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Investigation of NESDIS's Calibration Algorithm of the Imagers for IR Channels on GOES-12

Ki-Ho Chang†, Tae-Hyung Oh, Myung-Hwan Ahn, Nam-Seo Cho, and Sung-Nam Oh

Remote Sensing Research Lab., Meteorological Research Institute, KMA

Abstract : The prototype radiometric calibration algorithm of the imagers for IR channels has been developed according to the Weinreb's method. Applying the algorithm to the GOES-12 count data, we have shown that the calibration coefficients (slope and intercept) evaluated by the algorithm gives good agreement with the NESDIS's ones, and that the scanning error due to the scan mirror emissivity and stripe error are almost eliminated by the East/West angle dependent scan-mirror correction and the respective calculation of intercept for each North/South scan line, respectively.

Key Words : Radiometric calibration; Infrared Sensor; Space look; Black body; Meteorological Imager.

1. Introduction

COMS (Communication, Ocean and Meteorological Satellite), the first Korean geostationary satellite, will be launched in 2008. The COMS' meteorological imager will scan the earth including Korea peninsula with the visible and IR (InfraRed) sensors. The IR sensors of the COMS' meteorological imager will play an important role, especially for the night watching of earth.

The radiometric calibration algorithm, converting the instrumental counts value into the radiance is the first step to utilize the IR sensor data. The performance of the calibrated IR data gives directly effect on the quality of the meteorological products calculated by using the IR radiance such as sea surface temperature. Because of the importance of the imager sensor radiance data, there have been a lot of researches to obtain the more precise radiance data (Beriot *et al*, 1982; Brooks *et al*, 1984; Minnis *et al*, 2002).

The IR radiometric calibration is to evaluate the calibration coefficients (slope and intercept), under the assumption of the linearity between the counts and radiance. The method to obtain the two calibration coefficients is slightly different: the slope is induced for the black body calibration process while the intercept is updated by using the space look data. After GOES-8, the IR calibration equation has been improved by including the variation of the instrument's scan-mirror emissivity with scan position (Weinreb *et al.*, 1997).

In this paper, the prototype radiometric calibration algorithm for the IR sensors, developed by the Weinreb *et al*'s method, has been tested by applying

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† Corresponding Author: K. – H. Chang (khchang@metri.re.kr)

the algorithm to the GOES-12, operated from April 1 2003, radiance count data. The calibrated calibration coefficients are compared with those of the NESDIS (National Environmental Satellite, Data, and Information Service) operating the GOES-12. It is shown that applying the IR calibration algorithm for each scanning line makes the stripes greatly reduced.

2. Brief Description of GOES-12

The GOES-12 is a geostationary satellite with the imager and sounder, located at 75 W (Space Systems-Loral, 1994). The GOES-12 imager uses MgF2 instead of SiO (GOES-8 and 9 used it) as a coating of scan mirror to reduce its absorption and the systematic dependency of the radiometric calibration on scan-mirror angle and temperature. Table 1 shows the spectral and spatial characteristics of the GOES-12 imager.

Table 1. Spectral and spatial characteristics of GOES-12 imager.

Closest GOES-12 Channel	Spectral Range (μm)	Resolution at nadir (km)	Detector Material	No. of using detectors (Detector No.*)
Visible	0.55-0.75	1	Si	8
IR1	3.8-4.0	4	InSb	2 (1,2)
IR2	5.8-7.3	4	HgCdTe	2 (3,4)
IR3	10.2-11.2	4	HgCdTe	2 (5,6)
IR4	13-13.6	8	HgCdTe	1 (7)

* This is the assigned number for convenience.

3. Calibration for Variation in Scan-Mirror Emissivity

Relation between the radiance R and the output X (counts) of the instrument is

$$R = qX^2 + mX + b \qquad (1)$$

where q, m, and b are the coefficients. The value of q was known a priori, having been determined from measurements made by ITT (http://www.itt.com) before launch.

The coefficients m and b, termed the slope and the intercept respectively, are obtained during the in-orbit operation: at each blackbody look, m is determined by (Weinreb *et al.*, 1997)

$$m = [r_{BB} - q(X_{BB}^2 - X_{sp}^2)]/(X_{BB} - X_{sp}), \qquad (2)$$

where

$$r_{BB} = [1 - \varepsilon(45)]R_{BB} + [\varepsilon(45) - \varepsilon(sp)]R_{M,BB}, \qquad (3)$$

$\varepsilon(45)$ and $\varepsilon(sp)$ are scan mirror's emissivity at the black body and space look position, respectively. Here, X_{BB} and X_{sp} are the radiance of the blackbody and the scan mirror, respectively, calculated from the corresponding temperature. It is noted that the mirror's angle at space look position is ± 10.4 degree from nadir, which depends on the operation against solar intrusion.

The radiance R may be calculated from the spectral response function $\Phi(v)$ and , where v is the wave number and monochromatic radiance, as follows:

$$R = \frac{\int R(v)\Phi(v)dv}{\int \Phi(v)dv}. \qquad (4)$$

At each space look, the intercept is determined from

$$b = -mX'_{sp} - qX_{sp}'^2 + \varepsilon(sp)R_{m,sp}, \qquad (5)$$

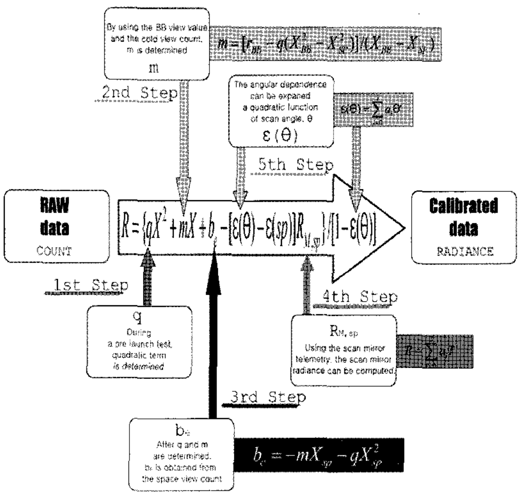

Fig. 1. Schematic diagram of the prototype IR calibration algorithm including the Weinreb's scan-mirror angle dependence correction.

where the prime means the count updated from the most recent space look data, i.e., the mirror radiance at the time of the space look. These procedures of radiometric calibration are briefly described in Fig. 1.

4. Results and Discussion

The prototype algorithm of the IR calibration including the radiometric contribution of scan mirror emissivity dependent on the scan mirror angle has been studied for the COMS imager. Applying this algorithm to the IR data of GOES-12, the effect of scan mirror correction to the physical radiance has been investigated.

Figure 2 shows that the calibration coefficients calculated by considering the scan mirror angle dependence give better agreement with the NESDIS' ones than the scan-angle independent coefficients for each case. The difference between our calculated and NESDIS' coefficients is due to the difference of machine complier because the difference is very small. On the other hand, we have a question: Is the NESDIS' algorithm is the best solution for the IR calibration?

Figure 3 shows that the NESDIS', i.e., our

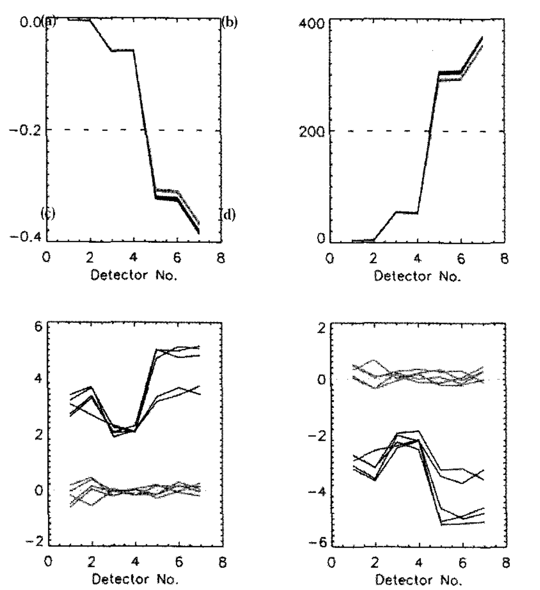

Fig. 2. The (a) slope, (b) intercept, (c) slope bias, and (d) intercept bias calculated for 5 cases versus the detector number of table I. Here the bias (%) denotes the values between the corresponding values and NESDIS' coefficients for each case. In (a) and (b), the red line denotes the scan-mirror corrected and NESDIS' coefficients, and the red line the coefficient without scan-mirror correction. In (c) and (d), the red (black) line is the bias between the scan-mirror corrected (uncorrected) and NESDIS's coefficients for each case.

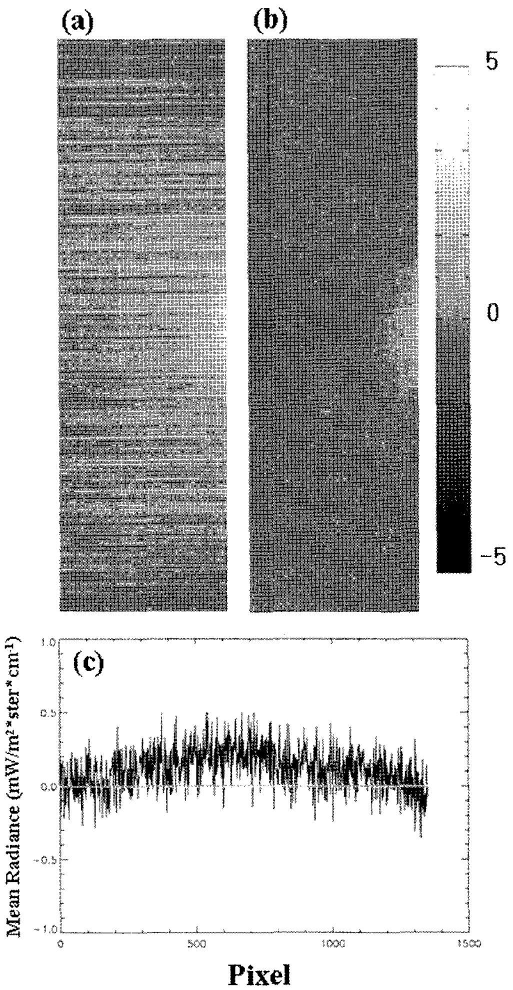

Fig. 3. The space look counts bias calibrated by using the (a) horizontally (400 sampling along x-axis) and vertically (y-axis) and (b) horizontally averaged space-look data during the scanning period from 14:45 7 December 2004. In (c), the vertically averaged values of (a) and (b) are shown for the x-axis.

algorithm gives the almost constant radiance data for the scan lines: the stripe error along North/South scan line are much improved by the respective calibration process for each N/S scan line while the scan mirror correction almost eliminates the variance of radiance along the East/West scan line. This suggests that the NESDIS' algorithm of IR calibration gives the uniform radiance data for both N/S and E/W scanning.

In conclusion, the IR calibration algorithm, developed by Weinreb's method, gives good radiance data from the GOES-12 imager count data. Especially, focusing on the space view data, the NESDIS(Weinreb)'s calibration gives the uniform radiance data: almost constant for E/W scanning by including the scan-mirror correction and for N/S scanning by the respective calculation of intercept for each N/S scan line.

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