CGMS-XXVIII JPN-WP-12
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CALIBRATION METHOD FOR EMERGENCY CASE WHEN CALIBRATION SHUTTER DATA ARE NOT AVAILABLE

This report describes a new calibration method without calibration shutter information developed in the Meteorological Satellite Center (MSC) against mal-functioning of calibration shutter system which occurs irregularly. This method can provide calibration data with standard errors of less one level.

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1. INTRODUCTION

In flight calibration methods of the infrared channels, the Visible and Infrared Spin Scan Radiometer (VISSR) uses a blackbody and a calibration shutter. The blackbody temperature as a reference is measured during of performing the every hourly VISSR observation using the calibration shutter. Keeping on synchronizing with the satellite rotation, the shutter controls to convert whether the incoming radiation energy from blackbody to the detectors or the incoming energy from mirrors to the detectors.

Soon after the in-orbit test period of GMS-5 began, however, the phenomena had occurred that the incoming radiation energy from blackbody had often got into the field of view of sensors while the sensors were scanning the earth. It's caused because the motion of shutter didn't synchronize with the satellite rotation.

To avoid the interference with the signals on images, the operation of the shutter was changed as follows: Namely, an electric current of the shutter was turn off immediately after being gotten the calibration data, and then it was turn on when sensors finish scanning the earth. This operation was started on August 9, 1995 and controlling the movement of the shutter forcibly has normally performed the calibration procedure up to now.

However, the following issue is raised corresponding to the operation of GMS 5 over its expired lifetime.

- A possibility of changing the unlocked shutter condition from normal condition.
- A possibility of trouble of the shutter due to the payload of on-off operation.

Therefore, it is necessary to develop an alternative method, which does not require calibration shutter information. The essence of the method is the use of housekeeping telemetry data on temperature of various parts of VISSR.

2. METHOD AND RESULTS

A principle of operational calibration method for IR channels of GMS-5 VISSR makes use of a linear relationship between incoming IR radiance and output voltage of IR channel. Taking the space as a cold source and a calibration shutter in VISSR as a warm source, a calibration regression equation to convert output voltage of IR channel into temperature is determined.

In this report, a digital count (Sh) (calibration shutter radiance) is statistically estimated, which corresponds to output voltage when VISSR views calibration shutter. In this procedure, it is assumed that there exists a linear relation between output voltage when VISSR views calibration shutter under normal condition and effective shutter temperature (Te) estimated from housekeeping telemetry data.

2.1 THE CASE OF NON-ECLIPSE PERIOD

Utilizing the all hourly data under normal condition during the period of January 1, 1997 through May 22, 2000 except V16 and V17 during eclipse period, analysis is made on the relationship between calibration shutter radiance and the effective shutter temperature. The results of IR-1, IR-2 and IR-3 are shown in Figures 1 (a), (b) and (c) respectively. The ordinate is digital count of calibration shutter radiance and abscissa is the effective shutter temperature. It can be seen that there is a good linearity in the relationship of two items. Based on this analysis Eq. (1) is derived.

$$Sh = a\ Te + b \qquad (1)$$

where Sh and Te are calibration shutter radiance (level) and effective shutter temperature (K) respectively while a and b are constants. On Table 1 the values of a, b, correlation coefficient (R) and standard error of estimation for dependent data are shown. Standard error is smaller than one level.

Table 1

The Values of coefficient a and b of Eq.(1), Correlation Coefficient (R) and Standard Error (in Digital Count) of Estimation of Calibration Shutter Radiation from Effective Shutter Temperature for Dependent Data

Channel	**Coefficient**		**Correlation Coefficient (R)**	**Standard Error**
	A	**b**		
IR-1	**1.826**	**-378.56**	**0.999**	**0.28**
IR-2	**1.720**	**-348.96**	**0.997**	**0.36**
IR-3	**2.407**	**-585.91**	**0.998**	**0.48**

Furthermore, the above data are allocated between dependent data and independent data as the following three cases, and then the above method is evaluated as independent data.

(1) Dependence data: from January 1, 1997 to December 31, 1998.
Independence data: from January 1, 1999 to December 31, 1999.

(2) Dependence data: from January 1, 1998 to December 31, 1999.
Independence data: from January 1, 1997 to December 31, 1997.

(3) Dependence data: from January 1, 1997 to December 31, 1999 except from January 1, 1998 to December 31, 1998.
Independence data: from January 1, 1998 to December 31, 1998.

The results show that the method is effective since the standard error of estimation difference between for dependence data and for independence data is very small, and F-value at 0.05 % confidence for independence data exceeds over the standard value in the all cases. For example, the statistic in the case (1) is shown in Table-2.

Table 2

The Values of coefficient a and b of Eq.(1), Correlation Coefficient (R) and Standard Error (in Digital Count) of Estimation of Calibration Shutter Radiation from Effective Shutter Temperature for Dependent Data (StdErrD) and Independent Data (StdErrI) in the Case (1)
Difference is Standard Error Difference between for Independent data and for Dependent data.

Channel	Coefficient		Dependent		Independent	Difference
	a	B	R	StdErrD	StdErrI	ΔStdErr
IR-1	1.8263	-378.7463	0.9986	0.2821	0.2965	0.0144
IR-2	1.7229	-349.6655	0.9979	0.3256	0.4607	0.1351
IR-3	2.3993	-583.6852	0.9977	0.4897	0.5010	0.0113

2.2 THE CASE OF ECLIPSE PERIOD

A similar analysis is made using the data of the eclipse period, which indicates that there is a deviation from the linear condition. Examples of vernal eclipse and autumnal eclipse are shown in Figures 2 and 3 respectively. Compared with the previous case a little deviation from linearity is recognized. Especially the characters is conspicuously appeared in IR-1 and IR-2 for V16 in vernal eclipse since there is about 5-count difference at effective shutter temperature 290 K compared with the non-eclipse period. It is considered that the cause of this difference is due to over cooled of detector during the eclipse period. Further analysis indicates that there is correlation between the detector temperature control voltage and deviation of shutter radiance from that of normal condition.

Analysis is made by adding the detector temperature control voltage V to Eq. (1) as shown in Eq. (2).

$$Sh = a\,Te + bV + c \qquad (2)$$

where a, b and c are constants.

The obtained values of coefficients a, b and c, standard error and coefficient of determination are shown in Table 3 together with that obtained from case of Te only. It can be seen that the result is improved compared with the case of Te only especially in window channels. The error is almost same as that of utilizing calibration shutter information.

Table 3

The Coefficients of Eq. (2) and Accuracy to Estimate Shutter Radiance from Effective Temperature and Detector Temperature Control Voltage. A.E.: Autumnal Eclipse, V.E.: Vernal Eclipse, S.Err: Standard Error, R: Coefficient of Determination. The Standard Error and Coefficient of Determination for the Case of Te only is shown for Comparison.

CH.	Eclipse	Coefficients					Case of Te Only	
		A	B	c	S.Err	R	S.Err	R
IR-1	A.E	1.778	0.668	-365.67	0.535	0.994	0.634	0.983
	V.E	1.891	2.173	-401.62	0.893	0.989	1.552	0.936
IR-2	A.E	1.664	0.825	-334.03	0.526	0.993	0.674	0.978
	V.E	1.772	2.320	-368.80	0.943	0.987	1.651	0.921
IR-3	A.E	2.300	-1.011	-552.30	0.365	0.998	0.641	0.988
	V.E	2.473	-0.238	-603.98	0.537	0.997	0.555	0.994

Furthermore, the above data are allocated between dependent data and independent data in the same way as in the previous session, and then the above method is evaluated for independent data.

The results show that the method is effective since the standard error of estimation difference between for dependence data and for independence data is very small, and F-value at 0.05 % confidence for independence data exceeds over the standard value in the all cases. For example, the statistics in the same period as in the case (1) of the previous session is shown in Table-4.

Table 4

The Coefficients of Eq. (2) and Accuracy to Estimate Shutter Radiance from Effective Temperature and Detector Temperature Control Voltage. A.E.: Autumnal Eclipse, V.E.: Vernal Eclipse, S.Err: Standard Error, R: Coefficient of Determination. The Standard Error and Coefficient of Determination for the Case of Te only is shown for Comparison.

CH.	Eclipse	Coefficient			Dependence		Indepen.	Diff.
		a	B	c	R	StdErrD	StdErrI	ΔStdErr
IR-1	V.E.	1.8908	2.2098	-401.5630	.9779	.9194	.8825	.0491
	A.E.	1.7809	0.6365	-366.2676	.9882	.5358	.5422	.0121
IR-2	V.E.	1.7652	2.3753	-366.7207	.9740	.9543	.9880	.0930
	A.E.	1.6574	0.8208	-332.1490	.9878	.5115	.5857	.0631
IR-3	V.E.	2.4624	-0.2150	-600.9214	.9936	.5583	.5296	.0321
	A.E.	2.2971	-1.0403	-551.4956	.9965	.3604	.3841	-.0289

3. CONCLUDING REMARK

The new method without using calibration shutter information was developed against mal-functioning of calibration shutter system, which occurs irregularly. This method can provide calibration data with standard errors of less one level.

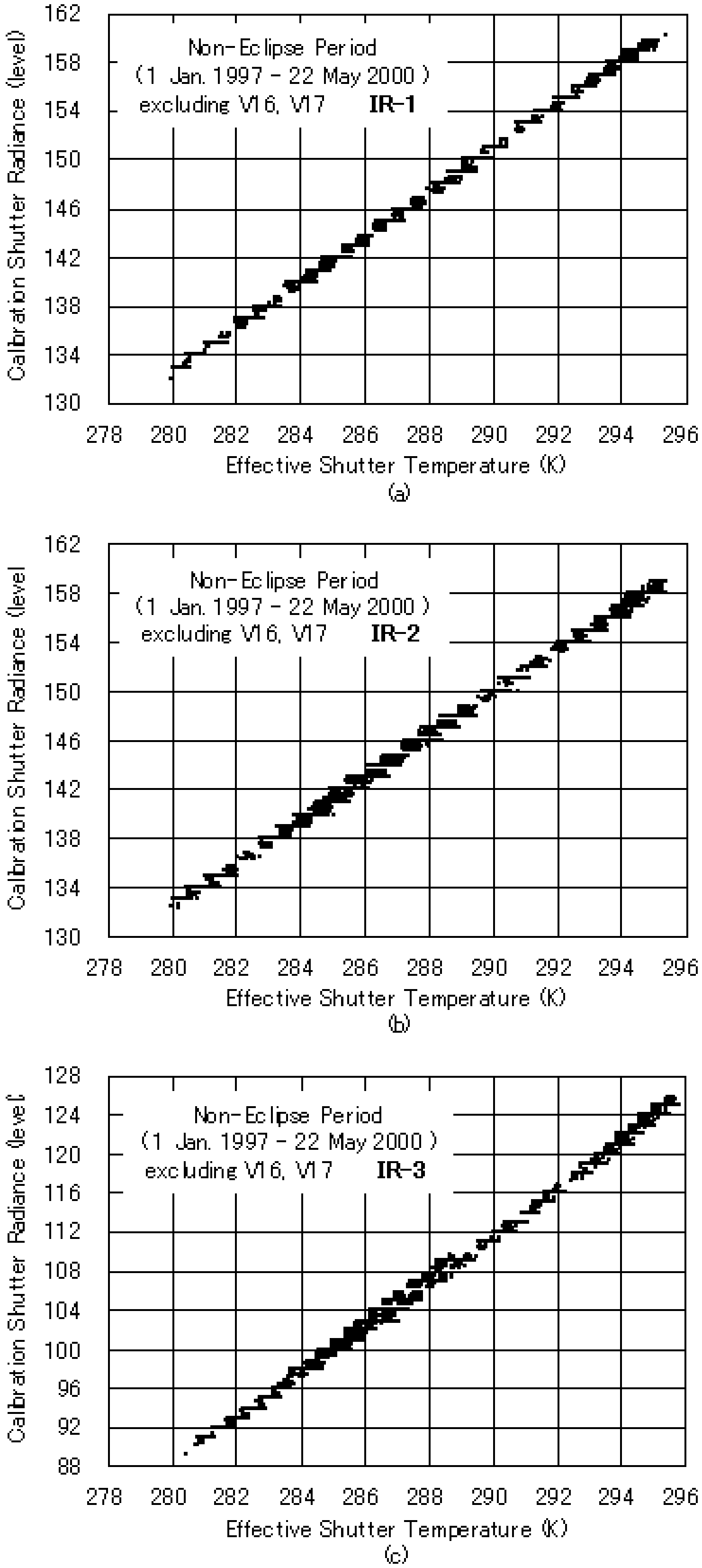
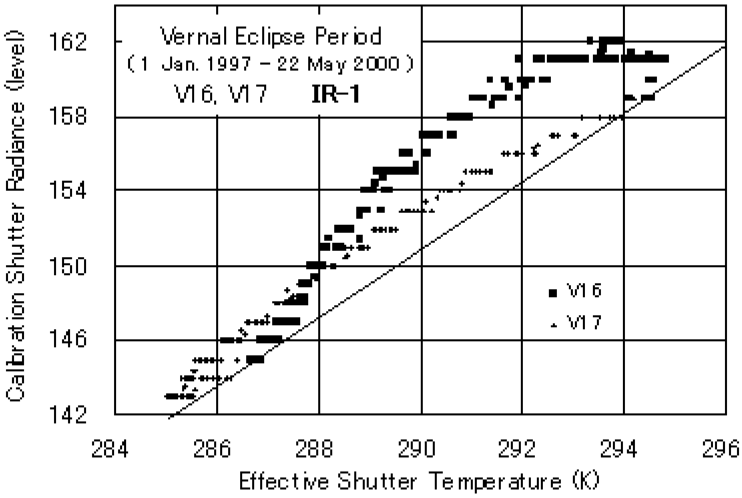
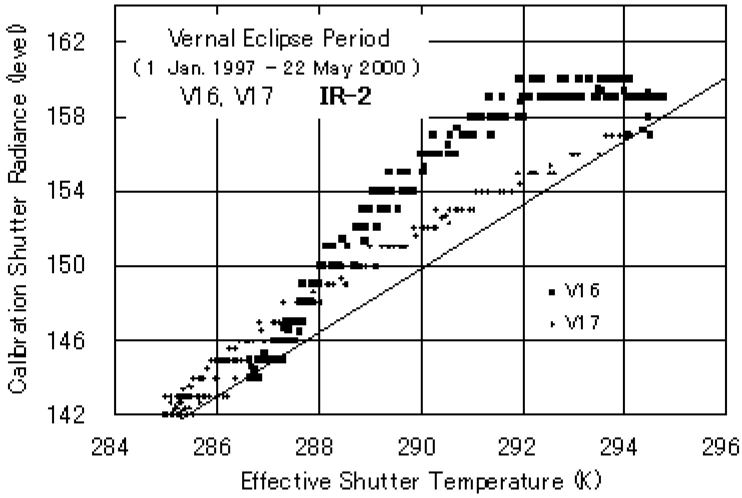


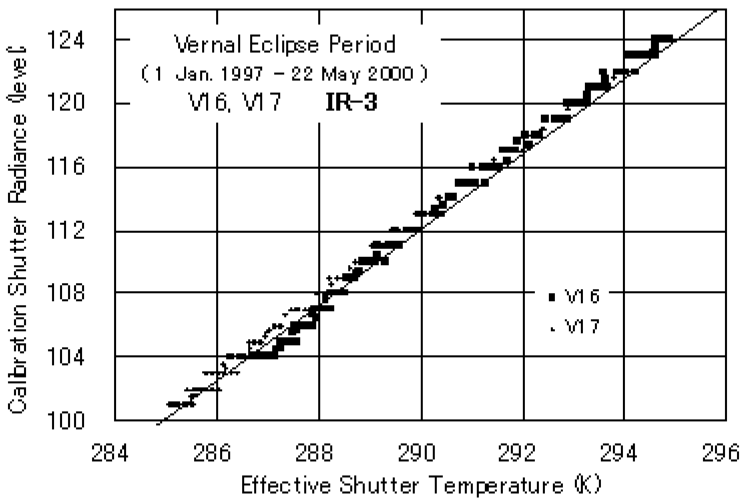
Figure 1
Relation between Effective Shutter Temperature and Calibration Shutter Radiance during the normal period (1 Jan. 1997 - 22 May 2000) excluding V16 and V17 during eclipse period.
(a): IR-1, (b): IR-2: (c) : IR-3



(a)



(b)



(c)

Figure 2
the same as Fig.1 except for during vernal eclipse.

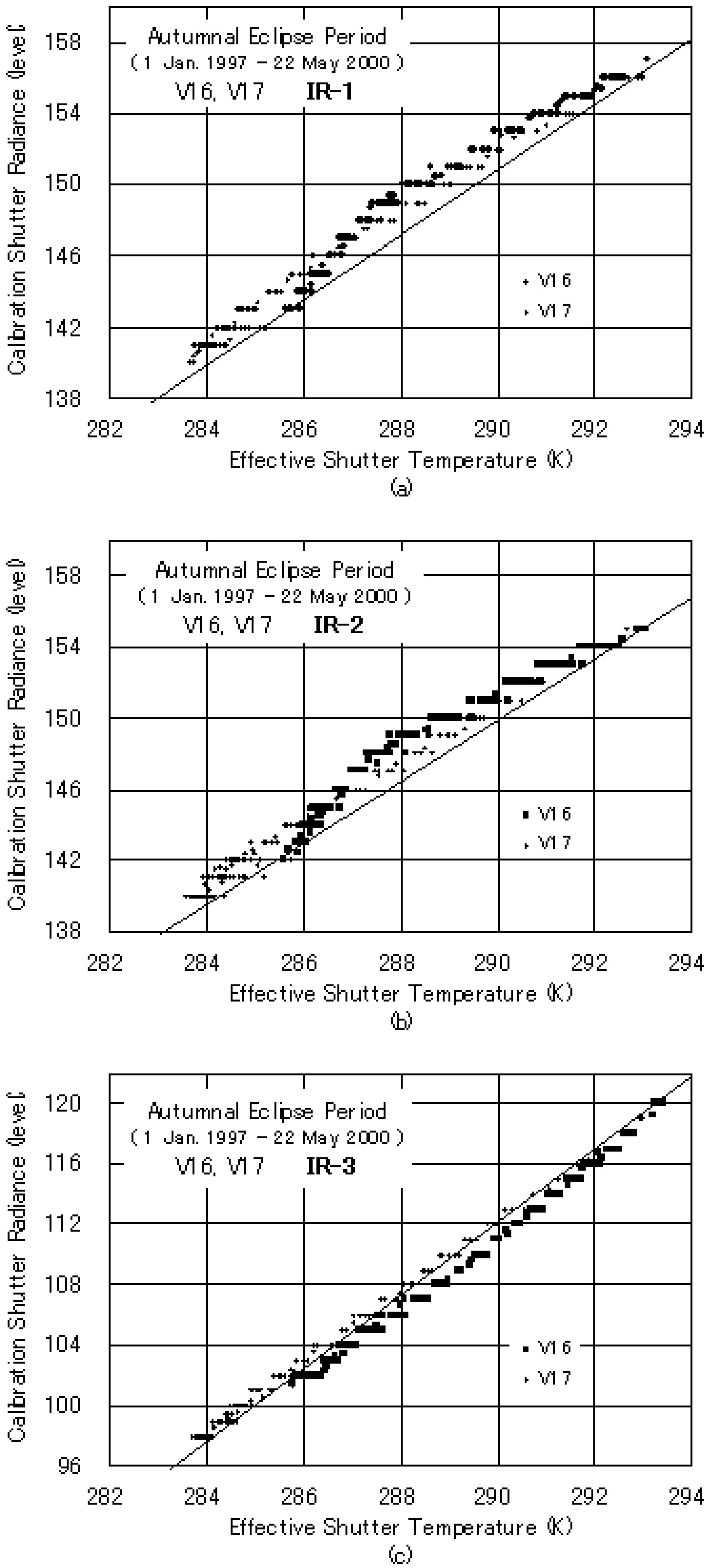


Figure 3
the same as Fig.1 except for during autumnal eclipse.