COMPARISONS OF MTSAT-1R INFRARED CHANNEL MEASUREMENTS WITH MODIS/TERRA

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KEY WORDS: MTSAT-1R, MODIS, Terra, intercalibration

ABSTRACT:

Infrared channels of newly launched Japanese geostationary satellite, MTSAT-1R are compared with well calibrated MODIS/Terra infrared measurements at 3.7, 6.7, 11, 12 μm bands. There are four steps in this intercalibration method: 1) data collection, 2) spectral response function correction, 3) data collocation, and 4) calculation of mean bias and conversion coefficients. In order to minimize the navigation error of MTSAT-1R, comparisons are made over the area in which the viewing angle of MTSAT-1R is less than 50°. The calibration method was tested for August 2005 and within the 40°N-40°S, 100°E-180°E domain. The differences of spectral response functions were corrected through radiative transfer model simulation. Constructing collocated data differences in viewing geometry, observation time and space were taken into account. In order to avoid the radiance variation induced by cloud presence, clear-sky targets are selected as intercalibration target. The mean biases of 11, 12, 6.7, and 3.7 μm bands are about -0.16, 0.36, 1.31, and -6.69 K, suggesting that accuracies of 3.7 μm is questionable while other channels are comparable to MODIS

1. INTRODUCTION

To product many quantitative scientific products using satellite measurements, it is imperative that correct calibration should be applied for quantitative satellite measurements. Newly launched Japanese satellite MTSAT-1R (the Multi-functional Transport Satellite-1 Replacement) observes northeast Asia region and it is essential to the weather forecasting in this region. This study uses an intercalibration method, which may provide a monitoring method for the operational calibration and bias correction for global data from different satellites, i.e.: MTSAT-1R IR brightness temperatures are compared with converted values for 3.7, 6.7, 10, 11 μm bands from well-calibrated MODIS (the Moderate Resolution Imaging Spectroradiometer) /Terra measurements.

2. METHOD

There are four steps in this intercalibration method: 1) data collection, 2) spectral response function correction, 3) data collocation, and 4) calculation of mean bias and conversion coefficients.

2.1 Data Collection

The calibration method is tested for August 2005 and within the 40°N-40°S, 100°E-180°E domain. In order to minimize the navigation error of MTSAT-1R, comparisons are made over the area in which the viewing angle of MTSAT-1R is less than 50°.

MTSAT-1R has one visible channel and four IR channels while MODIS has 35 channels. For this study, MTSAT-1R 0.2° gridded count values and brightness temperatures for 11 and 12 μm split window channels (WIN1 and WIN2), 6.7 μm water vapor channel (WV), and 3.7 μm short wave IR channel (SWIR) data and corresponding MODIS 20, 27, 31, 32 channels data are collected. In addition, MODIS geolocation product and cloud mask data are collected for data collocation and selection target.

TIGR 2000 data are used as initial atmospheric profile data for radiative transfer model (RTM) simulation from which relationships between MTSAT-1R and MODIS response functions. TIGR 2000 data set, which was used as RTM input data, is a climatological library of 2311 atmosphere profiles. Each atmosphere is described by its temperature, water vapor and ozone profile. RTTOV model, which allows rapid simulations of radiances for satellite infrared or microwave nadir scanning radiometers given an atmospheric profile of temperature, variable gas concentrations, cloud and surface properties, referred to as the status vector (Saunders, 2002) is used for the radiative transfer calculation.

2.2 Spectral response function correction

Since differences in spectral response functions lead to differences in the measured radiance, spectral response function correction is needed. The transfer function converts MODIS brightness temperature to corresponding MTSAT-1R brightness temperature, but through the RTM simulations with a large number of atmosphere profiles (König et al., 1999).

At least for split window channels, the linear relationship between radiances of similar satellite channels was described by Tjemkes et al. (1997). The model results suggest that the relationship of MODIS brightness temperature and MODIS equivalent MTSAT-1R brightness temperature is described as a linear function for all MTSAT-1R IR channels. Consequently, the transfer function has linear form:

$$TB_{MTSAT} = a + b \times TB_{MODIS} \qquad (1)$$

where a and b are coefficients calculated from RTTOV simulations. Figure 1 shows a relationship for the window channel.

Since viewing geometry and surface type also affect radiance, RTM simulations are made for every 5° viewing angles and surface type is divided as land and ocean. The slope and the y-intercept of linear function vary with viewing angle difference and surface types. The variation of y-intercept relates to viewing angle is greater than variation of slope. The viewing angle difference has a maximum effect on WV channel (0.57 K), because of the WV channel is sensitive to the upper tropospheric humidity field between about 200-600 hPa. The effect of surface type difference is smaller than the effect of viewing angle difference.

This transfer function is inapplicable to cloud due to the coefficients are simulated in clear condition. Therefore cloud simulation is required to use cloud target for intercalibration. In this study cloud pixels were excluded and cloud simulation was omitted.

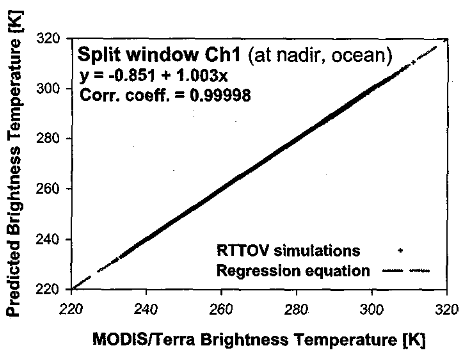

Figure 1. Scatterplots of RTM simulations for WIN1, over ocean at nadir.

2.3 Collocated data construction

Data collocation requires the consideration of differences of field-of-view (FOV) resolution, viewing angle, and observing time between MTSAT-1R and MODIS.

First of all, MODIS brightness temperature pixels of 0.2° resolution grid are averaged for overcoming FOV resolution differences. The maximum viewing angle difference of MTSAT-1R and MODIS is limited to 5° in order to minimize the effect of atmosphere difference. Gunshor et al. (2004) tested how fast-forward model calculated brightness temperature for the infrared window and water vapor regions vary with satellite viewing angle. The brightness temperature difference by viewing angle is less than 0.5 K when the viewing angle and the viewing angle difference are limited 50° and 5°, respectively.

Since surface and atmospheric conditions change with the satellite movement, measured radiances of two satellites are not comparable unless observation time difference is negligibly small. Therefore, MTSAT-1R data are collocated with MODIS data if the observation time difference is less than 5 minutes.

SWIR channel is also influenced by solar radiation. To remove the effect of solar radiation, collocation data are made only during the nighttime.

Also removed are cloud-contaminated targets because different viewing angle and resolution give difference can result in difference bi-directional reflectances which give rise to different radiances at the TOA. For the cloud MODIS cloud mask data are used.

2.4 Calculation of mean bias and conversion coefficients

MTSAT-1R provides scaled radiances (C) which are related linearly to the radiances L.

$$L = \alpha(C - C_0) \qquad (2)$$

where α is conversion coefficient and C_0 is offset count. To obtain the mean bias and present a new conversion coefficient, following equations are used.

$$TB'_{MTSAT} = a + b \times TB_{MODIS} \qquad (3)$$

$$L' = \frac{\int B_\lambda (TB'_{MTSAT}) \times \Phi \, d\lambda}{\int \Phi \, d\lambda} \qquad (4)$$

$$\alpha_{NEW} = \frac{L'}{C - C_0} \qquad (5)$$

TB'_{MTSAT} and Φ in equation (4) are MODIS equivalent MTSAT-1R brightness temperature and spectral response function of MTSAT-1R. The radiance obtained from (4) and corresponding MTSAT-1R count C are regressed to obtain new conversion coefficient α_{NEW}.

3. RESULT

Figure 2 compares MTSAT-1R measurements from four channels with comparable MODIS measurements. It shows that the current calibration of MTSAT-1R spilt window and WV channels are generally in good agreement with MODIS. On the other hand, there is not only a large minus bias but also a nonlinear relationship between SWIR MTSAT-1R measurements and MODIS equivalent MTSAT-1R brightness temperature.

Table 1 summarizes obtained calibration results. It shows that the mean bias and RMSE of SWIR channel are much lager than other channels. Theses results indicate that data quality of SWIR channel is questionable.

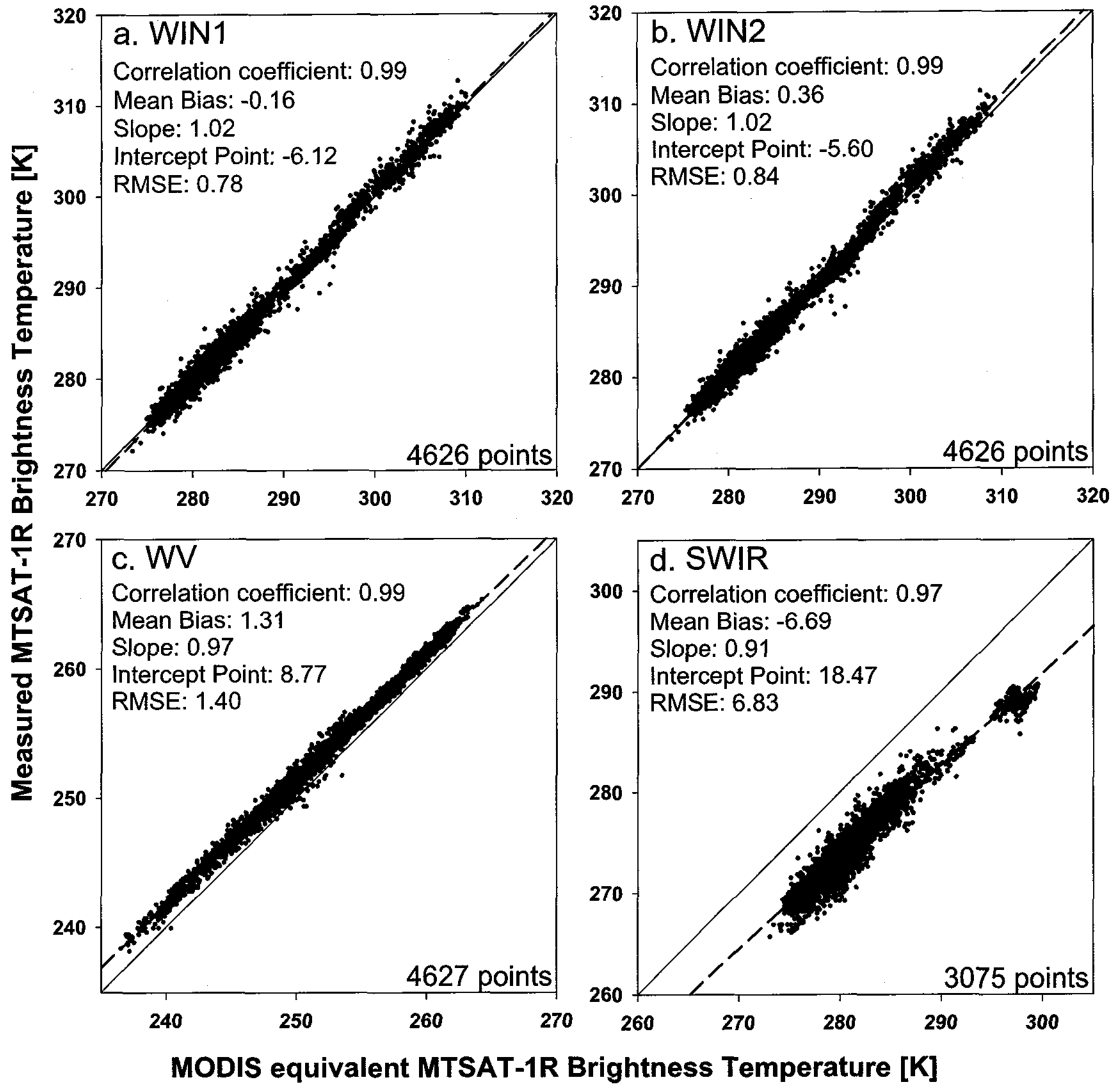

Figure 3. Scatterplots of measured MTSAT-1R and MODIS equivalent MTSAT-1R brightness temperatures for (a) WIN 1, (b) WIN 2, (3) WV, and (4) SWIR channel.

Table 1. Comparison of statistics of MTSAT-1R infrared channel brightness temperature vs. MTSAT-1R equivalent MODIS brightness temperatures (August 2005)

	WIN1	WIN2	WV	SWIR
Correlation Coefficient	0.99	0.99	0.99	0.97
Mean Bias (K)	-0.16	0.36	1.31	-6.69
Slope	1.02	1.02	0.97	0.91
Intercept Point (K)	-6.12	-5.60	8.76	18.47
RMSE (K)	0.78	0.84	1.40	6.83

Figure 3 illustrates time series of new conversion coefficient (solid line) and offered conversion coefficient (dashed line). Since daytime data of SWIR channel is excluded, new conversion coefficient is calculated at every 6 days for SWIR while 3 days for other three channels. The agreements of MTSAT-1R two split window channels are within 5% and WV channel is within 7% for the conversion coefficients. However the maximum error of the conversion coefficient of SWIR channel is about 50%.

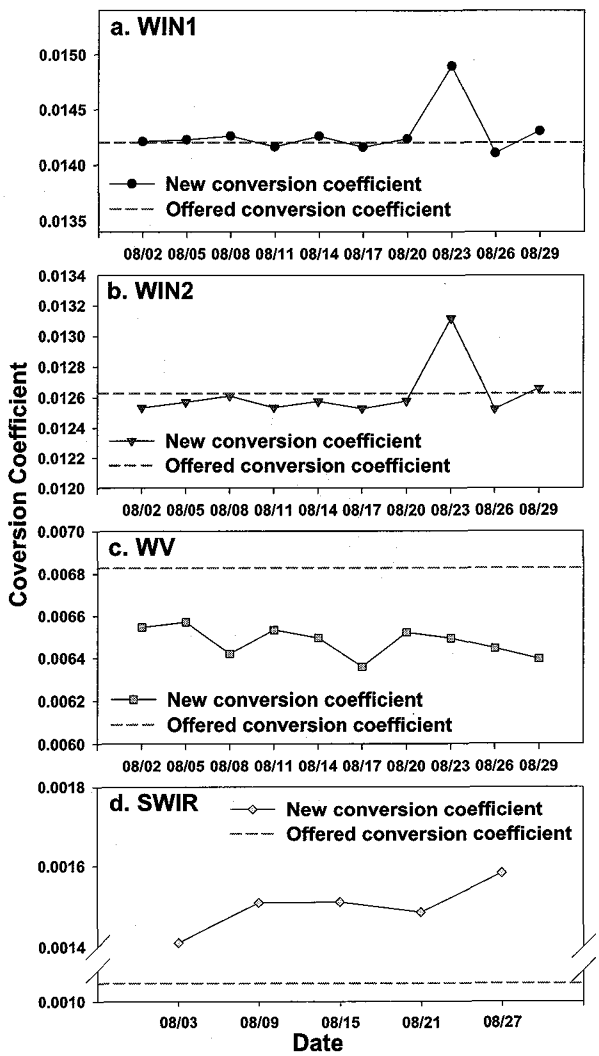

Figure 3. Time series of conversion coefficient for (a) WIN 1, (b) WIN 2, (3) WV, and (4) SWIR channel

4. CONCLUSIONS

Intercomparison indicated that mean biases of two split window and WV channels are about -0.16 K, 0.36 K and 1.31 K, suggesting that accuracies of those three channel measurements are comparable to MODIS measurements. It was suggested that the accuracies of split window channels are better than water vapor channel and the mean bias of water vapor channel about 1 K is consistent with recent result (Gunshor, M. M. et al., 2006). On the other hand, the mean bias of SWIR channel shows a much larger difference of up to -6.69 K and RMSE is 5-8 times larger than other channels, indicating that data quality of SWIR channel is much questionable. Furthermore, the relationship between SWIR channel brightness temperature of MTSAT-1R and of MODIS appears to be non-linear for the SWIR channel.

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ACKNOWLEDGEMENTS

This research has been supported by the Korean Geostationary Program (COMS) granted by the KMA, and by the BK21 Project of the Korean Government.