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INTERCALIBRATION OF GEOSTATIONARY (GOES, METEOSAT, GMS) AND POLAR ORBITING (HIRS AND AVHRR) INFRARED WINDOW RADIANCES

An overview of procedures and results for intercalibrating the geostationary infrared window radiances using one polar orbiting sensor as a reference.

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INTRODUCTION

Intercalibration of the polar orbiting and geostationary satellite systems is necessary to achieve consistency of data sets involving more than one sensor. The community of satellite operators is exploring viable approaches for intercalibration of their operational sensors that would minimize the calibration uncertainty and maximize calibration uniformity. This paper presents recent work at the NESDIS Cooperative Institute for Meteorological Satellite Studies (CIMSS) for calibrating the geostationary satellites with a single polar orbiting satellite using temporally and spatially collocated measurements in the infrared window channels. Currently NOAA-14 HIRS and AVHRR are being compared to GOES-8, GOES-10, METEOSAT-5, METEOSAT-7, and GMS-5.

APPROACH

As indicated in previous CGMS papers, collocation in space and time (within thirty minutes) is required. Data is 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 collection is restricted to mostly clear scenes with mean radiances greater than 80 $mW/m^2/ster/cm^{-1}$, no effort is made to screen out clouds from the study area. Data from each satellite is averaged to 100 km resolution to mitigate the effects of different field of view (fov) sizes and sampling densities (HIRS undersamples with a 17.4 km nadir fov, AVHRR GAC achieves 4 km resolution by undersampling within the fov, GOES imager oversamples 4 km in the east west by 1.7, and METEOSAT-5, METEOSAT-7, and GMS-5 have a nadir 5 km fov). Mean radiances are computed within the study 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

$$\Delta R_{cal} = \Delta R_{mean} - \Delta R_{calc}$$

or for a comparison of a geostationary satellite to HIRS

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

where GEO indicates geostationary, HIRS indicates the HIRS instrument, mean indicates the mean measured radiance, and calc indicates the forward calculated clear sky radiance. Conversion to temperatures for a comparison between a geostationary satellite to HIRS is accomplished by

$$\Delta T_H = \left[\frac{R^{GEO}_{mean}}{dB/dT^{GEO}_{mean}} - \frac{R^{GEO}_{calc}}{dB/dT^{GEO}_{calc}}\right] - \left[\frac{R^{HIRS}_{mean}}{dB/dT^{HIRS}_{mean}} - \frac{R^{HIRS}_{calc}}{dB/dT^{HIRS}_{calc}}\right]$$

An identical method is used for calculating the temperature difference between a geostationary satellite and the AVHRR instrument (ΔT_A).

RESULTS

Table 1 shows the results for all five geostationary satellites. In all cases the temperature difference between geostationary and NOAA-14 instruments is within 0.5K. The absolute mean indicates the mean of the absolute value of all the differences; this is an absolute magnitude of how far from a difference of 0K each satellite is. The mean indicates the normal mean of all cases and a negative sign indicates HIRS or AVHRR is measuring higher radiances on average than the geostationary instrument. In nearly all cases the geostationary instruments measure lower radiances, or colder temperatures, than the polar orbiting instruments. This data covers February through July of 1999 and does not show a seasonal trend or any trends based on time of day.

Table 1. Feb to Jul 1999 IR window comparison of geostationary satellites and NOAA-14 HIRS/AVHRR.

Delta (geo – leo)		GOES-8	GOES-10	MET-5	MET-7	GMS-5
Number of Comparisons	ΔT_H	9	36	9	18	6
	ΔT_A	8	36	9	18	6
Absolute Mean	ΔT_H	0.31 K	0.23 K	0.28 K	0.40 K	0.40 K
	ΔT_A	0.34 K	0.16 K	0.27 K	0.39 K	0.37 K
Mean	ΔT_H	-0.06 K	-0.13 K	-0.24 K	-0.40 K	0.05 K
	ΔT_A	0.08 K	-0.12 K	-0.27 K	-0.37 K	-0.15 K
Standard Deviation	ΔT_H	0.36 K	0.23 K	0.26 K	0.19 K	0.59 K
	ΔT_A	0.49 K	0.14 K	0.25 K	0.21 K	0.42 K

Figure 1 shows a comparison of GOES-10 and HIRS mean brightness temperatures. The two are highly correlated and compare well over a wide range of temperatures. Figure 2 shows a comparison of GOES-10 mean radiance values to the corresponding temperature difference between GOES-10 and HIRS (ΔT_H). There is a strong inverse correlation between ΔT_H and GOES mean radiance. The inverse correlation persists in the absence of a spectral response correction (not shown). There is a similar relationship between ΔT_A and GOES mean radiance (not shown). METEOSAT-7 does not exhibit this behavior. The number of comparisons is too small for the other sensors to infer any correlations. Onboard calibration differences in the sensors are being explored; inaccurate estimation of responsivity in one or both sensors could produce such comparisons.

AUTOMATION

Routine intercalibration is needed. Ample comparisons must be achieved to assist in trend analyses. However comparisons are not easily achieved. Table 2 shows the percentage of comparisons successfully completed for each geostationary instrument. Cloudy indicates the percentage when the comparison was not attempted because the scene was too cloudy. Failure indicates the percentage when comparison failed due to missing sensor data, missing model data, or other causes. Successful comparisons occur less than 50% of the time, except for GOES-10 where over 60% of the comparison attempts succeeded (there was no cloud interference during this period). It is not likely that this approach to intercalibration can be easily accomplished with aperiodic efforts; some level of automation appears to be desireable but difficult to achieve. In the near term, manual intercomparisons will be continued.

Table 2. Efficency of data comparisons.

Geostationary Satellite	Success (%)	Cloudy (%)	Failure (%)
GOES-8	29	29	42
GOES-10	62	0	38
MET-5	24	40	36
MET-7	49	13	38
GMS-5	16	42	42

CONCLUSIONS

This paper describes and analyzes one approach for calibrating all geostationary sensors with respect to a single polar orbiting sensor. Radiances from two sensors near nadir view containing mostly clear sky are averaged to 100 km resolution. Differences in mean scene radiances are corrected for spectral response differences through a clear sky forward calculation. The corrected mean differences are attributed to calibration differences. These results, based on between 6 and 36 cases per satellite, suggest the infrared window sensors on GOES-8, GOES-10, MET-5, MET-7, and GMS-5 are within 0.5 C of each other (and within 0.4 C of the NOAA-14 HIRS and AVHRR). Further studies are ongoing to explore seasonal or diurnal effects.

This intercalibration approach works well, but currently requires a considerable time commitment from one individual. Computer automation will be investigated, but it is likely that some human interaction will still be required for quality control of the intercomparison data sets.

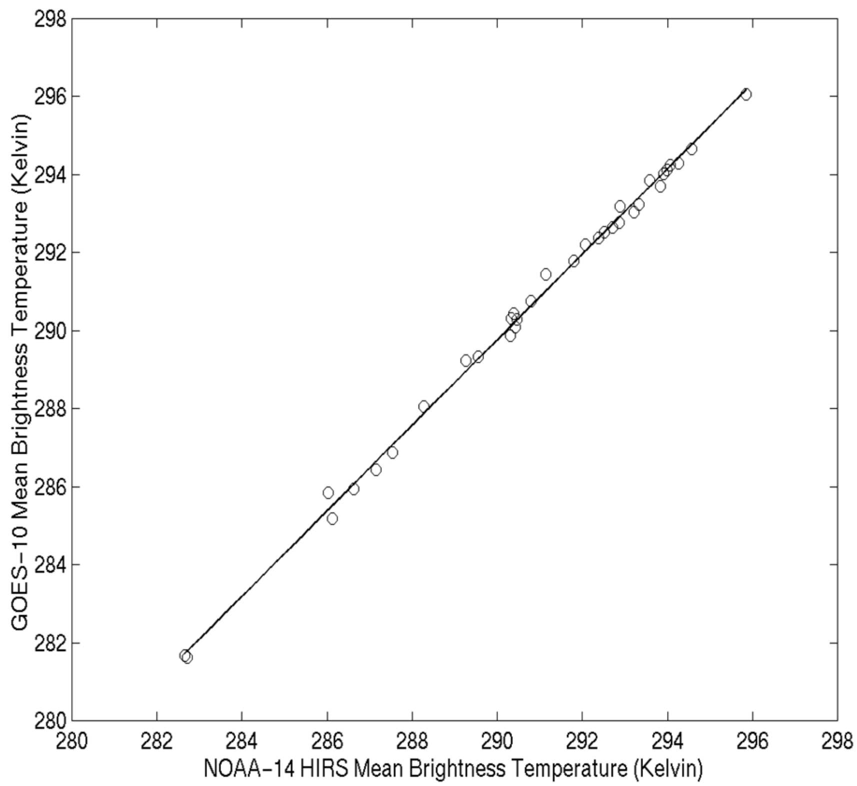

Figure 1. GOES-10 Brightness Temperature vs NOAA-14 HIRS Brightness

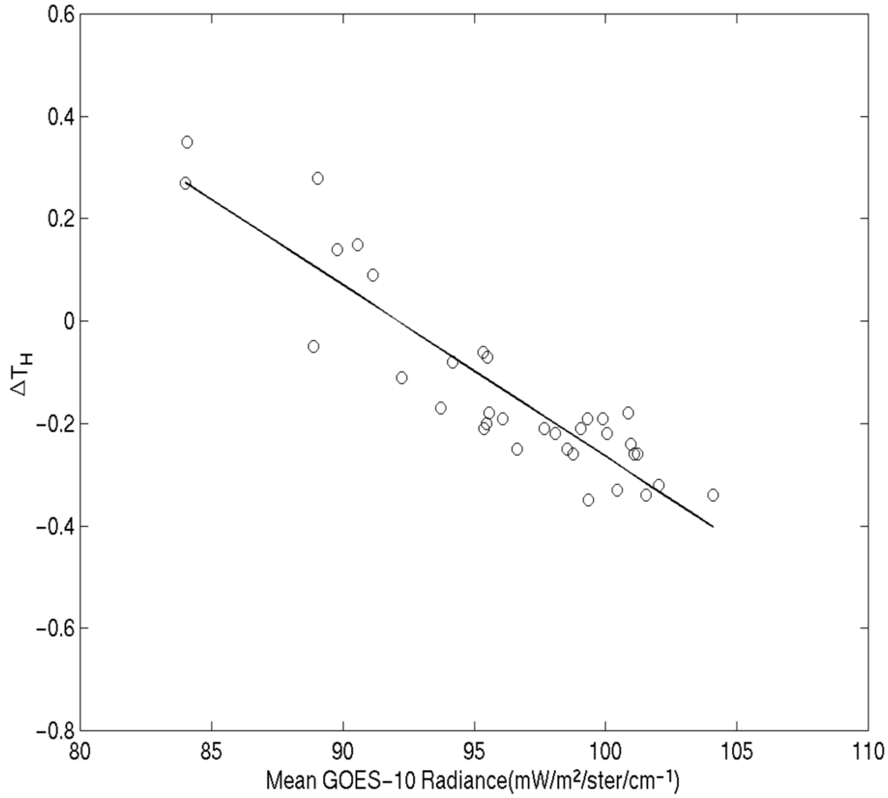

Figure 2. GOES-10 Mean Radiance vs ΔT_H