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Agenda Item: II.2

New Analysis with the Intercalibration of Geostationary and Polar-Orbiting Radiance Measurements

Update on results from the continuing intercalibration of geostationary infrared window and water vapor radiances using one polar-orbiting sensor as a reference.

Action Requested: None

NEW ANALYSIS WITH THE INTERCALIBRATION OF GEOSTATIONARY AND POLAR-ORBITING RADIANCES

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1. INTRODUCTION

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) has been intercalibrating geostationary satellites (GOES-8, -9, -10, -12 Imagers, METEOSAT-5, -7, GMS-5) with a polar-orbiting satellite (NOAA-14, -15, -16 HIRS and AVHRR) on a routine, automated basis using temporally and spatially co-located measurements in 11-µm infrared window (IRW) and 6.7-µm water vapor (WV) channels. GOES-12 replaced GOES-8 over the Western Atlantic on April 1, 2003. GOES-9 replaced GMS-5 over the Western Pacific on May 22, 2003. NOAA-14 was de-activated on October 7, 2002. This paper reports on GEO-LEO intercalibrations to date and investigates the effects of using different forecast models for calculating the clear sky radiances and including cloudy scenes in the comparisons.

The intercalibration approach used was described in prior CGMS proceedings; it is briefly summarized here. Collocation in space and time (within thirty minutes) is required. Data are selected within 10 degrees from nadir for each instrument in order to minimize viewing angle differences. Measured means of brightness temperatures of similar spectral channels from the two sensors are compared. Data from each satellite are averaged to an effective 100 km resolution to mitigate the effects of different field of view (fov) sizes and sampling densities; HIRS under-samples with a 17.4 km nadir fov, AVHRR GAC achieves 4 km resolution by under-sampling within the fov, GOES imager over-samples 4 km in the east west by 1.7 and METEOSAT and GMS have a nadir 5 km fov. Mean radiances are computed within the collocation area. Clear sky forward calculations (using a global model for estimation of the atmospheric state) are performed to account for differences in the spectral response functions. The observed radiance difference minus the forward-calculated clear sky radiance difference is then attributed to calibration differences. Thus,

$$\Delta R_{cal} = [R^{GEO}_{mean} - R^{GEO}_{clear}] - [R^{HIRS}_{mean} - R^{HIRS}_{clear}]$$

where *GEO* indicates geostationary, *HIRS* indicates the HIRS instrument, *mean* indicates the mean measured radiance, and *clear* indicates the forward calculated clear-sky radiances. Conversion to brightness temperatures is accomplished by,

$$\Delta T_{HIRS} = [B^{-1}{}^{GEO}_{mean} - B^{-1}{}^{GEO}_{clear}] - [B^{-1}{}^{HIRS}_{mean} - B^{-1}{}^{HIRS}_{clear}]$$

where B^{-1} indicates the inverse Planck Function. An identical approach yields GEO and AVHRR (ΔT_{AVHRR}) comparisons.

2. RESULTS

Intercalibration results for the seven geostationary satellites (between July 2002 and September 2003) compared with NOAA-15 and -16 are shown in Tables 1 and 2 (there are no WV comparisons between NOAA-15 and Meteosat-7 in Table 1 due to a scheduling conflict). The mean is the average of all cases for the indicated satellite and a negative sign indicates HIRS or AVHRR measurements, after correction for spectral response differences, are warmer than GEO measurements. The standard deviation is the deviation about the mean. In the past the IRW measurements were restricted to scenes with a mean radiance of 80mW/m^2/ster/cm^{-1} but this restriction has been removed for this year's analysis. It can be seen that the differences for the infrared window bands are smaller than between the various water vapor bands. Table 3 shows the difference between cases above and below this old radiance threshold. Table 4 shows the results for a short time period using different forecast model data in the fast forward model calculations; the usual NOGAPS model results are compared with AVN model results.

3. DISCUSSION

As in previous reports, the GEO and LEO instruments compare more favorably for IRW than WV. GEO-HIRS standard deviations are larger than those for GEO-AVHRR. The time sequence for GOES-10 versus NOAA-15 HIRS IRW reveals periods of high variability (Figure 1) while GOES-10 versus NOAA-15 AVHRR (Figure 2) does not. Problems with fluctuations in the HIRS filter wheel temperature may be responsible, but this has not yet been proven. Also the NOAA-16 AVHRR spectral response functions used in this work (Table 2 and Figure 4) have not been updated to the newly released version that are assumed to be more accurate.

Table 1 shows NOAA-15 IRW comparison results for GOES (and GMS) instruments are mostly within 0.5K and results for the Meteosats are also within 0.5K, but the two "families" differ by over 1K. These differences grow larger in the water vapor channel, where characterization of the spectral response function is less certain and spectral variability is greater. In past years the GEO-LEO IRW comparisons were closer using NOAA-14. Table 2 shows the NOAA-16 comparisons; differences have changed somewhat but the major conclusions are still the same.

Table 3 shows GOES and NOAA-15 comparisons of mean radiances greater than 80 mW/m^2/ster/cm^{-1} are generally closer than comparisons of mean radiances less than 80 mW/m^2/ster/cm^{-1}. The opposite is true with Meteosat and GMS. Warm versus cold temperature intercomparisons appear to differ somewhat. Table 4 shows preliminary results of NOGAPS versus AVN model clear sky radiance calculations; NOGAPS produces results closer to 0K than AVN. The mean is more sensitive to model type than the standard deviation, possibly indicating that there is a bias between the forecast models but otherwise they are fairly consistent. The model that most accurately predicts the atmospheric state should yield the most representative intercomparison.

Conversely, a single GEO instrument can be used as a reference for several LEO instruments. Tables 1 and 2 suggest that HIRS on NOAA-15 and –16 compare within 0.5 K with respect to GOES-10 in the IRW. The AVHRR's have larger differences, comparing within 1.5 K. However, if Meteosat-7 is used as the reference the AVHRR's compare within 0.1 K. Time series plots of Meteosat-7 compared to NOAA-15 (Figure 3) and NOAA-16 (Figure 4) AVHRR show the cumulative average (an average of all cases up to any given point) difference steadily decreases; there is also considerable scatter in Figure 4. In contrast, GOES-10 compared to NOAA-15 AVHRR in Figure 2 hardly varies from the mean during the entire time period.

4. CONCLUSIONS/FUTURE WORK

Using a polar orbiter as a reference, the operational geostationary satellites can effectively be compared in similar spectral bands. HIRS/3 problems with fluctuating filter wheel temperatures need to be accounted for and NOAA-16 AVHRR spectral response functions need to be updated to incorporate more accurate characterization. Using NOAA-15 and –16 as references, the GOES-GMS compare within 1K and the Meteosats compare within 1K; but the two groups compare only within 3K (these NOAA-15 and –16 results are not as favorable as those obtained with NOAA-14 when all GEOs compared within 1K in the IRW). WV comparisons are within 4K, possibly indicative of calibration problems in some of these instruments. Additional results can be found at http://cimss.ssec.wisc.edu/goes/intercal. GEO comparisons with well calibrated AIRS and MODIS are being started, as well as 13.3 micron LEO comparisons with GOES-12.

Table 1. July 2002 through September 2003 IRW (top) and WV (bottom) brightness temperature differences of GEOs versus NOAA-15 HIRS and AVHRR. No Meteosat-7 comparisons were made due to a scheduling conflict.

N-15 IRW (geo – leo)		GOES-8	GOES-10	MET-5	MET-7	GMS-5	GOES-12	GOES-9
N	ΔT_{HIRS}	79	273	278	239	81	36	50
	ΔT_{AVHRR}	79	273	278	239	81	36	50
Mean	ΔT_{HIRS}	0.3 K	-0.1 K	-1.7 K	-1.7 K	-0.2 K	1.0 K	0.1 K
	ΔT_{AVHRR}	0.5 K	-0.1 K	-1.9 K	-1.4 K	-0.3 K	0.1 K	0.1 K
Std Dev	ΔT_{HIRS}	1.9 K	2.9 K	2.2 K	1.8 K	1.7 K	1.6 K	1.9 K
	ΔT_{AVHRR}	0.5 K	0.6 K	1.1 K	0.9 K	0.8 K	0.7 K	1.1 K

N-15 WV (geo-leo)		GOES-8	GOES-10	MET-5	MET-7	GMS-5	GOES-12	GOES-9
N	ΔT_{HIRS}	89	260	263	-	91	50	49
Mean	ΔT_{HIRS}	0.4 K	1.8 K	3.3 K	-	0.0 K	1.0 K	0.1 K
Std Dev	ΔT_{HIRS}	1.0 K	1.7 K	1.7 K	-	2.2 K	1.5 K	1.5 K

Table 2. July 2002 through September 2003 IRW (top) and WV (bottom) brightness temperature differences of GEOs versus NOAA-16 HIRS and AVHRR.

N-16 IRW (geo – leo)	GOES-8	GOES-10	MET-5	MET-7	GMS-5	GOES-12	GOES-9

N	ΔT_{HIRS}	74	150	185	256	166	40	47
	ΔT_{AVHRR}	74	150	185	256	166	40	47
Mean	ΔT_{HIRS}	-0.4 K	0.3K	-1.5 K	-0.8 K	-0.1 K	0.2 K	0.6 K
	ΔT_{AVHRR}	0.0 K	-1.6 K	-3.0 K	-1.4 K	0.5 K	-0.6 K	0.3 K
Std Dev	ΔT_{HIRS}	1.3 K	2.0 K	2.1 K	2.9 K	2.7 K	1.2 K	2.3 K
	ΔT_{AVHRR}	0.8 K	0.6 K	1.7 K	1.7K	2.4 K	0.9 K	2.1 K

N-16 WV (geo-leo)		GOES-8	GOES-10	MET-5	MET-7	GMS-5	GOES-12	GOES-9
N	ΔT_{HIRS}	98	173	207	83	193	92	64
Mean	ΔT_{HIRS}	0.3 K	2.2 K	3.3 K	4.2 K	0.4 K	1.3 K	0.9 K
Std Dev	ΔT_{HIRS}	1.2 K	1.7 K	1.6 K	2.4 K	2.0 K	1.9 K	1.8 K

Table 3. July 2002 through September 2003 IRW GEO versus NOAA-15 HIRS and AVHRR brightness temperature differences for cases with mean scene radiance greater than 80 $mW/m^2/ster/cm^{-1}$ (top) and less than 80 $mW/m^2/ster/cm^{-1}$ (bottom).

N-15 IRW (geo – leo) mean Rad > 80		GOES-8	GOES-10	MET-5	MET-7	GMS-5	GOES-12	GOES-9
N	ΔT_{HIRS}	31	201	200	203	35	10	24
	ΔT_{AVHRR}	31	201	200	203	35	10	24
Mean	ΔT_{HIRS}	-0.3 K	-0.7 K	-2.2 K	-1.9 K	-0.8 K	0.1 K	-0.2 K
	ΔT_{AVHRR}	0.3 K	-0.3 K	-2.1 K	-1.5 K	-0.7 K	-0.1 K	-0.2 K
Std Dev	ΔT_{HIRS}	1.5 K	1.9 K	2.0 K	1.5 K	1.3 K	1.1 K	1.2 K
	ΔT_{AVHRR}	0.5 K	0.4 K	1.1 K	0.8 K	0.7 K	0.3 K	0.3 K

N-15 IRW (geo – leo) mean Rad < 80		GOES-8	GOES-10	MET-5	MET-7	GMS-5	GOES-12	GOES-9
N	ΔT_{HIRS}	48	72	78	36	46	26	26
	ΔT_{AVHRR}	48	72	78	36	46	26	26
Mean	ΔT_{HIRS}	0.7 K	1.6 K	-0.5 K	-0.5 K	0.2 K	1.4 K	0.5 K
	ΔT_{AVHRR}	0.6 K	0.7 K	-1.4 K	-1.1 K	0.1 K	0.2 K	0.3 K
Std Dev	ΔT_{HIRS}	2.0 K	4.2 K	2.2 K	2.7 K	1.7 K	1.6 K	2.3 K
	ΔT_{AVHRR}	0.5 K	0.7 K	1.0 K	1.0 K	0.8 K	0.8 K	1.5 K

Table 4. June 2003 through September 2003 IRW brightness temperature comparisons of GEOs versus NOAA-15 HIRS and AVHRR using the NOGAPS forecast model (top) and the AVN forecast model (bottom) for calculation of the clear sky radiances.

N-15 IRW (geo – leo) NOGAPS	GOES-10	MET-5	MET-7	GOES-12	GOES-9

N	ΔT_{HIRS}	64	68	49	22	35
	ΔT_{AVHRR}	64	68	49	22	35
Mean	ΔT_{HIRS}	-0.3 K	-1.0 K	-1.6 K	1.2 K	0.2 K
	ΔT_{AVHRR}	-0.2 K	-1.7 K	-1.5 K	0.2 K	0.1 K
Std Dev	ΔT_{HIRS}	1.8 K	1.9 K	1.0 K	1.5 K	1.7 K
	ΔT_{AVHRR}	0.5 K	1.0 K	0.4 K	0.9 K	0.5 K

N-15 IRW (geo – leo) AVN		**GOES-10**	**MET-5**	**MET-7**	**GOES-12**	**GOES-9**
N	ΔT_{HIRS}	64	68	49	22	35
	ΔT_{AVHRR}	64	68	49	22	35
Mean	ΔT_{HIRS}	0.3 K	-1.1 K	-2.0 K	1.4 K	0.6 K
	ΔT_{AVHRR}	-0.0 K	-2.2 K	-2.2 K	0.3 K	0.2 K
Std Dev	ΔT_{HIRS}	1.7 K	1.9 K	1.0 K	1.6 K	1.7 K
	ΔT_{AVHRR}	0.5 K	1.0 K	0.5 K	0.9 K	0.5 K

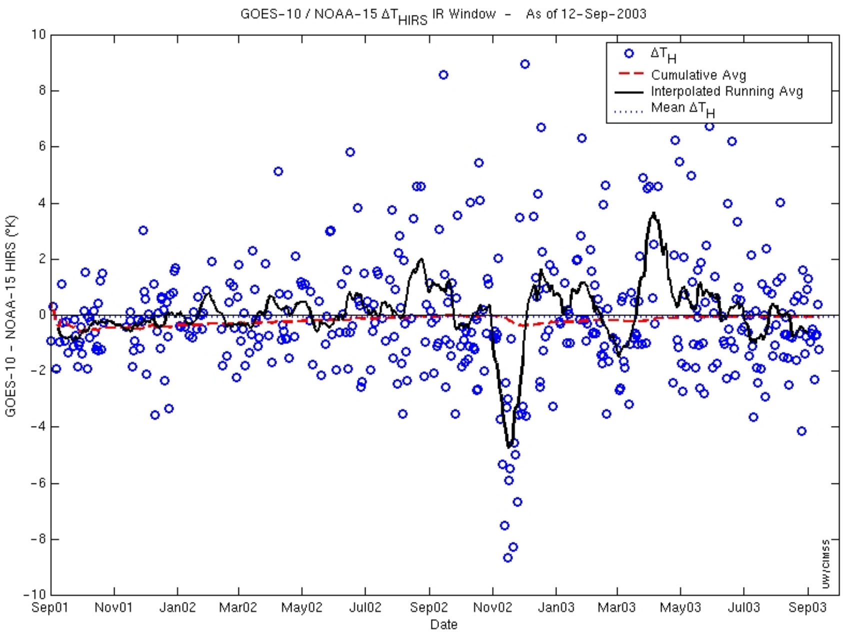

Figure 1. IRW brightness temperature differences GOES-10 versus NOAA-15 HIRS (ΔT_{HIRS}) from September 2001 through September 2003. The larger peaks are also seen in similar time series for other GEOs. The running average (solid line) is interpolated over 20 cases. The cumulative average (dashed line) is the average of all cases up to that point. The mean (dotted line) is the mean for the entire time period.

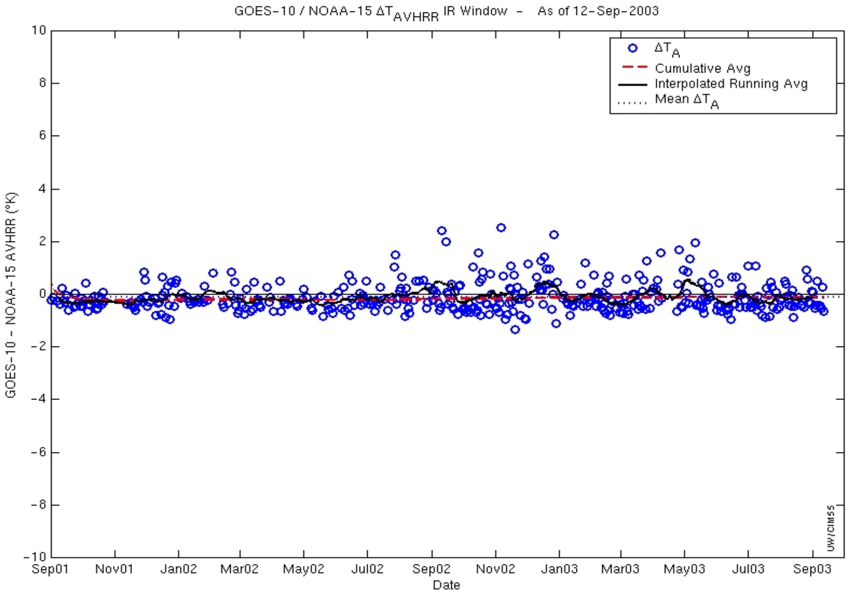

Figure 2. IRW brightness temperature difference for GOES-10 versus NOAA-15 AVHRR (ΔT_{AVHRR}) from September 2001 through September 2003.

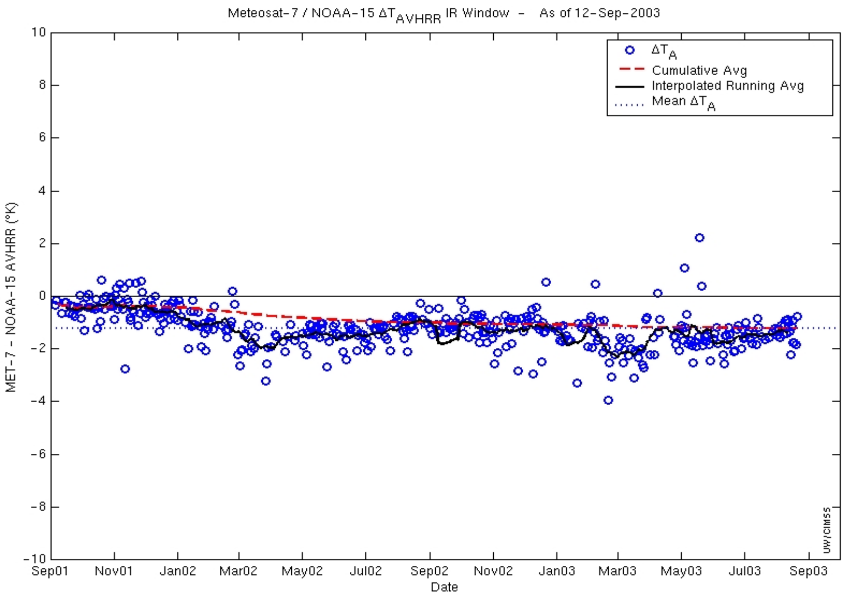

Figure 3. IRW brightness temperature difference for Meteosat-7 versus NOAA-15 AVHRR (ΔT_{AVHRR}) from September 2001 through September 2003.

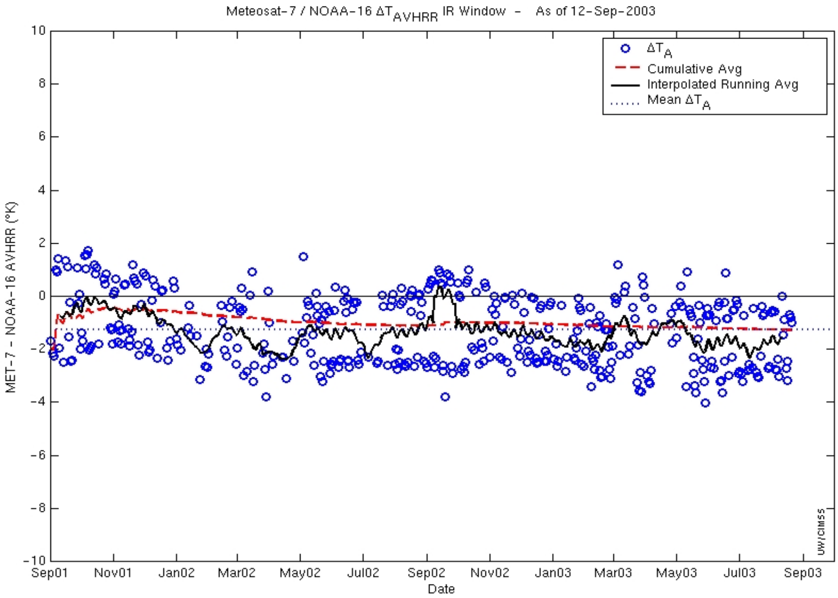

Figure 4. Brightness temperature difference for Meteosat-7 versus NOAA-16 AVHRR (ΔT_{AVHRR}) from September 2001 through September 2003.