ROUTINE BASIS INTERCALIBRATION BETWEEN GMS-5 AND NOAA-16

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Abstract

This paper describes an intercalibration of geostationary and polar-orbiting Infrared window radiances. The method is especially described in detail.

Meteorological Satellite Center (MSC)/Japan Meteorological Agency (JMA) developed an operational intercalibration in September 2002. The intercalibration is restricted to the comparisons of Visible and Infrared Spin Scan Radiometer (VISSR) infrared 1 (11 microns) and the infrared 2 (12 microns) channels of GMS-5 with Advanced Very High Resolution Radiometer (AVHRR) infrared 4 and infrared 5 channels of NOAA-16. Eleven months investigation show that the equivalent black body temperature (TBB) of VISSR IR channels 1 and 2 is about 0.5 K to 2 K lower than that with AVHRR channels 4 and 5 on NOAA-16 with some fluctuation. MSC/JMA is planning to continue the intercalibration and to post it on Web page.

1. INTRODUCTION

Intercalibration generally means a comparison of the characteristics of each sensor on board polar orbiting and geostationary satellite systems. In this paper we define this word as a comparison of TBB, which is gained from collocated clear radiance pixels. For monitoring purposes and making globally normalized data sets, operational intercalibration is necessary. Intercalibration of the polar orbiting and geostationary satellite systems offers an opportunity for comparison of the infrared calibrations of all the geostationary sensors.

Ideally, the TBB difference between geostationary satellites and polar orbiting would be constant sequentially if the calculations were performed under identical viewing conditions and at exactly the same time. So performing intercalibration on a routine basis is useful in describing the instruments' performance. It will be a monitoring tool for identifying problems in the operational calibration. The Coordination Group for Meteorological Satellites (CGMS) recommends to the Satellite operators to post on the CGMS homepage the relevant available papers on satellite radiance inter-comparisons and to start routine inter-comparisons of polar orbiting and geostationary and to strive to post the results on their own web pages.

Gunshor et al. [(7)] reported the National Environmental Satellite Data and Information Service (NESDIS) Cooperative Institute for Meteorological Satellite Studies (CIMSS) has been intercalibrating automatically the five geostationary satellites with a single polar orbiting satellite (NOAA-14) using temporally

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and spatially co-located measurements, and the results have been reported on the web with daily updates (http://cimss.ssec.wisc.edu/goes/intercal). European Meteorological Satellite Organization (EUMETSAT) reported that there are biases (Meteosat-HIRS) of about -1 to -2 K as a main result of comparison of IR-window channels of Meteosata-7 and Meteosat-5 with channels 8 of the High Resolution Infrared Sounder (HIRS) instrument on NOAA-14 in the working paper [8].

In the case of Japan, the review of the past activities on this study is shown in the working paper [2],[3],[4],[5] presented at the CGMS meeting. And the past detailed investigation Paper[3] about the intercalibration in the infrared window reported that the TBB of VISSR IR channels 1 and 2 is about 1 K lower than that with AVHRR channels 4 and 5 on NOAA-14. This investigation was done with the aid of NOAA/NESDIS for providing AVHRR's data offline. MSC has begun to get the Global Area Coverage AVHRR's data (GAC) of every observation on June 2002 via Internet. This made it possible to proceed with the intercalibration on a routine basis.

2. DEFINITION OF THE VALUE OF INTERCALIBRATION

Basically MSC uses the intercalibration method in the working paper [1], USA-WP-15, presented at the CGMS-XXV meeting and in the Paper [3] authored by Tokuno and Kurihara. For the sake of completeness of understanding of the meaning and purpose of intercalibration, it is important to explain repeatedly here the definition of the value and meaning of the value of the intercalibration. The purpose of the intercalibration is to discuss about the difference of each sensor onboard GMS-5 and NOAA-16, and to compare the differences of each sensor. At first, it is necessary to compare the TBB that each Satellite observes. Because each sensor has its own spectral response function, it is also necessary to compare the theoretical TBB difference. So the observed TBB minus the theoretical TBB difference is attributed to calibration differences and is the final value of intercalibration.

Thus

$$\triangle TBB = \triangle TBBmean - \triangle TBBcalc \qquad (2\text{-}1)$$

Where △ TBB indicates the value of our purpose, △ TBBmean indicates the mean measured TBB difference in a target area, and △ TBBcalc indicates the theoretical TBB difference.

In short, the value of intercalibration is a value for which we can't explain now the reason why the difference occurs, and a value for which we should investigate the reason in order to improve the operational calibration.

3. INTERCALIBRATION METHOD

In the present method, the target region is regarded as a clear region and as a scene from the same (nadir) viewing angle. When we proceed with the intercalibration, ideally, the target areas would be identical under identical viewing conditions, and would be in exactly the same time. In practice, each measurement will be performed under different conditions. The satellites do not normally see a given calibration target at exactly the same time. A larger time difference implies changing atmospheric conditions, especially concerning the presence of clouds.

To compare the target under as nearly identical conditions as possible, the present method accounts for the conditions as follows. Figure 2 is a sample figure made after receiving information on conditions as shown below. It may be useful for the sake of understanding the meaning of the conditions as shown below.

Space and Time Conditions

The mean VISSR radiance over the target area is taken (using the operational calibration of these instruments). The target area size is about 2000 km x 2000 km. The center of the target area is 0.0 latitude 140.0 E longitude. The target areas chosen are consistent with those of the request in date and time and area from the International Satellite Cloud Climatology Project/Satellite Calibration Center (ISCCP/SCC) to JMA, one of the purposes of which is periodically calculating intersatellite normalization parameters. The target area is divided into sub-grid areas (1 degree by 1 degree), because the satellites do not have the same spatial resolution. For this study, the AVHRR GAC data were used, since the GAC spatial resolution (4 Km x 3 Km) is close to that of the GMS IR data (5 Km x 5 Km). However, the instantaneous field of view (IFOV) of the AVHRR is about 1 Km x 1 Km, and the individual GAC sample size is about 4 Km x 1 Km. When we perform the intercalibration, ideally, we have to take into consideration the difference of the spatial resolution size which each satellite's imager has. But in the present method, the final value (△ TBB) includes the effect. The time difference between the geostationary and the polar orbital satellite is restricted to less than 15 minutes to avoid the effect of the presence of clouds.

Viewing Geometry conditions

Only those sub-grid areas are retained which are seen within a viewing angle (angle from sub-satellite point) of less than 30° and with a difference of viewing angles between the two satellites within +/- 10°. Figure 1 shows the brightness temperature calculated at one-degree intervals from zero degree of the satellite-viewing angle to eighty degrees by LOWTRAN 7 radiative transfer model. The calculated brightness temperature typically decreases as the satellite viewing angle increases. This tendency is vivid when the viewing angle is more than 30 degrees. So if the viewing angle is less than 30 degrees, we can regard the transmittance as close to zero, and we don't have to take account of the variation (i.e., atmospheric effects due to the differences of observational path) of radiance.

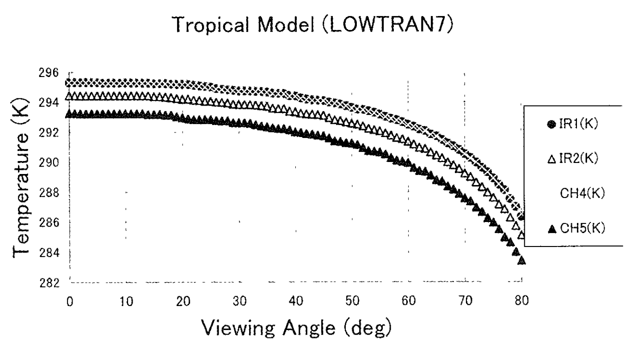

Fig. 1 Brightness temperature theoretically measured by GMS-5 and NOAA-16 for a tropical standard atmosphere (a value of sea surface temperature is 300 K) as a function of satellite viewing angle.

Removing cloud conditions

Data collection should be restricted to mostly clear scenes. After an investigation of sea surface temperature near the equator, we believe it adequate to use 293 K to 303 K for the value of TBB as a threshold when we perform the intercalibration. In the present method only those sub-grid areas are adopted where the mean TBB is greater than 293 K to get a clear area.

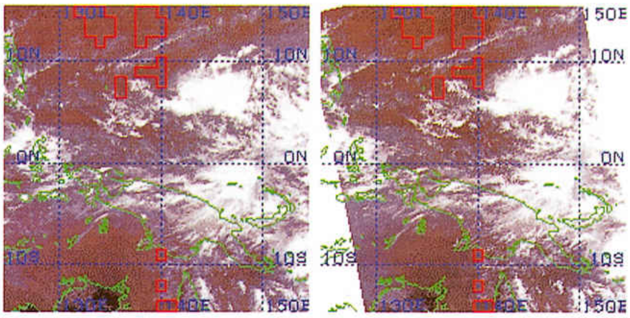

Fig. 2 A sample figure after passing information about space and time conditions and viewing geometry conditions, and removing cloud conditions. The left hand figure is from GMS-5, and the right hand is NOAA-16. Boxed areas show target areas.

4. METHOD OF CALCULATING △ TBBcalc

For estimating the △ TBBcalc, it is necessary to investigate the theoretical brightness temperature for each imager by using a certain reliable radiance scheme.

To calculate the theoretical brightness temperature, we took advantage of the KLM User's Guide (http://perigee.ncdc.noaa.gov/docs/klm/html/d/app-d2.htm) to investigate the response function of the NOAA-16 imager. Table 1 shows GMS-5 infrared channels 1 and 2 and NOAA-16 AVHRR channels 4 and 5 brightness temperatures estimated by LOWTRAN 7 for a tropical standard atmosphere which is made by reassigning a constant relative humidity value from zero km altitude to 19 Km altitude (sea surface temperature is 300 K). The value of channel 4 minus channel 5 means that of the related relative humidity. So we can estimate the relationship of the theoretical TBB difference between IR1 and CH4 (or IR2 and CH5) corresponding to the relative humidity from Table 1. In the present method △ TBBcalc is calculated by using the approximation formula as follows.

In case of the theoretical TBB difference between IR1 and CH4

$$\triangle \text{TBBcalc}=0.0017x^3+0.0111x^2+0.0407x-0.1521 \quad (4\text{-}1)$$

In the case of the theoretical TBB difference between IR2 and CH5

$$\triangle \text{TBBcalc}=0.0098x^3-0.0944x^2+0.6345x+0.2461 \quad (4\text{-}2)$$

Where x indicates the mean measured difference of brightness temperature between NOAA-16 AVHRR channels 4 and 5. Figure 3 shows the reasonableness of the approximation formula.

RH (%)	IR1 (K)	CH4 (K)	BTD (IR1-CH4)	IR2 (K)	CH5 (K)	BTD (IR2-CH5)	BTD (IR1-IR2)	BTD (CH4-CH5)
0	299.31	299.47	-0.16	299.64	299.33	0.31	-0.33	0.14
10	298.70	298.80	-0.11	298.81	298.22	0.59	-0.12	0.59
20	298.10	298.21	-0.11	298.19	297.49	0.70	-0.09	0.72
30	297.71	297.81	-0.10	297.37	296.45	0.92	0.34	1.36
40	296.94	296.98	-0.04	296.34	295.25	1.09	0.59	1.73
50	296.04	296.05	-0.01	295.28	294.04	1.24	0.76	2.01
60	295.23	295.18	0.05	294.17	292.83	1.34	1.06	2.35
70	294.26	294.19	0.07	292.91	291.39	1.51	1.36	2.80
80	293.23	293.11	0.12	291.68	290.09	1.58	1.55	3.02
90	292.18	292.02	0.17	290.44	288.80	1.63	1.75	3.21
100	291.15	290.96	0.19	289.21	287.51	1.71	1.93	3.46

Table 1 GMS-5 infrared channels 1 and 2 and NOAA-16 AVHRR channels 4 and 5 brightness temperatures are estimated with LOWTRAN 7.

This calculation is performed by using the tropical standard atmosphere under a specific assumption of constant radiative humidity from 0 to 19 km height at zero degree of satellite viewing angle. BTD means Brightness Temperature Difference.

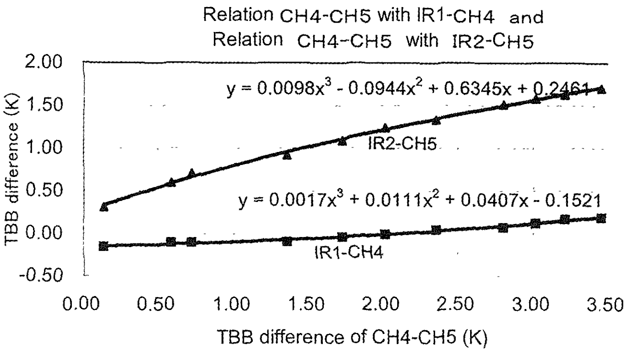

Fig. 3 Relation between the approximation formula and the result of the calculation by LOWTRAN7.

BTD(CH4-CH5)	a BTD(IR1-CH4) (TS=308.15 K)	b BTD(IR1-CH4) (TS=298.15 K)	a-b
0.00	-0.17	-0.15	-0.03
1.00	-0.13	-0.09	-0.05
2.00	-0.05	0.01	-0.06
3.00	0.06	0.13	-0.07
4.00	0.20	0.27	-0.08
5.00	0.35	0.43	-0.08

Table 2a Comparisons with relations between CH4-CH5 and IR1-CH4 by changing the sea surface temperature by LOWTRAN 7 radiative transfer model

BTD(CH4-CH5)	a BTD(IR2-CH5) (TS=308.15 K)	b BTD(IR2-CH5) (TS=298.15 K)	a-b
0.00	0.38	0.25	0.13
1.00	0.88	0.76	0.12
2.00	1.33	1.19	0.14
3.00	1.71	1.56	0.15
4.00	2.02	1.91	0.11
5.00	2.27	2.28	-0.01

Table 2b Comparisons with relations between CH4-CH5 and IR2-CH5 by changing the sea surface temperature by LOWTRAN 7 radiative transfer model

When the sea surface temperature changes, the results of Table 1 of course change, because the value of TBB is mainly affected by the sea surface temperature. Table 2a and 2b show the results of investigating how the approximation formula is affected when the sea surface temperature changes from 298.15 K (25.0 °C) to 308.15 K (35.0°C). The method of making these two tables is the same as that of Table 1. The brightness temperature difference in IR1-CH4 and IR2-CH5 is affected a little when the sea surface temperature changes. But the absolute values of the difference are less than 0.15 K. From this result the effect of the sea surface temperature change on the estimated approximation formula is not taken account of in the present method.

5. INTERCALIBRATION ON ROUTINE BASIS

Figure 4 shows the process from the acquisition of satellite data to the provision of the information of the intercalibration results at MSC.

The VISSR data and the NOAA GAC data available at the NOAA homepage via the Internet are processed to grid data. The grid data are matched for a target in reference to the condition file indicating the Area Selection. The detailed methods for the intercalibration, including the selection of a target and the grid matching, are shown in this paper mentioned above.

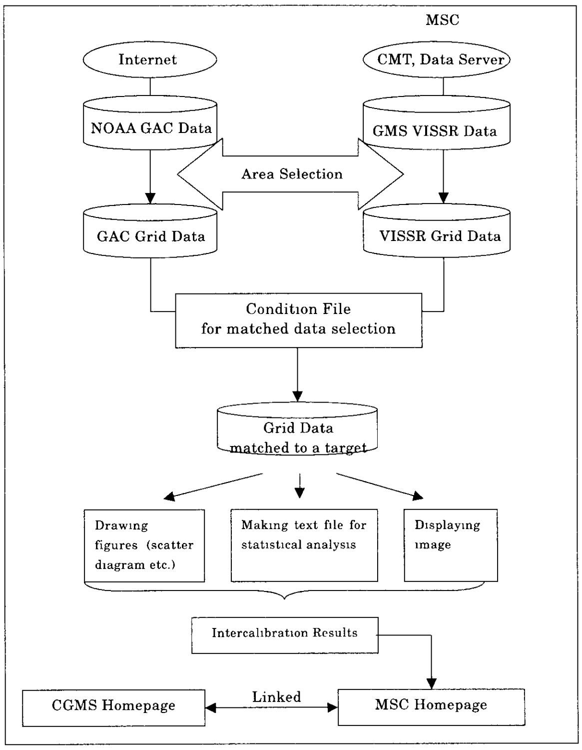

Fig.4 Intercalibration and Information Provision at MSC

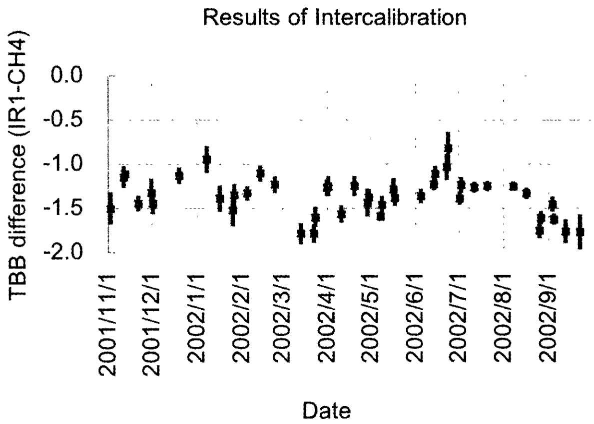

Fig. 5a Values of △ TBB between IR1 and CH4. Error bars show the standard deviation.

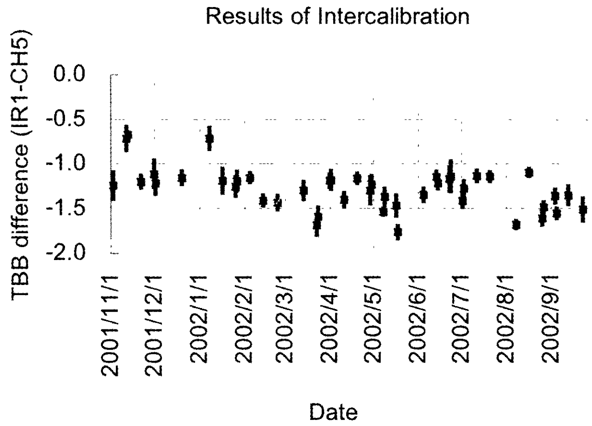

Fig. 5b Values of △ TBB between IR2 and CH5. Error bars show the standard deviation.

Figures 5a and 5b show examples of intercalibration on a routine basis. If the number of sub-grid areas which satisfies the conditions mentioned above is zero or one, we omit the study case (day). From both of the figure the TBB of VISSR IR channels 1 and 2 is about 0.5 K to 2 K lower than that with AVHRR channels 4 and 5 on NOAA-16. The past investigation Paper [3] reported that the TBB of VISSR IR channels 1 and 2 is about 1 K lower than that with AVHRR channels 4 and 5 on NOAA-14. In this study the value of △ TBB changes between 0.5 K to 2 K, but the large number of intercomparisons needs to make it clear whether the change is due to seasonal effects or not. More data must be processed to confirm this. In the future, as more data are being collected, the effect of age on the instruments can also be explored.

6. CONCLUSIONS

MSC/JMA has been performing research to define the method of intercalibration between GMS-5 and NOAA sensors. The convenience of getting the GAC data of NOAA-16 AVHRR from the Internet makes it possible to perform the intercalibration job on a routine basis. The intercalibration is restricted to the comparisons of the infrared 1 (11 microns) and the infrared 2 (12 microns) channels of GMS-5 with AVHRR channels 4 and channels 5 of GAC data. The result of eleven months shows that the TBB of VISSR IR channels 1 and 2 is about 0.5 K to 2 K lower than that with AVHRR channels

4 and 5 on NOAA-16, with some fluctuation. There might be some problem to be considered in the present method from two points of view. First, the results of eleven months have some fluctuation. The result may be derived from the uncertainty in the present method, especially in removing the cloud. There might be further efforts to remove clouds. Secondary, in this method the theoretical TBB difference is calculated by using an approximation formula. To calculate the theoretical TBB difference correctly, it is necessary to estimate the current atmospheric state correctly. And it is necessary to calculate the theoretical TBB in each case study. We have to continue further investigation for the value of the intercalibration to lead to a more correct value.

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ルーチンベース.での GMS － 5 と NOAA － 16 のインターキャリブレーション

岡崎　賢治　海藤　幸広

概　要

本報告は GMS-5 と NOAA-16 との赤外チャンネルでのインターキャリブレーションについて、その手法をメインに述べたものである。気象衛星センターでは 2002 年 9 月にオペレーショナルなインターキャリブレーションの手法を開発した。現在のところ GMS-5 の赤外 1 と赤外 2 と NOAA － 16 の赤外 4 と赤外 5 の比較を行っている。11 ヶ月間の調査を行った結果 GMS － 5 の赤外チャンネルはＮＯＡＡ－ 16 に比べて 0.5℃から 2℃低いことがわかった。ルーチンベースでのインターキャリブレーションについては、今後改良を重ねその結果をホームページにも掲載していく予定である。