman Alsweiss, Zorana Jelenak, Paul S. Chang, and Jun Park, NOAA

In May 2012, the Japanese Aerospace Exploration Agency (JAXA) successfully launched the Global Change Observation Mission-Water (GCOM-W1) with the Advanced Microwave Scanning Radiometer-2 (AMSR2) onboard. AMSR2 is a microwave radiometer system that measures dual polarized [vertical (V-pol) and horizontal (H-pol)] radiances at 6.9, 7.3, 10.65, 18.7, 23.8, 36.5, and 89.0 GHz. It is a sun-synchronous orbiter that acquires microwave radiance data by conically scanning the Earth's surface to obtain measurements along a semicircular pattern in front of the spacecraft. It operates at a nominal earth incidence angle (EIA) of 55º that results in a wide swath of 1,450 km. The aperture diameter of AMSR2 antenna is 2.0 meters with an instantaneous field of view (IFOV) spatial resolution that varies inversely with frequency.

The observed brightness temperatures (TBs) from AMSR2 will be used to infer several geophysical parameters over land and ocean. Thus, well calibrated AMSR2 observations will significantly improve the performance and accuracy of the geophysical retrieval algorithms and reduce retrieval errors.

The double difference (*DD*) technique was utilized to investigate any residual calibration biases in AMSR2 measurements. The main advantage of the *DD* method is that it accounts for center frequency, EIA, and orbital differences between instruments being inter-calibrated. For a sun-synchronous radiometer like AMSR2 (local time of ascending node 13:30), a non-sun-synchronous, low inclination orbiter will create a larger amount of collocated observations to be used in the analysis. Hence, TRMM Microwave Imager (TMI) was chosen as the reference radiometer to study the calibration biases of AMSR2.

To calculate *DD*, we need first to find the single difference (*SD*) for each radiometer, which is the difference between the observed and the simulated radiometer TBs, with the latter generated using a radiative transfer model (RTM)) and ancillary data.

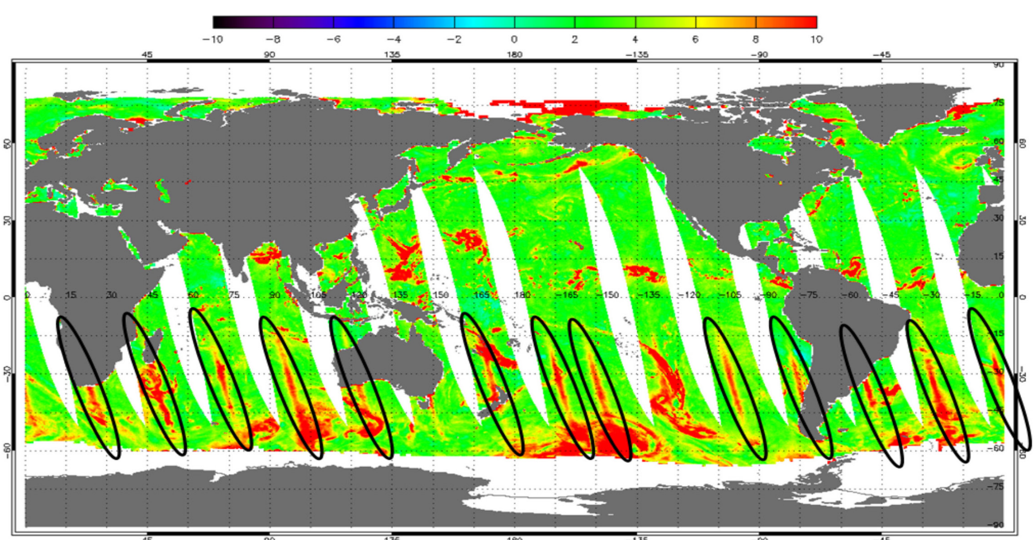

Figure 1. Sun glitter effect on AMSR2 ascending orbits.

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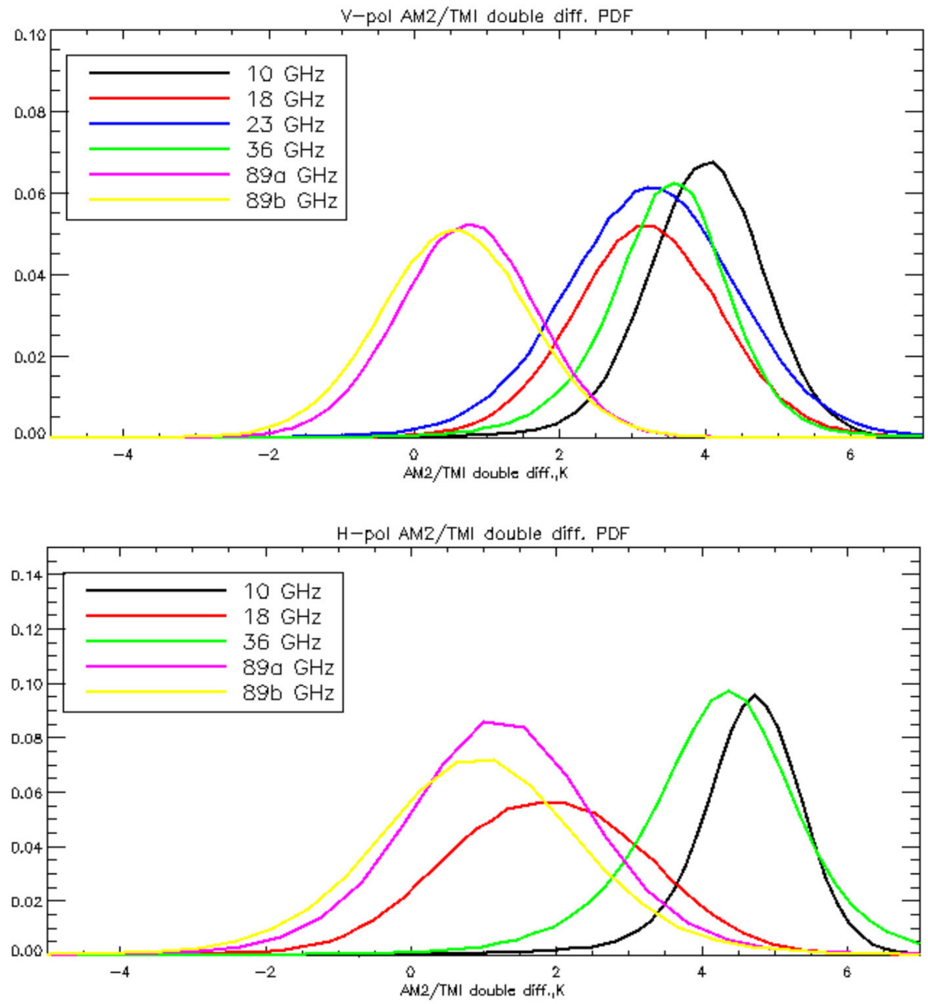

Figure 2. AMSR2 double difference probability density functions for (a) V-pol, and (b) H-pol.

$$SD = Tb_{observed} - Tb_{simulated}$$

$$DD_{Freq.,Pol} = SD^{AMSR2}_{Freq.,Pol.} - SD^{TMI}_{Freq.,Pol.} \quad (2)$$

AMSR2 data used in this study are JAXA's Level 1B version 1.1 (GW1AM2 L1B v1.1) released on March 1, 2013. In addition to observed TBs, this data product contains the observation position (latitude, longitude), time, and orbit information. The product summary and description is available online at [2]. For TMI, the data used herein are version 7 (v7) of the Level 1B Calibrated TB product (TMI 1B11). The product summary and description for TMI 1B11 can be found in the Goddard Earth Sciences Data and Information Services Center (GES DISC) web page.

To perform AMSR2 inter-calibration with TMI, observations of the corresponding channels (frequency and polarization) from the two radiometers were collocated to establish a subset of ocean scenes that have homogeneous environmental conditions. A 30-minute maximum time difference and 10 km maximum distance between the two sensors' observations were chosen as the collocation criteria.

The collocated points are then filtered for rain and clouds to assure rain-free clear-sky observations. TMI environmental daily retrieval maps (version 4) provided by Remote Sensing Systems (RSS) were used for that purpose [4]. In addition, AMSR2 ascending orbits were filtered for any sun glitter contamination using sun azimuth and elevation information provided in the GW1AM2 L1B data files. Figure 1 shows the difference between measured and simulated AMSR2 TBs (K) for the 6 GHz V-pol channel, where sun glitter contaminated areas are encircled. Finally, an aggressive land mask is applied to remove any possible land contamination in the observed TBs (100 km away from the coast).

Using the filtered collocation dataset (separated by frequency, polarization, and ascending/descending), the *DD* between AMSR2 and TMI was calculated. Figure 2 depicts the probability density functions (PDF) for AMSR2 *DD* results for both V- and H-pol channels (Figure 2-a and 2-b respectively). Results revealed some rather significant residual calibration errors exist in AMSR2 TB measurements (AMSR2 TBs are ~ 2 – 4 K warmer than TMI).

The NOAA GCOMW1 processing system accounts for these calibration biases found in AMSR2. Corrections are operationally applied to AMSR2 Level-1B (L1B) and level-1R (L1R) datasets before being used to derive advanced satellite data products.

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Inter-calibration of Observations from SAPHIR and ATMS instruments

by Isaac Moradi, ESSIC/CICS, University of Maryland, Ralph Ferraro, NOAA

Sondeur Atmosphérique du Profil d'Humidité Intertropicale par Radiométrie (SAPHIR) onboard Megha-Tropiques (M-T) and Advanced Technology Microwave Sounder (ATMS) onboard Soumi NPP have several channels operating at frequencies near the water vapor absorption line at 183 GHz. These instruments provide valuable information about temporal, spatial, and vertical (layer-averaged) distribution of tropospheric water vapor (Moradi et al., 2013). Although, these instruments are calibrated and tested before launch, they require extensive post-launch assessment and validation due to possible drift in calibration (Moradi et al., 2010). Inter-comparing data from similar instruments is one of the methods that can be used to identify the relative differences between the instruments and allow for proper usage of their measurements and derived products for weather and climate applications. Hence, this paper focuses on inter-comparing SAPHIR and ATMS observations.

M-T, launched in Nov 2011, is a low-inclination satellite, meaning that the satellite only visits the tropical band between 30 S and 30 N. There were primarily two MW instruments onboard M-T: MADRAS (Microwave Analysis and Detection of Rain and Atmospheric Systems), and SAPHIR. MADRAS instrument, whose primary purpose was to measure surface properties and precipitation, experienced several malfunctions and is now not operating, so the SAPHIR is currently the only microwave instrument onboard the M-T satellite. More information about Megha-Tropiques mission is available at http://meghatropiques.ipsl.polytechnique.fr/.

In this study, we first collocated ATMS and SAPHIR observations in clear sky conditions. The collocation criteria were less than 30 minute time difference and less than 25 km spatial distance between the SAPHIR and ATMS observations. Figure 1 shows the comparison btween collocated ATMS and SAPHIR observations. The frequencies of ATMS and SAPHIR channels as well as the statistics for the comparison are printed on the plots. As is shown, the mean difference between the ATMS and SAPHIR observations is -0.7, -1.5, -1.3, and 0.5 K for the lower to upper channels, respectively. The correlation coefficient and slope of the fitted lines are greater than 0.98 and 0.97, respectively, for all the channels. It should be noted that, as is shown, none of the SAPHIR and ATMS channels operate at the same exact

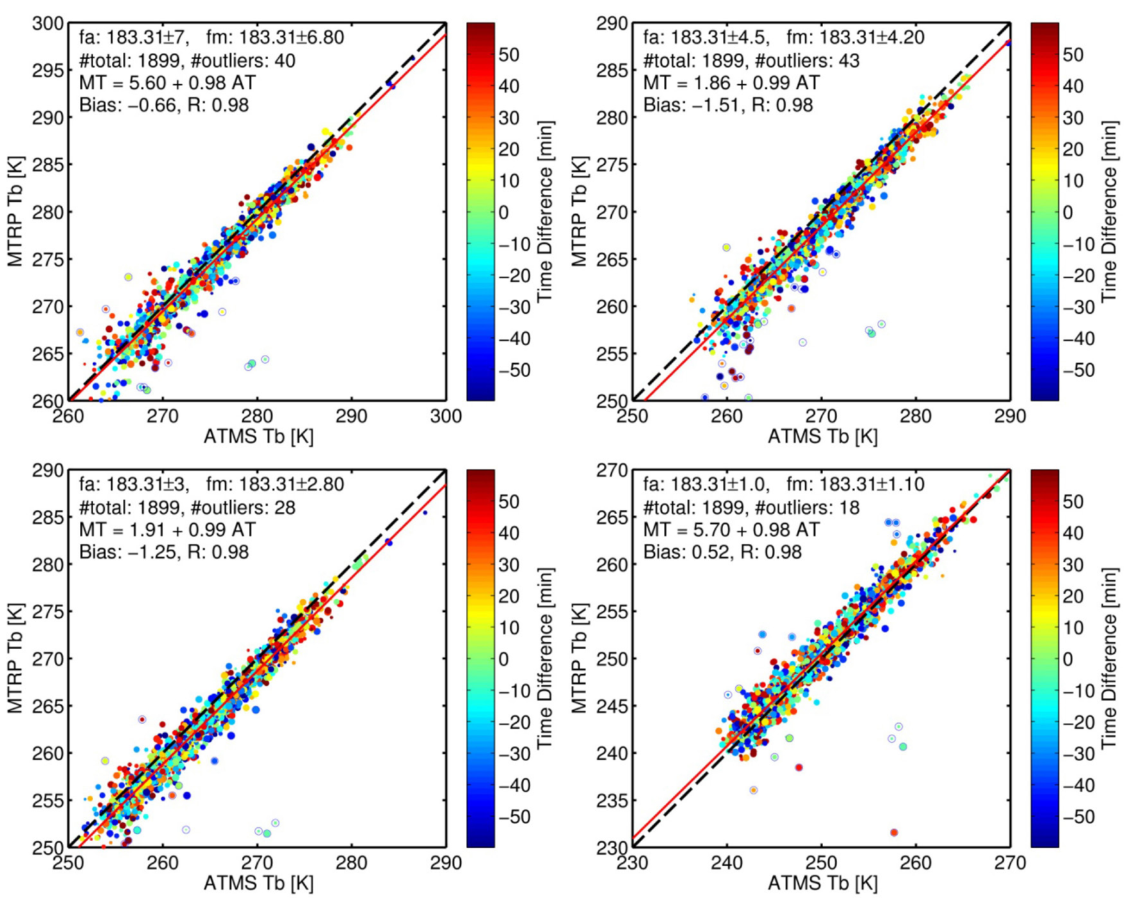

Figure 1: Comparison between collocated SAPHIR and ATMS observations. The colorbar shows the time difference between SAPHIR and ATMS observations and the size of the markers shows the spatial distance between the ATMS and SAPHIR observations. Number of observations (#total) are included, fa and fm shows the frequency of ATMS and SAPHIR channels, respectively. MT = a + b AT shows the linear fit coefficients between SAPHIR (MT) and ATMS (AT) collocations and R shows the correlation coefficient. Datapoints where the difference between ATMS and SAPHIR was larger than 3NEDT are marked as outlier. Statistics are calculated using all the datapoints; excluding or including the outliers in the analysis does not affect the statistics since only a few points show a large difference.

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frequencies. Therefore the weighting functions of the similar channels peak at slightly different altitudes, which introduces a systematic difference between the observations of the two instruments. We used a radiative transfer model and radiosonde data to quantify these systematic differences by simulating ATMS and SAPHIR brightness temperatures for corresponding channels then subtracting simulations from each other. The mean differences between the observations and simulations are shown in Table 1. The last column in Table 1 shows the mean difference between observed and simulated differences, which is known as double difference and indicates the actual bias between the two instruments.

Overall, the results show that the differences between ATMS and SAPHIR observations are small compared to the noise of the instruments, and the measurements from the two instruments are generally consistent. It is planned to develop a package to routinely inter-compare the observations from ATMS and SAPHIR in the future. This work will support both SAPHIR and ATMS calibration activities at NOAA, as the inter-comparison can reveal any drift in the observations.

Table 1: Mean difference between the measured and simulated ATMS and SAPHIR brightness temperatures. Freq shows the frequency of the channels, ObsBias shows the mean difference between SAPHIR and ATMS observations, SimBias shows the systematic difference between SAPHIR and ATMS due to frequency difference between the channels, Obs – Sim shows the bias between ATMS and SAPHIR observations, and NEDT shows the noise equivalent temperature in SAPHIR observations which is a measure of expected uncertainty in the data

Freq ATMS [GHz]	Freq SAPHIR [GHz]	ObsBias [K]	SimBias [K]	Obs – Sim	NEDT [K]
183±7.0	183±6.8	-0.66	-0.42	-0.24	1.03
183±4.5	183±4.2	-1.51	-0.91	-0.6	1.38
183±3.0	183±2.8	-1.25	-0.93	-0.32	1.36
183±1.0	183±1.1	0.52	0.9	-0.38	1.45

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The Intercalibration of Three Decade of Satellite Microwave Observations for Ocean Climate Research

by Frank Wentz, Remote Sensing Systems

A realistic and reliable assessment of climate trends and variability requires long-term, accurate, and homogeneous time series of climate data. Microwave radiometers provide the most accurate remote sensing measurements over the ocean of several essential climate variables crucial for the water cycle, including through-cloud sea surface temperature, surface wind speed, vertically integrated water vapor, cloud water, and rain rate. Nearly 30 years of Earth observations by satellite microwave radiometers have occurred. This long-term record requires the combination of time series measured by several different radiometer designs orbiting on more than a dozen different satellites, including 6 DMSP SSM/I, 3 DMSP SSMIS, TMI on TRMM, AMSR-E on Aqua, WindSat on Coriolis, and most recently AMSR-2 on GCOM-W1. To obtain an accurate and homogeneous data record, the systematic differences due to radiometer design and calibration must be taken into account, otherwise biases specific to one satellite or another will introduce artificial shifts in the time series. These shifts can have a huge impact on the results of climate analysis, especially those of climate trend analysis.

To perform satellite intercalibration we use a physically-based technique that ensures a consistent and traceable calibration starting from raw sensor counts (Wentz, 2012). There are many potential sources of error in sensor calibration, but we have found that four primary sources dominate the error budget. First is error in the pre-launch determination of the antenna spillover. The spillover is part of the familiar antenna pattern correction, which is the crucial conversion from antenna temperature to brightness temperature. Second is error due to specifying the effective hot load temperature on orbit. The design of the hot load for F16 SSMIS, for example, allows sunlight to enter, either directly or via a single reflection. This introduces significant thermal gradients that decorrelate the temperature measured by the embedded thermistors from the effective radiating temperature of the load. More

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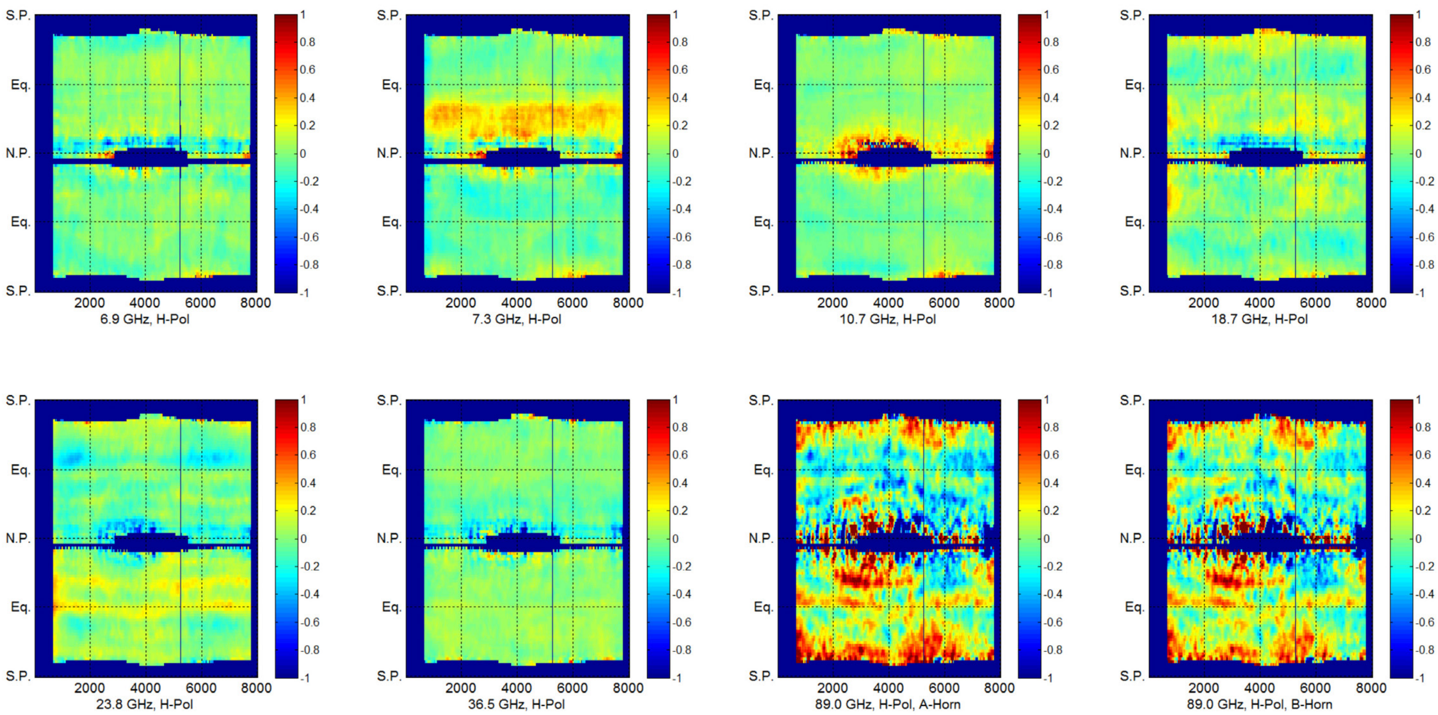

Figure 1: The difference between AMSR-2 antenna temperature (TA) measurements and the RTM TA using WindSat ocean retrievals for the RTM inputs. The color scale goes from -1 to 1 K. Each image is a different channel [6.9, 7.3, 10.7, 18.7, 23.8, 36.5, and 89.0 GHz] and only horizontal polarization is shown. For each image, the x-axis is the orbit number (5000 orbits = ~ 1 year) and the y-axis is the AMSR-2 orbit position going from South Pole to North Pole and back. Areas of missing data (dark blue) are the polar ice caps. The yellow/orange band in the 7.3 GHz channel is due to RFI. The larger noise in the 89 GHz channels is due to the sensitivity to clouds at this high frequency.

generally, we have also found that the effective hot loads on all sensors tend to be about 1 K cooler than the thermistor readings. Third is error due to direct emission from the antenna. This error is difficult to handle, but it only affects the TMI and SSMIS sensors. Fourth is error due to the spacecraft and calibration targets entering the field of view during a scan. This error is easily corrected because it is a systematic error that repeats every scan. All of these errors, in addition to many other minor errors, are removed using our intercalibration technique that is based on comparing satellite observations to a common and well developed radiative transfer model (RTM) (Meissner and Wentz, 2012).

We use the rain-free ocean as our absolute calibration reference and an RTM of the ocean and intervening atmosphere in the absence of rain. This avoids the problem of absolute calibration errors in one sensor aliasing into another. It also simplifies the inter-calibration of sensors having significantly different channel sets and viewing angles (such as SSM/I and WindSat). Furthermore, it provides a precise definition of absolute calibration that can be applied to all sensors. Another advantage of calibrating the brightness temperature measurements to the RTM is that one can then more readily examine the interplay between brightness temperature calibration and the inverse problem of geophysical retrievals. The fact that the latest (V7) calibration adjustments are done in terms of physical rather than ad hoc quantities provides the likelihood that the ocean-based calibration is also applicable over land. Recent analyses over the Amazonian rain forest indicate that this is correct. The RTM in a relative sense over the full range of environmental conditions (excluding rain) is predicting brightness temperatures to an accuracy near 0.2 K and certainly better than 0.5 K as shown in Figure 1. Some channels vary over 100 K going from the Polar Regions to the Tropics, and hence the 0.2 K difference represents a 0.2% error.

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Inter-Calibration of AMSU-A Window Channels

by Wenze Yang, ESSIC/CICS, University of Maryland, Huan Meng, and Ralph Ferraro, NOAA

More than one decade of observations from the window channels of Advanced Microwave Sounding Unit-A (AMSU-A) onboard the polar-orbiting satellites NOAA-15 to NOAA-19 and EUMETSAT MetOp-A provide global information on water vapor, cloud, and precipitation, etc. However, reprocessing must be conducted first for these observations to be consistent for climate applications. After the geolocation (Moradi et al., 2013) and cross-scan bias corrections (Yang et al., 2013) have been applied to the dataset, more research has been focused on the comparison among AMSU-A window channels from the different satellites to remove any inconsistency. This is a critical step towards the development of a set of fundamental and thematic climate data records (CDRs) for hydrological and meteorological applications.

The inter-satellite differences can arise from many error sources, such as bias drift, Sun-heating-induced instrument variability in brightness temperatures, scene temperature dependent biases due to inaccurate calibration nonlinearity, etc. (Zou and Wang 2011). The Integrated Microwave Inter-Calibration Approach (IMICA) developed by Zou et al. (2006, 2009, 2010, and 2011) has demonstrated its effectiveness in removing or minimizing these biases for AMUS-A temperature sounding channels. The IMICA approach is adopted in this study for the inter-satellite calibration of AMSU-A window channels after certain modifications are made. Specifically, a study is carried out to identify the appropriate standard deviation (STD) thresholds for deriving Simultaneous Nadir Overpass (SNO) data.

The IMICA approach takes into account not only the relationship between counts and brightness temperatures of a channel within one satellite but also the relative calibration offsets (δR) and nonlinearities (μ) between satellite pairs. These coefficients, quite different from those from pre-launch operational calibration, are obtained through two phases: in the first phase, the coefficients describing the co-nonlinearity between two satellites are derived from SNO least-squares regression; the second phase is an iterative process, in which the nonlinearity coefficient of the reference satellite is adjusted, and the level-1c radiances for all available AMSU satellites are generated, until the mean standard deviation (STD) of the paired difference of mean brightness temperature time series over tropical ocean is minimized (Zou and Wang 2011).

In addition, 50.3 GHz of NOAA-16 suffers from bias drift, which was removed by introducing time-varying calibration offsets.

By applying the optimal μ, δR, we produced an inter-calibrated, new set of level-1c window channel brightness temperatures for all satellites from 2000 to 2010. To illustrate the effect of the corrections, the nadir-view brightness temperatures over the tropical ocean are extracted. This region is selected to avoid strong diurnal variation and the impact of sea ice. Figure 1 and 2 compare the time series of brightness

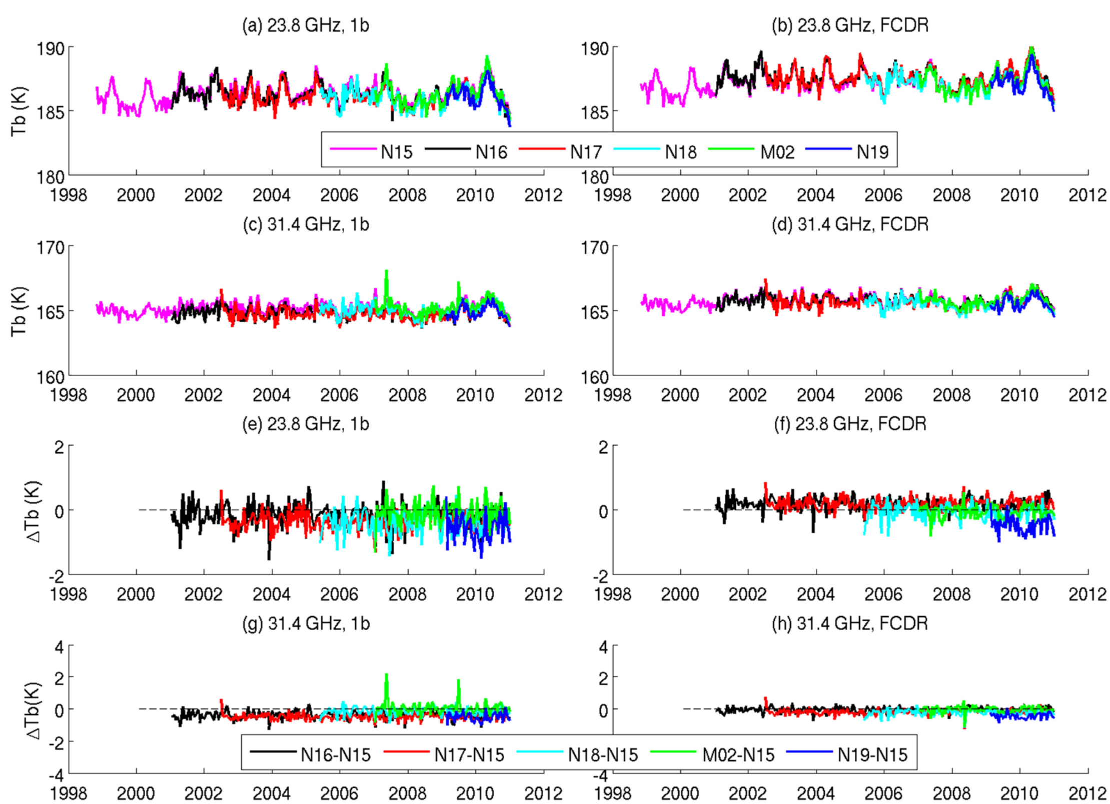

Figure 1: Tropical ocean mean brightness temperature (Tb) and difference (ΔTb) for 23.8 and 30.4 GHz channels. Left panels display the values before correction, while right panels are after correction.

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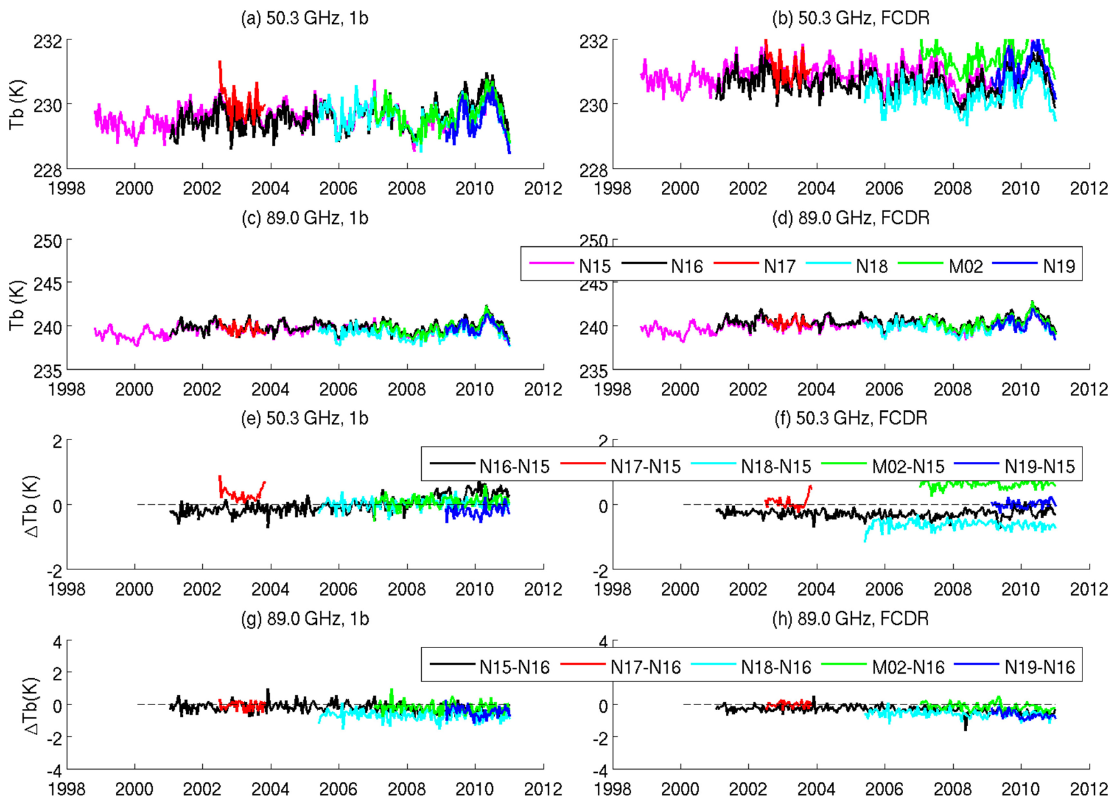

Figure 2: Similar to Figure 1, but for 50.3 and 89.0 GHz channels.

temperatures and their differences before and after the corrections.

The inter-calibration minimized the impact of the aforementioned errors. The corrected brightness temperatures, labeled as FCDR in the figures, exhibit better agreement between satellites than the operational 1b data. The comparison of the STD of ΔTb calculated from Figure 1(e)-(h) and Figure 2(e)-(h) shows that the improvement of these channels is approximately 50%. For instance, the STD value for the 23.8 GHz of N16-N15 pair was 0.374 K before correction, but reduced to 0.217 K after correction.

A special issue is that the 89.0 GHz of NOAA-15 appears to suffer from frequency shift, which requires further investigation. For this reason, NOAA-16 is selected as the reference satellite for this channel, whereas NOAA-15 is is used as the reference satellite for the other three window channels. The potential improvement to the thematic CDR as a result of the inter-satellite calibration is under investigation.

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Creating a Microwave Based FCDR for Tropospheric Humidity: Initial Assessment of SSM/T-2 Radiances

by Viju O. John, EUMETSAT, UKMO, and Eui-Seok Chung, RSMAS, University of Miami

Water vapor is one of the most important parameters controlling the hydrological cycle and hence the weather and climate of Earth. Therefore we need quality datasets of tropospheric humidity from satellites as they provide a global picture. Here, we summarize a short study to assess quality of SSM/T-2 data as part of an undertaking to combine SSM/T-2, AMSU-B and MHS measurements to produce more than 20 years of microwave based humidity FCDR, under the framework of EUMETSAT's CM "SAF" FCDR. The SSM/T-2 was the first satellite microwave humidity sounder and was flown on 4 DMSP satellites: F11, F12, F14, and F15. Table 1 lists the channel characteristics and Figure 1 displays the equator crossing times.

As a first step to assess the quality of SSM/T-2 measurements, monthly-mean, zonal-mean brightness temperatures (TB) are constructed and Figure 2 shows this for the 183.31±3 GHz channel. Since the TB are determined by atmospheric temperature and mid-tropospheric humidity, TB tend to decrease away from the tropics. For all satellites the TB maxima are observed to locate in the sub-tropics of both hemispheres. Since atmospheric temperature is generally uniform in the lower latitudes, the spatial variations result mainly from the differences in mid-tropospheric humidity whose distribution is closely related to the pattern of large-scale flow. Seasonal variations in lower latitudes are mainly attributable to the seasonal migration of the ITCZ. Therefore the measurements show expected variations in temperature and humidity.

The accuracy of geometrical calibration is examined on the basis of the land-sea surface temperature and emissivity differences. Analyses of the spatial distribution of daily TB of the 90.665 GHz channel over Australia and surrounding oceans suggest that geo-location is generally good because the TB exhibit a sharp discontinuity along the coastline.

Temporal variations of cold and warm counts are examined in order to assess the stability and accuracy of SSM/T-2 calibration systems. Since the cold count represents the cosmic background radiation, the value of cold counts should be constant and identical among the satellites. Although the SSM/T-2 instruments show roughly constant values of cold counts, in some parts of the time span there are also substantial fluctuations and inter-satellite differences. In particular, F11 shows anomalously high counts and high standard deviations until 1995, indicating careful quality control would be needed with these data. F12 shows large deviations in 1995-1996 and 2002. In contrast, comparatively stable patterns are observed for the humidity channels on F14 and F15. Variations in cold counts imply potential biases in TB records. Because the cold counts fluctuate substantially for the surface channels (especially, 150 GHz channels), we conclude that the surface channels of SSM/T-2 are not suitable for long-term climate monitoring. Similar conclusions can be drawn from the analysis of daily mean of standard deviation. In other words, the humidity channels could

Table 1: Channel characteristics of SSM/T-2 instrument. Note these are the instrument specified values and they are different in reality, especially the NEDT.

Ch.	Frequency (GHz)	Nadir FOV (km)	Beam width (deg)	Peak sensitivity	NEDT (K)
1	183.31 +/- 3.00	48	3.3	Mid troposphere (MT)	0.6
2	183.31 +/- 1.00	48	3.3	Upper troposphere (UT)	0.8
3	183.31 +/- 7.00	48	3.3	Lower troposphere (LT)	0.6
4	91.665 +/- 1.25	84	6.0	Surface	0.6
5	150.0 +/- 1.25	54	3.7	Surface/LT	0.6

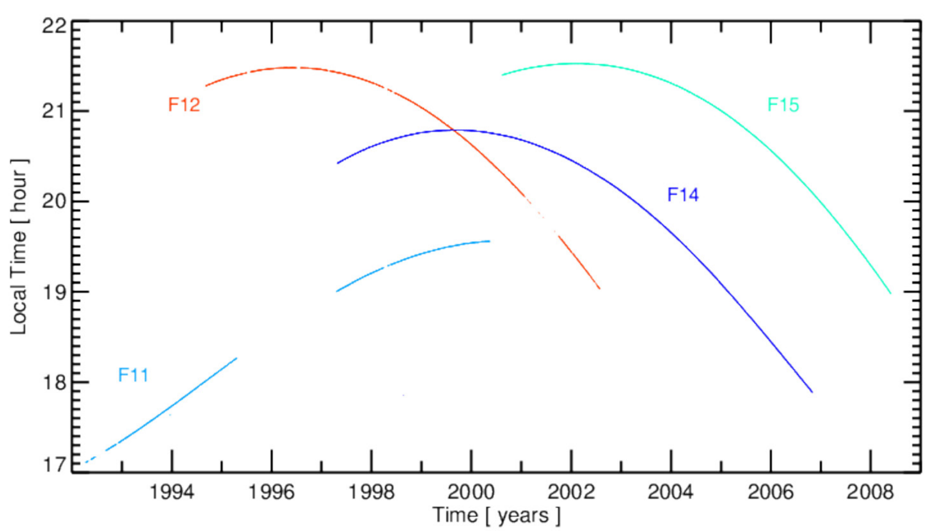

Figure 1: Equator crossing times of the ascending nodes of DMSP satellites. Only those satellites which have SSM/T-2 instruments on-board are shown.

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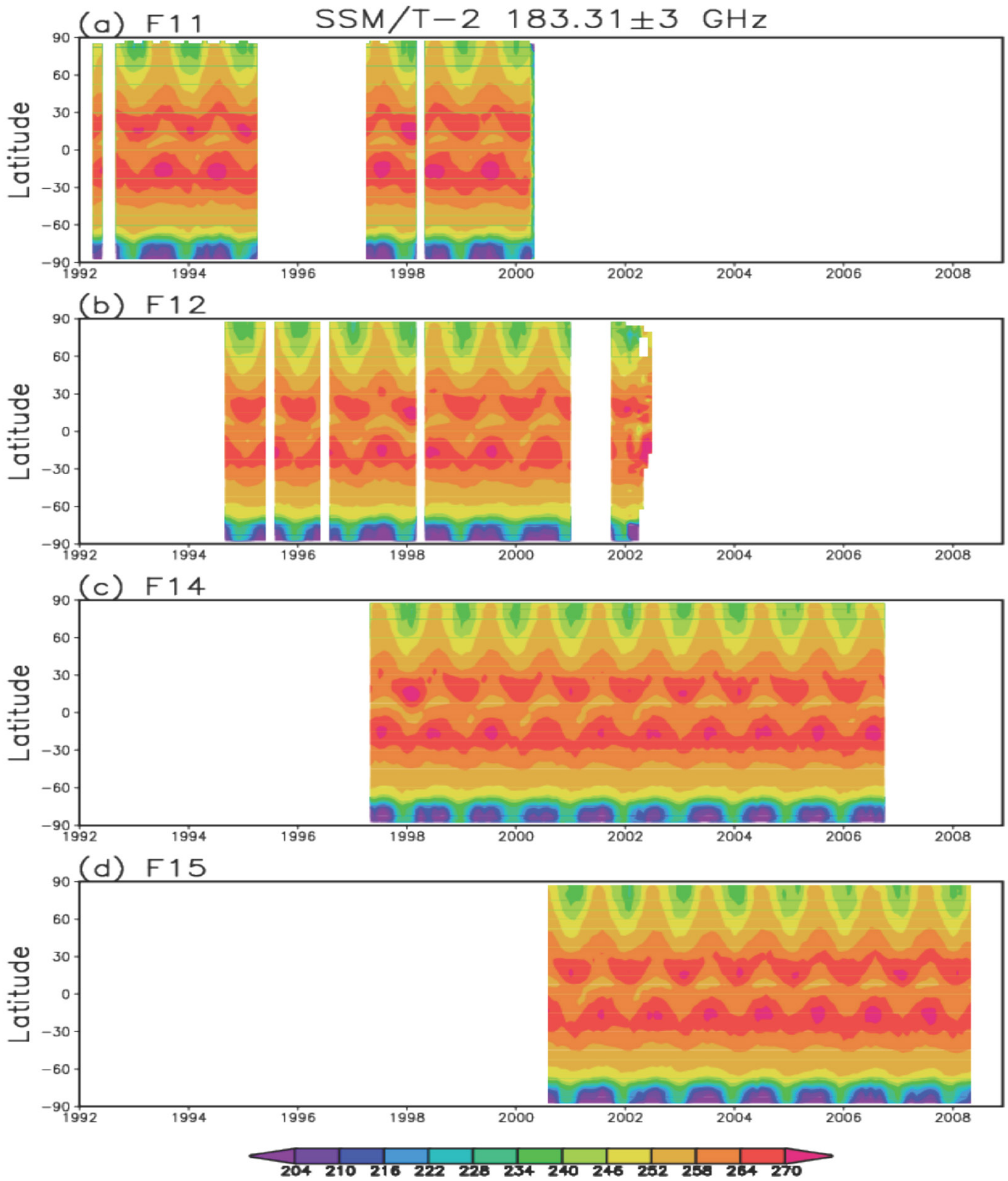

Figure 2: Zonal averaged brightness temperatures of Channel 1 of SSM/T-2

be used for climate monitoring after correcting biases except for F11 which needs careful quality control. Similar inferences were made by analyzing the warm counts, which measure radiation from an onboard blackbody target.

We have also noticed that 2-4 pixels (depending on satellite) on the right edge of the scan show unexpected lower TB. This anomaly in TB at the right edge of the scan is due to the obstruction caused by the "Glare Obstruction Bracket" (GLOB). The GLOB was actually used to reduce the amount of glare caused by direct sunlight on Operational Linescan System (OLS).

In summary, this is the first time the SSM/T-2 radiance measurements have been assessed for their potential for monitoring of atmospheric humidity. Some anomalies are seen with the data but there are sufficient stable periods to make these data worthy of consideration for extending the microwave humidity dataset back in time before the start of AMSU-B in 1998. More detailed analyses and validation of these data are necessary before we combine these measurements with AMSU-B and MHS measurements to create >20 years of tropospheric humidity data set from microwave instruments (Chung et al., 2013 and references therein).

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News in this Quarter

by Manik Bali

2014 Annual Meeting of GSICS Research and Data Working Groups

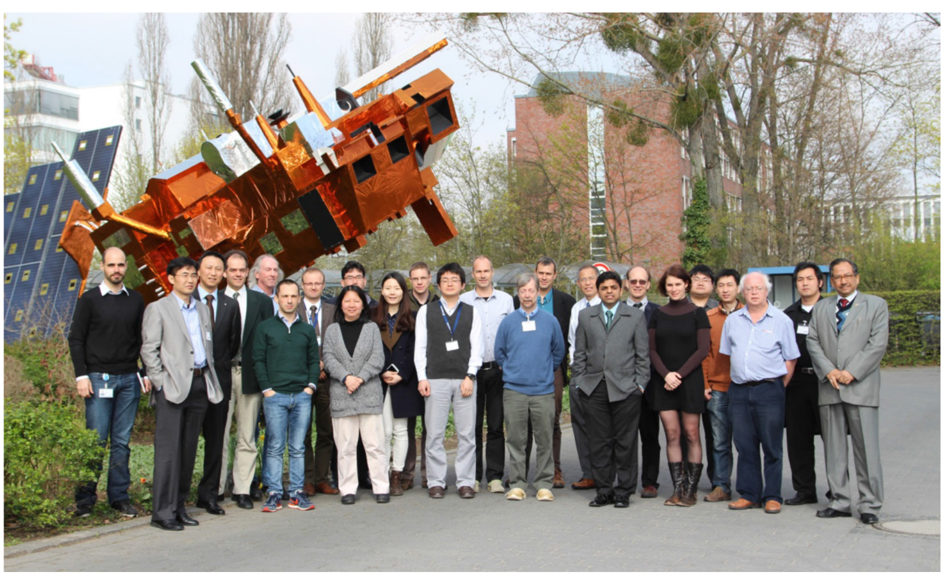
by Tim Hewison (EUMETSAT) - GRWG Chair and Manik Bali (NOAA) - interim GDWG Chair

This year's meeting of the GRWG and GDWG was hosted at EUMETSAT, Darmstadt, Germany, on 24-28 March 2014. The attendance was excellent, with 12 of the GSICS Member and Observer agencies represented, including ISRO and IMD for the first time, and invited experts from five other organizations. Also represented was the Infrared and Visible Optical Sensors (IVOS) subgroup of the CEOS Working Group on Calibration/Validation (WGCV), which allowed agreement of future cooperation between IVOS and GSICS.

The meeting started with a one-day Mini Conference, highlighting a range of activities of interest to the calibration community. These included users of inter-calibration products, in particular SCOPE-CM projects working to generate Fundamental Climate Data Records (FCDRs) from satellite data archives. The calibration requirements for future instruments were also addressed, with several presentations from EUMETSAT.

A particular highlight of this session was a discussion on the possibility of operating reference instruments with on-board SI-traceable calibration, such as CLARREO or TRUTHS, onboard Chinese satellites. If realized, this will provide GSICS with much needed in-orbit references for inter-calibration to absolute standards.

The GRWG sessions reported progress with GSICS Corrections for the infrared channels of current geostationary imagers, some of which are expected to be ready to enter demonstration mode at three agencies this year (ISRO, CMA and KMA) and others to become the first operational GSICS products in 2014 (from NOAA, EUMETSAT and JMA). The development of inter-calibration products based on the Numerical Weather Prediction and Radiative Transfer Models (NWP+RTM) was also discussed and plans outlined to consolidate results from MICROS with existing GSICS products.



Participants in the GRWG GDWG Annual Meeting

Message from Outgoing Executive Panel Chair

Dr. Mitch Goldberg

My term as the chair of the GSICS executive panel has now concluded. When I reflect over the past 8 years as chair, I have an immediate sense of true accomplishment for the GSICS and satellite user communities. When we started GSICS back in 2005, we knew the importance of building a community of satellite operators and partners to become proficient in satellite instrument calibration and intercalibration. We knew the trend of agencies and users relying on other agencies' satellites would continue to increase and it would require a strong effort of comparisons among sensors and identification of corrections needed to remove biases that we may find to improve the impact of satellite data in a variety of applications.

We wanted the satellite operators to become responsible for these activities so that when satellite data are delivered from any agency there will be high confidence of the quality of the data traceable to agreed upon and understandable methodologies.

We realized that each agency has geostationary imagers with varying degrees of calibration issues. So we decided that our very first project (which continues to this day) would be to routinely intercalibrate those sensors to the more stable and accurate sensors found on polar orbiting satellites. And from this task, our community was formed. I am so proud of the collaboration throughout GSICS, not just in the executive panel, but in the research and data working groups. GSICS has grown from 8 agencies to over 14 agencies. We have a common mission and vision which will continue to guide us well into the future. It has been a privilege for me to serve, and I wish the very best to our new chair, Peng Zhang of CMA and the vice chair Kenneth Holmlund of EUMETSAT. I will continue to serve on the executive panel as the NOAA member.

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Also, a format was agreed to implement delta corrections into the netCDF format used for GSICS Corrections to allow users to transfer the calibration from one calibration reference to another, while, in the longer term, GSICS will aim to develop a community consensus reference, based on a blend of best quality instruments available. It is hoped that this approach will provide a robust system from which to derive FCDRs. Encouraging results were presented for AIRS, IASI and CrIS, as well as MODIS, VIIRS and MERSI, in this regard.

The Visible/Near-Infrared Sub-Group, lead by Dave Doelling, continued to develop an inter-calibration algorithm for the visible channels of geostationary imagers based on Deep Convective Clouds (DCCs). This is now sufficiently mature to allow the generation of demonstration products suitable for study by beta-testers.

A particularly interesting session on lunar calibration highlighted the potential of this method to inter-calibration channels in the Reflective Solar Band at the sub 1% accuracy level. Discussion about the issues faced by some agencies in implementing the ROLO lunar irradiance model led to EUMETSAT offering to investigate the possibility of hosting a Lunar Calibration Workshop in winter 2014/15. Watch this space for more!

In addition to this already busy week, we squeezed in short sessions dedicated to the newly formed UV and Microwave Sub-Groups, which included several remote participants joining by Webex. The Microwave Sub-Group started by discussing interactions with the counterpart in the CEOS WGCV. This was followed by reviewing different interpretations of the root cause of the bias patterns found in the inter-calibration of the window channels of microwave sounders. Meanwhile, the UV Sub-Group continued to scope five projects to develop different challenges of calibrating UV instruments, and also nominated Rosemary Munro (EUMETSAT) as chair and Lawrence Flynn (NOAA) as vice-chair of the sub-group.

In the midst of all the excitement of the annual meet, representatives of the GSICS Data working group (GDWG) presented their past year's progress and discussed ways and means to support the GRWG products in the future. First the members dived into issues related to 24x7 running of the GSICS data catalogue, GSICS Wiki and Product Taxonomy. Then topics related to Improvements in GSICS Procedure for Product Acceptance (GPPA), GSICS bias monitoring tool, event logging framework, calibration change alerts, Digital Identifiers for products, PICS data extraction for FY-3/MERSI/VIRR and new bias monitoring websites, were discussed in the GDWG breakout session.

Laurie Rokke introduced members to "Big Data." Members felt that this new technology can provide a scalable system to GSICS that can do trend analysis and SNO's efficiently. It would help support the GRWG in the future as more and more data get into the GSICS fold and their analysis becomes critical.

The meeting closed with IMD offering to host next year's meeting in New Delhi, India, which promises to continue this trend of excellent progress on GSICS products – and lack of snow!

Microwave Inter-Calibration Activities Reported at MicroRad 2014

by Vinia Mattioli, EUMETSAT

The 13th Specialist Meeting on Microwave Radiometry and Remote Sensing of the Environment (MicroRad'13) was held in Pasadena, CA, USA, this spring on March 24-27.

Over the years, Microrad has become an important venue to present MW research results, MW instrument designs and applications to an audience that comprises research, industry and academia.

The technical program of MicroRad'13 included sessions on current and future microwave missions, instruments design, calibration theory and techniques, RFI detection and mitigation, and microwave radiometer studies of the land, oceans and atmosphere.

Several oral and poster presentations were specifically devoted to inter-calibration.

For the CONAE Microwave Radiometer (MWR) on board the NASA SAC-D/Aquarius mission launched on June 2011, a calibration study was reported using two different techniques: a land cross-calibration with Windsat and the vicarious cold calibration

In the framework of the NASA/JAXA Global Precipitation Measurement (GPM) Mission, an inter-calibration method for AMSR2 was presented by the GPM Inter-satellite Calibration Working Group (X-CAL) The GPM mission will utilize several radiometers on different satellites to provide global coverage of precipitation measurement. Inter-calibration is a key aspect of the mission and is aimed to ensure consistent measurements. The presented inter-calibration method uses a double-difference inter-comparison technique. This method utilizes relative differences between the observations that are computed with respect to a reference radiometer and to each radiometer in the GPM constellation. It is foreseen that the transfer standard to provide radiometer inter-calibration will be the GPM Microwave Radiometer (GMI), but for the present TRMM Microwave Imager (TMI) and Windsat were used.

A specific presentation was devoted to the assessment of the long-term radiometric calibration stability of TMI and Windsat, using the double differences. The method consisted in computing double-differences (observed – theoretical) radiometric biases, were the theoretical brightness temperature differences between radiometers' channels were calculated using a radiative transfer model. The relative change in these calibration biases over five years was used to estimate the stability of one radiometer with respect to the other.

The CM SAF Fundamental Climate Data Record (FCDR) of SSM/I Brightness Temperatures is a long-term inter-calibrated dataset that includes all available data from the six SSM/I

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radiometers. This oral presentation was focused on the main calibration issues identified, and compared the different inter-calibration procedures implemented to homogenise the time series of their data

The meeting also covered Microwave Humidity Sounders. A study was presented evaluating inter-calibration of observations from similar channels on the Suomi NPP ATMS and Megha-Tropiques Sondeur Atmosphérique du Profil d'Humidité Intertropicale par Radiométrie (SAPHIR).Radiosonde data from Atmospheric Radiation Measurement (ARM) Program and GPS Radio Occultation Observations from the COSMIC mission were used to evaluate the ATMS measurements.

A method to inter-calibrate L-band orbiting radiometers was proposed using ESA's Soil Moisture and ocean Salinity (SMOS) instrument as a transfer radiometer between current L-band soil moisture and sea surface salinity sensing SMOS and Aquarius and the future NASA Soil Moisture Active Passive (SMAP) mission.].

Results of the Inter-comparison of brightness temperatures from the Advanced Microwave Scanning Radiometer 2 (AMSR2) onboard the Global Change Observation Mission 1st – Water (GCOM-W1) satellite against TRMM TMI and NASA/JAXA AMSR-E measurements were presented in the Calibration Techniques and Methods poster. The method also makes use of a double-differences method, computing differences between observed- and calculated-Tb for both AMSR2 and TMI to derive inter-calibration coefficients (slope and intercept).

The use of the double-difference technique applied to microwave humidity sounders was also envisaged in a poster presentation on the same Session to inter-calibrate the water vapor sounder SAPHIR on the Megha-Tropiques satellite using the Microwave Humidity Sounders (MHS) on NOAA and MetOp satellites.

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Meet GSICS Members

GSICS is not just a serious organization for exchanging scientific ideas. When we meet, we also exchange our likes, dislikes and maybe a laugh. We bring to you Dr Cheng-Zhi Zou, Dr. Pradeep Thapliyal, and Dr. Hu Yang (Tiger). More members will be introduced in upcoming issues. Contact Manik Bali manik.bali@noaa.gov if you want to be one of them.

Dr. Cheng-Zhi Zou

In 2013 the Executive Panel of GSICS decided to form the Microwave (MW) subgroup with the aim of bringing MW calibration experts across members together. In July of 2013 Dr. Cheng-Zhi Zou was elected its first chair. This MW subgroup joined alongside the existing subgroups of GRWG that are dedicated to VIS and UV.

Dr. Cheng-Zhi Zou brought in more than 20 years of experience with him. In 2007 he received the U.S. Department of Commerce Silver Medal for developing a calibration technique that enables detection of reliable long-term atmospheric temperature trends from satellite data. Again in 2013 he was awarded the NOAA Administrator's award for developing a science-quality long-term dataset of upper atmospheric temperatures from NOAA's microwave and infrared satellite measurements.

Within a short span of time of being elected chair, Dr. Zou was able to galvanize the newly formed subgroup into a vibrant international group of microwave experts and in Dec of 2013 the subgroup delivered its first product to GSICS namely the AMSU MSU FCDR. New MW products are in the offing.

At NOAA, Dr. Zou's research mainly focuses on microwave inter-calibration, developing microwave fundamental and thematical climate data records, and using microwave observations for climate change investigations.

Dr. Zou's vision for the future of the MW subgroup lies in fostering high quality calibration and inter-calibration of satellite microwave sensor products for weather and climate applications, facilitate international co-ordination in satellite microwave calibration activi-

[1] Full-length articles are currently under review and will be published at a later stage in the IEEE Xplore as part of the conference proceedings.

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ties, and promote accurate microwave calibration and inter-calibration.

Dr. Zou has enormous trust in the power of young scientists and he believes that encouraging them at an early stage motivates them for their lifetime and during his chairship he intends to lay special emphasis on encouraging them.

Finally, in his words,"I am excited to serve as the Chair of this Sub-Group, working with dedicated sub-group members as well as other GSICS group and sub-group chairs to achieve GSICS goals and objectives. This special MW issue of GSICS Quarterly introduced part of the accomplishments by the MW subgroup members and I would like to thank the authors and editors who made this available to the community."

Dr. Pradeep Thapliyal

Dr. Thapliyal works as a scientist in the Space Applications Centre, Indian Space Research Organisation (ISRO), Ahmedabad, India. Currently, he is leading the retrieval of atmospheric sounding products from infrared Sounder onboard Indian geostationary satellite INSAT-3D.

Besides atmospheric sounding, Pradeep is also an expert on retrieval of upper tropospheric humidity, outgoing longwave radiation and ocean surface shortwave radiation from geostationary infrared Imager observations and soil moisture using passive microwave observations from polar orbiting satellite.

He is an active member in GSICS Research Working Group and representative of ISRO, India. His focus is on the inter-calibration of the infrared channels of Imager and Sounder, the Indian geostationary satellites using Metop/IASI and Aqua/AIRS hyperspectral sounders. He used GSICS baseline algorithms for verifying and monitoring of the INSAT-3D Imager and Sounder infrared channel radiances immediately after the launch of the satellite.

Recently, Pradeep was invited by EUMETSAT to attend GSICS Research and Data Working Group meeting in Darmstadt, Germany, during 24-28 March 2014. Leading by example and in the most trying circumstances is his key trait. He proved this when in the GSICS annual meet he made a presentation on GPRC report of ISRO through WEBEX from India just before boarding his flight for Germany. But as they say all is well that ends well—the presentation was electrifying and GSICS members enjoyed his company when he finally landed in Darmstadt.

Dr. Hu Yang (Tiger)

Dr Yang often known by his nickname 'Tiger' is a Microwave expert and an active member of the of GSICS Microwave subgroup.

Since 2012, Tiger has been working at the Earth System Science Inter disciplinary Center (ESSIC) of University of Maryland. At ESSIC he is leading a JPSS project on calibration/validation of NPP instruments as its Principal Investigator.

Tiger has bought in many years of Microwave experience into GSICS. After receiving his PhD from the Institute of Remote Sensing Application, China Academy of Science, Beijing, in 2003, he joined as a senior research scientist in national satellite meteorological center, china meteorological administration(CMA). At CMA he lead the microwave instrument calibration and satellite ground application system development first as an instrument scientist and then subsequently as its program scientist.

In 2010 Tiger was awarded the National Defense Science Advancement Award from China Aeronautic and Space Agency (CASA) for his outstanding contribution to the development of China's first spaceborne microwave imager radiometer. He has published in over 40 peer reviewed journals.

More recently Tiger is leading an exciting project aimed at developing an Advanced Radiance Transformation System (ARTS) for microwave instruments. The project goal is to develop a generic full radiance calibration system for microwave sounding instruments operated by NOAA and other space agencies and apply the system to process the microwave data from past, present and future satellites in order to produce consistent climate data records for use in weather and climate applications.

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Announcements

Dr. Pen Zhang Accepts Chair of Executive Panel

by Manik Bali

In the meeting of GSICS executive panel on 16-17 May 2014, the Deputy Director General of National Satellite Meteorological Center (NSMC/CMA), accepted appointment as Chair of the GSICs Executive Panel.

Dr Zhang is a widely respected member of GSICS. As a member of GSICS Research Working Group he has been contributing to GSICS activities since its initial years and has contributed immensely in formulating its research activities and vision. Since 2009 he has been a member of the GSICS Executive Panel.

Dr. Zhang got his Ph.D. from IAP/CAS (Institute of Atmospheric Physics, Chinese Academy of Sciences) in Atmospheric Physics in 1998. From 1998 to 2001, he worked in EORC/NASDA (Earth Observation Research Center, National Space Development Agency of Japan) on the GLI/ADEOS II project. In 2001, he joined NSMC/CMA as a Scientist and since December 2005 has been working as a Senior Scientist at NSMC/CMA.

At NSMC Dr. Zhang is the leading scientist of FY-3 series of satellites. In this capacity he is actively involved in conceiving, developing, and operating satellite ground segment. He has authored and coauthored over 70 papers published in refereed scientific journals to date, in addition to editing two books and many book chapters and technical reports. Dr. Zhang brings with him wide experience in satellite calibration and inter-calibration.

Dr. Zhang is also the vice-chair of IEEE GRSS Beijing Chapter, a member of PSTG (Polar Space Task Group)/EC-PORS/WMO, a member of IEEE (Institute of Electrical and Electronics Engineers).

In the future, GSICS hopes to benefit immensely from Dr. Zhang's leadership as the Chair of its Executive Panel.

Dr. Ken Holmlund Accepts Vice Chair of Executive Panel

by Manik Bali

In the GSICS Executive Panel meeting held in Guangzhou (16-17 May 2014), Dr. Ken Holmlund accepted appointment as Vice Chair of the GSICS Executive Panel.

Dr. Holmlund started his career in satellite remote sensing at the Finnish Meteorological Institute in1986. In 1989 he joined the European Space Agency to work on the Meteosat satellite program, focusing on development of products and applications from geostationary satellite data. In 1995 he moved to EUMETSAT to work on the Meteosat Second Generation program, from where he subsequently moved to the Operations Department within EUMETSAT as head of the Meteorological Operations Division in 2002.

In January 2013 Dr. Holmlund became the head of the newly formed Remote Sensing and Products Division within the Technical and Scientific Support Department in EUMETSAT. In this role he is responsible for all centrally performed scientific developments targeting the extraction of Level-1 and Level-2 data from all instruments on the EUMETSAT missions. He is responsible for all calibration and quality aspects of the EUMETSAT instruments data, which combined with his experience from product operations constitutes a valuable input to the GSICS activities.

Dr. Holmlund has published numerous articles in various publications and has served as a member of several committees. Currently he is a member of the WMO Polar Satellite Task Group, the THORPEX Observation Panel, the ECMWF Technical Advisory Committee and the EUMETNET Science and Technology Advisory Committee.

GSICS would like to thank Dr. Holmlund for accepting the Vice Chairship and guiding it in meeting its coming challenges.

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GSICS-Related Publications

Bhatt, R. Et al (2014), Desert-based absolute calibration of successive geostationary visible sensors using a daily exoatmospheric radiance model. *IEEE Transactions On Geoscience And Remote Sensing* Vol. 52 No. 6 pp. 3670-3682

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Submitting Articles to GSICS Quarterly Newsletter:

The GSICS Quarterly Press Crew is looking for short articles (~ 700 words with one or two key, simple illustrations), especially related to cal/val capabilities and how they have been used to positively impact weather and climate products.
Unsolicited articles are accepted anytime, and will be published in the next available newsletter issue after approval/editing.
Note the upcoming spring issue would be a special issue on Ultra Violet. You are welcome to submit articles on Ultra Violet instruments. Please send articles to manik.bali@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 our European Correspondent, Dr. Tim Hewison of EUMETSAT, American Correspondent, Dr. Fangfang Yu of NOAA, Asian Correspondent, Dr. Yuan Li of CMA, and Larry Flynn, GCC Director, in helping to secure and edit articles for publication.

The Editor would also like to thank Cheng-Zhi Zou, Tim Hewison, Larry E. Flynn, Mio Tian, Korak Saha and Tanvir Islam for reviewing the articles in the Newsletter.

GCC team welcomes your feedback and suggestions about the GSICS Quarterly.