CGMS-35, NOAA-WP-18
Prepared by M. Goldberg
Agenda Item: II/4
Discussed in WGII

Real time Assessments of Instrument Performance from GSICS and NOAA Websites

IN RESPONSE TO CGMS RECOMMENDATION 34.12

Summary of the Working Paper

Instrument performance monitoring is critical for ensuring the level 1b product quality for both numerical weather prediction and climate change detection. There is a need to develop a comprehensive instrument performance monitoring system to address this issue. Prototypes of such systems for both polar orbiting and geostationary satellites have been demonstrated in the WMO/GSICS (Global Space-based Intercalibration System) program. Several examples are provided in this paper. The CGMS member agencies are encouraged to develop standardized instrument performance monitoring systems and share the results with the members through GSICS. This will greatly contribute to the improved accuracy in numerical weather prediction and climate change detection.

1 INTRODUCTION

Instrument performance directly affects the quality of satellite data used for numerical weather prediction and climate change detection. Real time assessment of instrument performance is especially important to NWP radiance assimilations. Unfortunately, this issue has not been fully addressed by the satellite data producers in the past. Although several instrument performance monitoring systems exists, they were developed by individual groups with different objectives. In many cases, it is difficult for individual systems to fully address the issues of instrument performance and its impact on data quality for the end users. In addition, many of these instrument performance monitoring systems were simply not available to everyone. For example, at NASA/GSFC, the HIRS filter motor and other temperature parameters were regularly trended and a hardcopy is printed and posted on the bulletin board regularly for those who work within the building. At NESDIS/OSDPD, software was developed and used for trending instrument performance parameters for all polar orbiting instruments. Although the data were made available online, users have to download and install the software which may or may not work depending on the particular configuration. At NESDIS/OSO, the GOES instrument performance trending is done entirely in house and no trending data or figures are released to the outside. Another problem is that while these systems are developed to monitor the instrument performance, they are typically unable to detect calibration biases which are most needed by the users such as NCEP for bias correction in numerical weather predictions. NCEP developed their own Radiance Assimilation Monitoring system for the GDAS (Global Data Assimilation System) by comparing satellite observations with forward model calculations. As a result, it is very difficult to get a comprehensive status overview of instrument performance and data quality. In addition, there is insufficient communication among the different groups.

To meet the challenges of the increasing demand for more accurate satellite data for NWP and climate change detections, new programs have been initiated to address these issues. In particular, the WMO/GSICS (Global Space-based Inter-calibration System) chaired by Mitch Goldberg of NOAA/NESDIS revolutionized the way of satellite instrument performance monitoring, as well as biases quantification among all operational satellites, and it will have a profound impact on the satellite data producers as well as data users. While GSICS is a very ambitious plan encompassing all aspects of calibration, two important aspects are the online instrument performance monitoring and intersatellite calibration with coincidental, collocated observations. This paper provides an overview of the major developments in these areas.

2 Real Time Assessment of Instrument Performance

Significant progress has been made in the development of an on-line trending system for instrument performance related parameters. In particular, a prototype time series of NOAA18/HIRS space view and blackbody counts, calibration coefficients and NEDN, and filter wheel, warm target, and instrument temperatures have been made available on the NOAA GSICS web site. In Figure 1, time series for the HIRS Channel 12 calibration slope and intercept, as well as detector NEDN, are shown. From this figure, significant noise can be found in the calibration coefficients and NEDT after January 27, 2006. This online trending has been used extensively by the investigation team for the noise anomaly. The cause of this noise is being investigated by scientists and the instrument manufacturer. A similar system has also been developed for the Microwave instrument AMSU. The development of this prototype on-line trending system highlights a major step forward in the ability to communicate the instrument status and performance to all data users in near real-time, which is a critical component of GSICS.

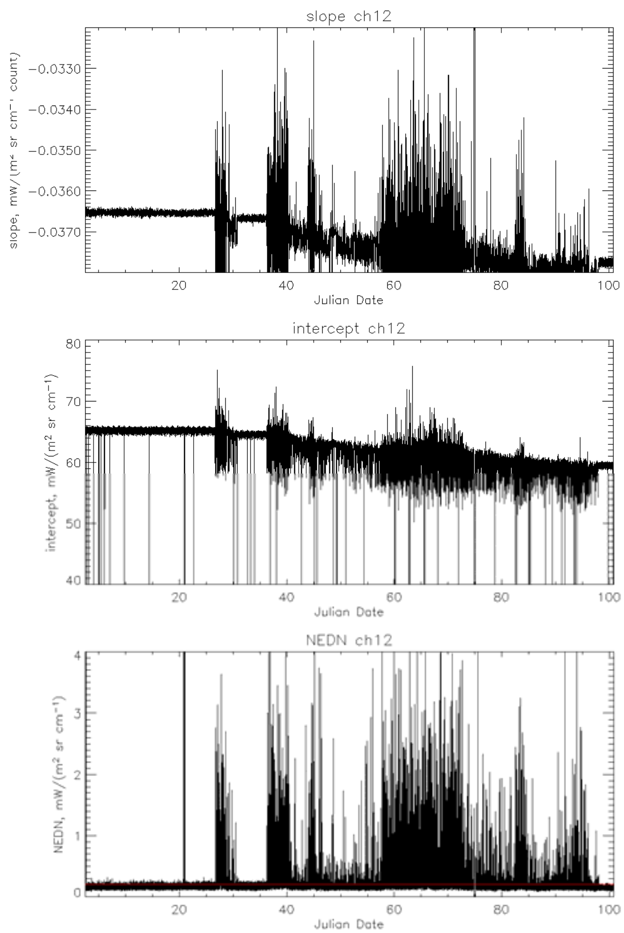

Figure 1: NOAA18/HIRS Channel 12 (water vapor channel) calibration slope (top), intercept (middle), and NEDN (bottom), from January 1, 2006 to March 8, 2006.

In the infrared, the instrument performance is heavily affected by the background radiation from the instrument component temperatures, which should be monitored closely. Figure 2 shows example trending of the component temperatures for MetOP/HIRS, including the baseplate, electronics, cooler housing, and detector temperatures.

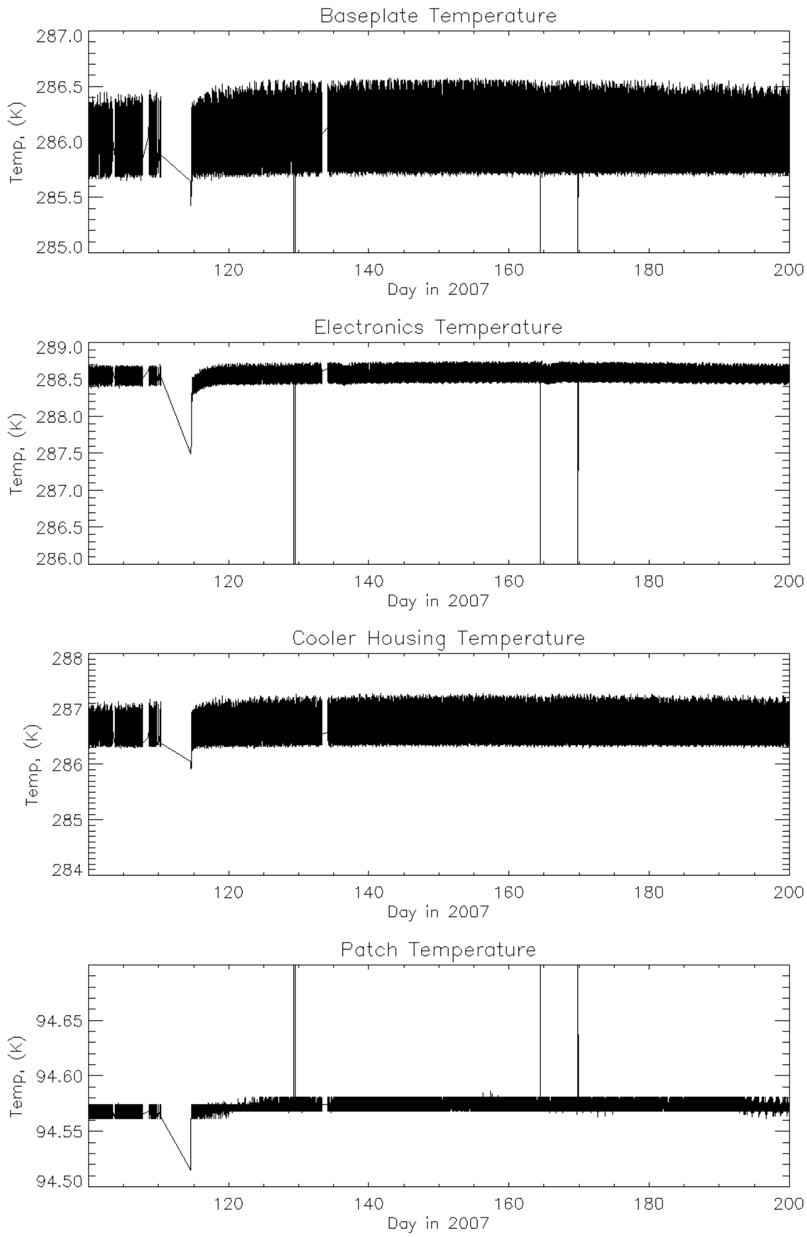

Figure 2. MetOP/HIRS instrument component temperature trending

In addition to telemetry monitoring and trending, the data quality of earth observations are monitored regularly near real time. Figure 3 exemplifies the earth view data monitoring for NOAA18/HIRS during low noise periods, where one orbit of data is displayed by channel for the 19 infrared channels.

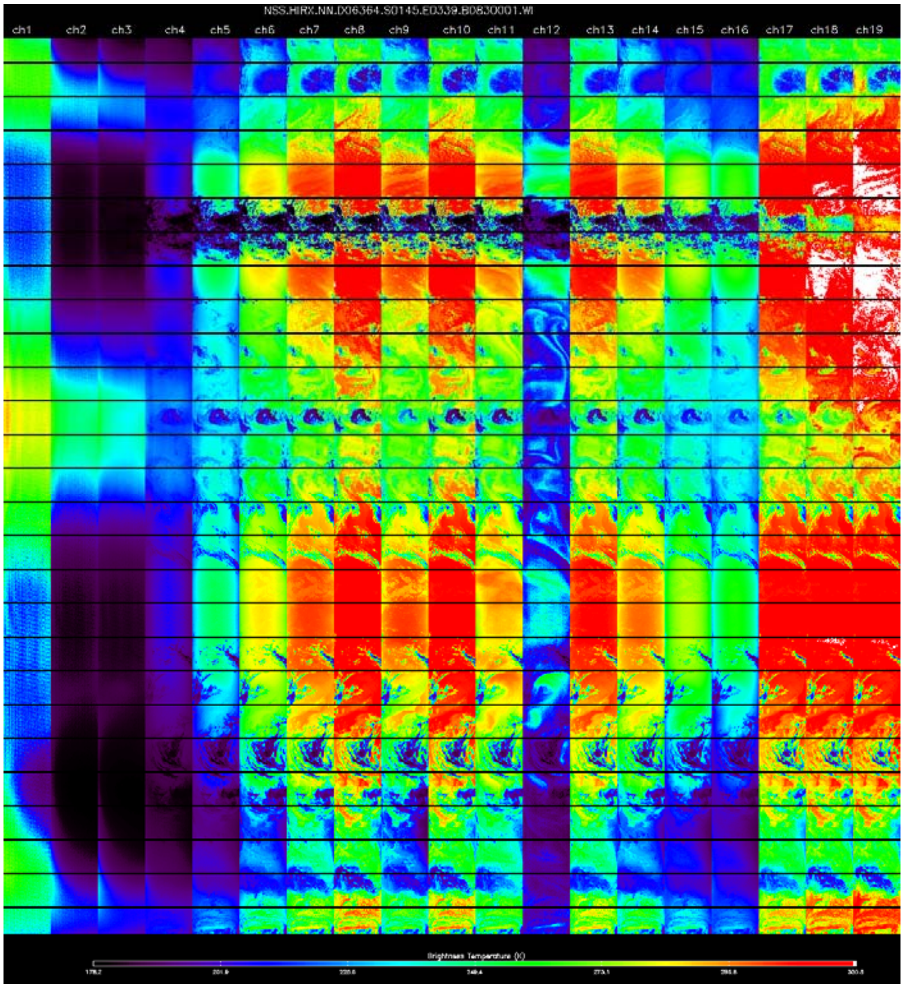

Figure 3. NOAA18/HIRS earth observation data quality monitoring.

Additional near realtime trending results can be found at http://www.orbit.nesdis.noaa.gov/smcd/spb/calibration/icvs/. We plan to add more instruments to the system internationally through the GSICS program.

3. Bias Estimates between AMSU-A Instruments on NOAA16, NOAA18, and EOS-Aqua

Major progress has been made using the SNO (simultaneous nadir overpapss) method to estimate the relative calibration biases among several similar instruments on different satellites, such as AMSU-A instruments flown on NOAA16, NOAA18, and EOS-Aqua satellites. Since AMSU-A on NOAA16, NOAA18, and EOS-Aqua are made identically, direct comparison of all radiometer channels using the SNO method is readily accomplished.

In Figure 4, AMSU-A brightness temperature biases derived from the SNO method between: 1) EOS-Aqua and NOAA16 (Aqua-N16), 2) EOS-Aqua and NOAA18 (Aqua-N18), and 3) NOAA16 and NOAA18 (N16-N18) are plotted as a function of AMSU-A channel. In addition, the N16-N18 biases estimated by subtracting the Aqua-N18 biases from the Aqua-N16 biases can be found in the figure. The most striking features of Figure 4 are 0.3 K to 0.6 K biases found for Aqua-N18 and N18-N16 in the AMSU-A1-1 channels (6, 7, and 9-15). Furthermore, the indirectly calculated (through Aqua, light blue curve) and directly calculated (yellow curve) bias between NOAA16 and NOAA18 are relatively close for channels 5 through 15, which are the sounding channels with minimal impact from the surface. These results show a tremendous skill in the SNO method to compute intersatellite radiometer biases.

For surface channels however the NOAA16 and NOAA18 biases from these two calculations do not agree. The cause of this is considered to be sometimes high surface emissivity variability, especially between land, water, and ice, in the large AMSU-A footprints (~ 50 km). In order to resolve this problem, surface characterization studies are planned to be able to perform calibration bias analyses as a function of surface type. In addition, study of the biases between AMSU-A1-1 instruments presented here is an important work in progress. This type of analysis using the SNO method is anticipated to be very useful in extending the mid- and upper- tropospheric temperature time series from the MSU and AMSU instrument era to that of the future instrument ATMS.

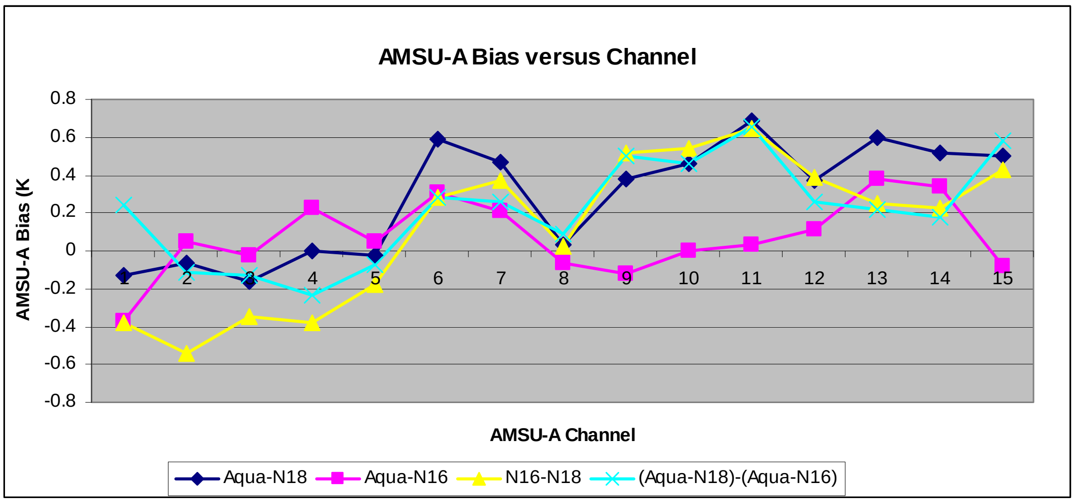

Figure 4: AMSU-A Bias versus AMSU-A Channel. Note biases of NOAA-18/AMSU-A in mid- to upper atmosphere channels.

4. Prototyping Instrument Performance Monitoring for GOES and GEOS-R

GOES-R/ABI will produce images with higher spectral, spatial, and temporal resolution, as well as to have greater calibration accuracy and long-term stability, than similar instruments flown on current GOES missions. In order to meet these performance goals, GOES-R instrument performance monitoring is an essential task, which will rely heavily on tested and peer-reviewed on-orbit calibration methodologies and includes a user-friendly web interface. The instrument performance monitoring system will include:

- Trending of sensor parameter and derived products
- Satellite-to-satellite instrument inter-comparison;
- Star and moon calibration;
- Vicarious calibration at reference sites; and
- Radiative transfer modeling using data from NWP models and earth validation sites.

As these elements are developed through the GSICS, they will be made available to users via the web.

Sensor parameter and derived product trending analyses allow measurement quality assurance monitoring to be performed at critical points in the data processing stream. They are designed to track the noise and stability of the sensor parameters that affect instrument calibration. They also allow the relationship between instrument calibration and level 1 and 2 product variability to be examined over time. Sensor parameter and derived product trending is planned to be carried out by plotting and performing statistical analyses on calibration-related instrument and product parameters. Statistical methods that can be applied to these data include simple spatial- and/or temporal-averaging and standard error analyses, as well as Fourier Transform, Empirical Orthogonal Function, and/or Principle Component analyses. Meanwhile, several parameters that can be tracked include: instrument temperatures; detector output; intercept, slope, and non-linear calibration coefficients; radiance; and derived nighttime sea surface temperature and aerosol optical depth. These analyses are important steps of data quality assurance that are of interest to GOES-R data users, as well as the broader global satellite data user community.

Audiences interested in sensor parameter trending vary considerable. Operational satellite data operators need to know near real-time changes in instrument performance, while climatologists creating climate data records may want to make hemispheric and regional data quality assessments of a series of instruments over their lifetimes as a function of season or time of day. Therefore, a sensor parameter trending system must be flexible enough for a user to be able to scale spatial and temporal analyses of calibration-related instrument parameters to their needs.

This type of analysis allows post-launch instrument performance to be examined in relation to design specifications, and to be flagged during the occurrence of large magnitude data irregularities. At the same time, longterm instrument performance monitoring is developed as instrument data sets expand with time. As an example of long-term sensor parameter trending, the slope of GOES-8 Channel 4 Detector 1 is plotted in Figure 5 as a function of time over the period 1994 to 2003.

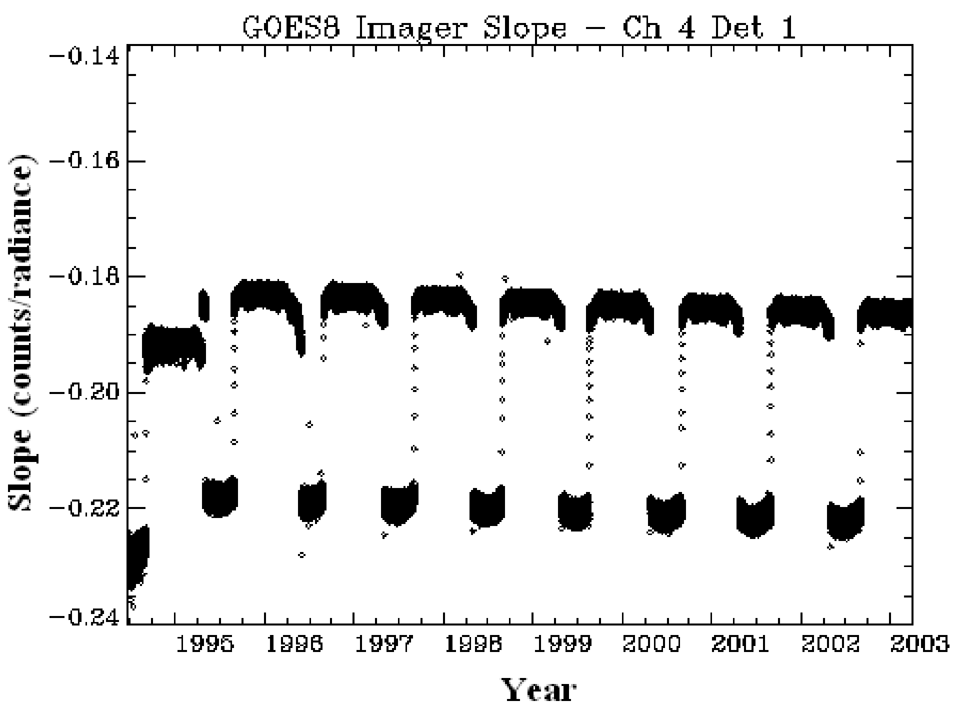

Figure 5: GOES-8 Channel 4 Detector 1 Slope from 1994 to 2003.

In Figure 5, an obvious seasonal cycle is present. Also, there is an increasing trend of the slope at the beginning of the time period, while there is a small discernable downward trend toward the end of the time period. The sudden increase in slope seen in the first quarter of 1995 emphasizes the need to have the flexibility to change the time perspective of the analysis, which is not present in this figure. During analysis, it is necessary to be able to determine exactly on what dates the sudden increase in slope occurred. In April 1995, the Satellite Operation Control Center introduced a scan mirror emissivity correction to the calibration algorithm, and a change in slope was observed. Although only instrument slope is shown in this example, this type of analysis can be applied to all calibration-relevant sensor parameters, such as instrument component temperatures, blackbody/solar diffuser stability. It also can be applied to level 1 radiances, and level 2 products such as nighttime SST and aerosol optical depth.

In summary, instrument performance monitoring is critical for ensuring the level 1b product quality for both numerical weather prediction and climate change detection. This paper shows that there is a need to develop a comprehensive instrument performance monitoring system to address this issue. Prototypes of such systems for both polar orbiting and geostationary satellites have been demonstrated in the WMO/GSICS (Global Space-based Intercalibration System) program. The CGMS member agencies are encouraged to develop standardized instrument performance monitoring systems and share the results with the members through GSICS. This will greatly contribute to the improved accuracy in numerical weather prediction and climate change detection.