CGMS-39, CMA-WP-08
Prepared by CMA
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FY-3 OPTIC AND IR INSTRUMENT CALIBRATION ANOMALIES

Summary of the Working Paper: The paper introduced the instrument calibration monitoring system establishment for the three FY-3A optical instrument (the MEdium Resolution Spectral Imager -**MERSI**, the Visible and InfraRed Radiometer –**VIRR**, and the InfraRed Atmospheric Sounder -**IRAS**) and reports the calibration trend and anomalies of these instruments. To monitor the trend of instrument calibration and make the alert for the anomalies , an integrated calibration and quality control system (QCS) is being established in the FY-3 ground application system. This system includes the onboard calibration (OBC) performance monitoring (IPM), monitoring the global reference sites and stable bright targets (DCC and sun-glint) and inter-calibration with some international reference sensors. The monitoring results show that three bands (one IR and two shortwave infrared bands) of FY-3A/MERSI appear the abnormal frequent fluctuation of their calibration because of random jump of MERSI electronic gain on orbit. The calibration monitoring also shows that there is significant degradation of short wavelength bands (<500nm) of MERSI with more than 10% degradation rate and it is relative stable for longer wavelength VNIR bands with less than 5% degradation during three years. The biggest degradation in band 8 of MERSI is more than 25%.

FY-3 Optic and IR Instrument Calibration Anomalies

1 INTRODUCTION

There are three optical and Infrared instruments (the MEdium Resolution Spectral Imager - **MERSI**, the Visible and InfraRed Radiometer –**VIRR,** and the InfraRed Atmospheric Sounder - **IRAS**) onboard FY-3A.

To monitor the trend of instrument calibration and make the alert for the anomalies , an integrated calibration and quality control system (QCS) is being established in the FY-3 ground application system. This system includes the onboard calibration (OBC) performance monitoring (IPM), monitoring the global reference sites and stable bright targets (DCC and sun -glint) and inter-calibration with some international reference instruments.

An integrated calibration system including several methods is designed and has been establishing since 2009. Figure 1 is the framework of FY-3A calibration monitoring and Data Quality Control System (QCS) for quality assessment of these instruments' L1 data.

A Calibration data platform is being established including the MERSI/VIRR OBC files (engineering and telemetry data), SNO data of reference sensors used for GSICS inter-calibration and the data of global reference sites and stable targets (DCCs and sunglints) of these three sensors. This is an important database for FY-3A Optical instruments Calibration monitoring and and anomaly identification.

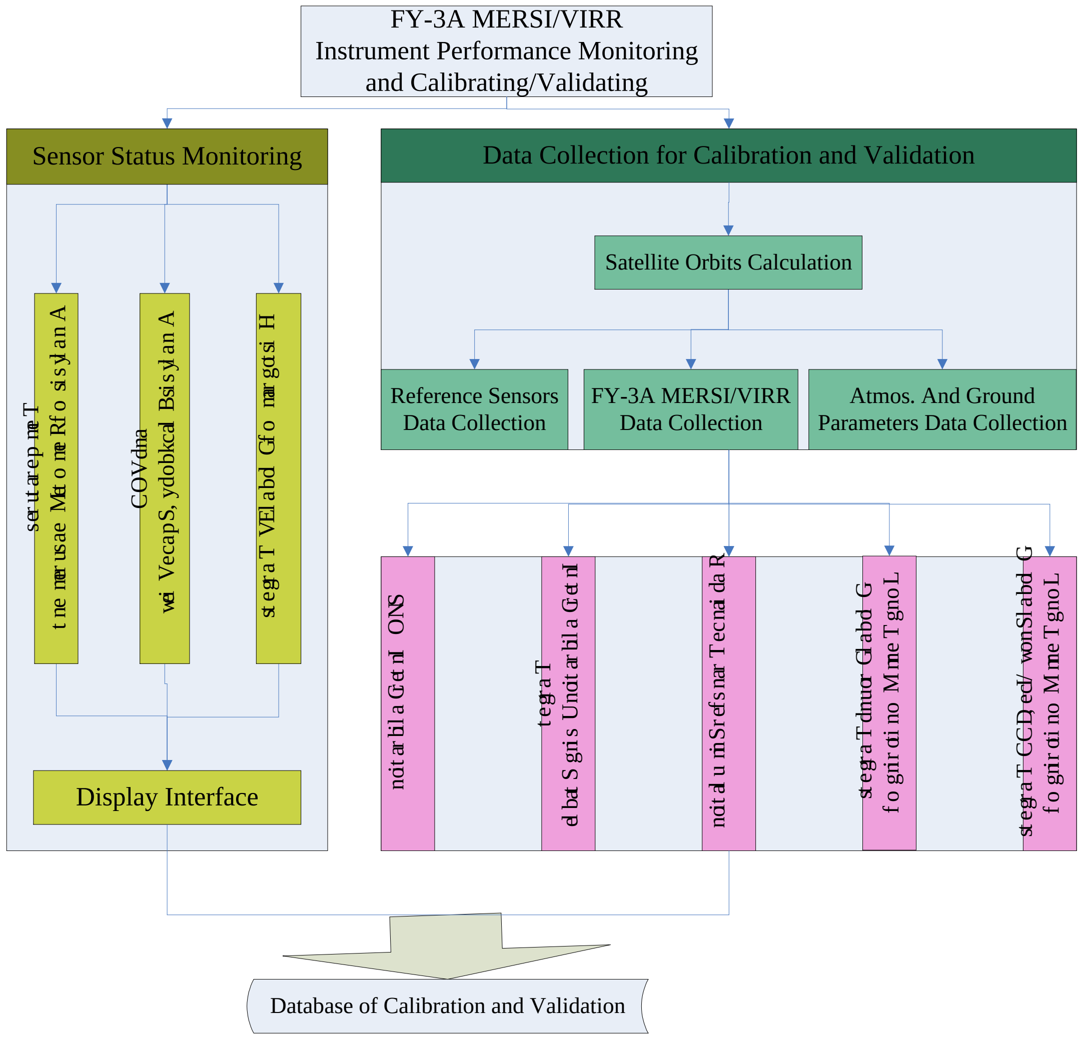


Figure 1. FY-3A Optical instruments calibration monitoring and quality control system (QCS) Framework

2 Instrument Performance Monitoring

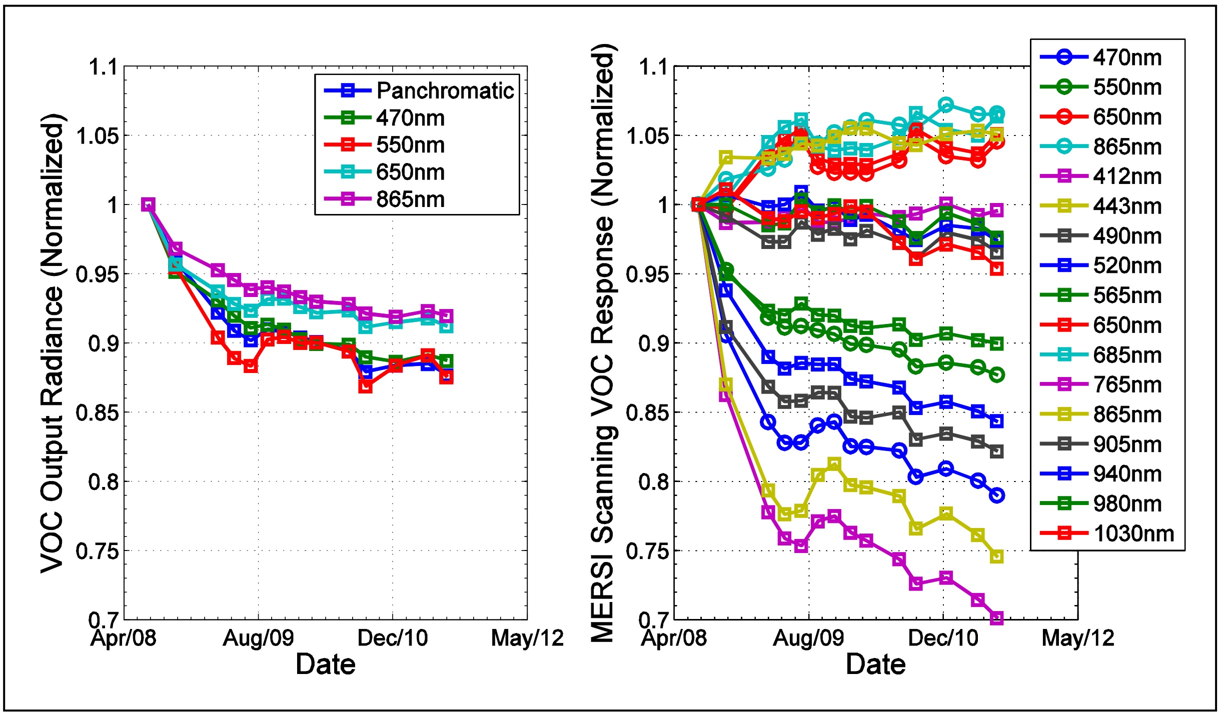
CGMS Recommendation 35.02: Satellite operators are requested to provide near real-time monitoring of instrument performance on easily accessible websites and to archive the information. Deadline: CGMS-36.

CGMS36 - NOAA WP14 gave the example and guide of establishment of A Web-based Interface for Near Real-time Instrument Performance Monitoring.

To response the CGMS recommendation, NSMC is establishing a near real-time monitoring system of instrument performance, firstly starting from the commission for FY-3A's optical sensors. MERSI/VIRR have produced the OBC files which include engineering and telemetry data of in-flight sensors when the EV files are generated in Data Preprocessing System (DPPS).

MERSI has a visible-NIR onboard calibrator (VOC) which is composed of an mini integrated sphere with interior lamp and sunlight import cone, export beam expanding system and absolute radiance trap detectors. Although the VOC can not realize the absolute radiometric onboard calibration, it can be used as a radiometric source to monitor the radiometric sensitivity degradation of MERSI.

Figure 2 shows MERSI radiometric response degradation monitoring based on VOC during three years from July 1, 2008 to July 15, 2011 . The interior lamp illumination degradation was detected by the trap detectors. Figure 2a has shown the radiance output of the MERSI VOC at different time (normalized into July1, 2008). The lamp illumination in VOC has more than 5% degradation in all spectral bands and more than 10% in less than 550nm wavelength. Deducted VOC output source change from MERSI scanning VOC signal, Finally sensitivity degradation rate of 19 solar reflectivity bands of MERSI was derived. It is shown at figure 2b. We can find the great sensitivity degradation with more than 15% in the band 1(470nm), 8(412nm), 9(443nm), 10(490nm) and 11 (520nm) of the MERSI since its launch. The greatest degradation is band 8 (412nm), nearly 30% during three years. Two green bands (550nm and 565nm) have the degradation of nearly 10%. Some bands in near infrared region between 650nm and 980nm are stable with less than 5% degradation in three years. To be interested, five bands in near infrared region have light response increase with about 5%. Figure 2 also show that the bands with apparent response degradation have the different speed of the degradation rate in different phase. It means the degradation rate of the MERSI instrument response is no-linear. There are quick degradation



speed in first year and then the speed decrease after one year.

Figure 2 MERSI radiometric response degradation monitoring based on VOC. (a)MERSI VOC's radiance output trend monitored by trap detectors; (b)derived response degradation of MERSI 19 reflective solar bands from scanning VOC at different date.

Except for the VOC viewing, MERSI also scans the deep space (space view, SV) and black body (BB), called DN_{sv} and DN_{bb}. These observation signals are used to monitor the instrument operational status and the radiometric performance change in the orbit. We found the signal anomaly jump of space view of band 5, 6, and 7 of MERSI (***figure 3***). The phenomenon of brightness jump of EV image appeared, especially, the image of band 5 (IR) appeared heavily saturated in desert area. The instrument vendor explained that it was induced from the electronic gain anomaly jump of MERSI NIR and IR bands because these bands are susceptible to contamination by extra electrons produced by high-energy protons from the natural environment hitting the detector. IR band 5 can be calibrated using BB and SV observation at the real time. But unfortunately, band 6 and band 7 can not adjust the calibration coefficient based on the electronic gain level immediately in current DPPS system. It will have to be done in the recalibration in the future.

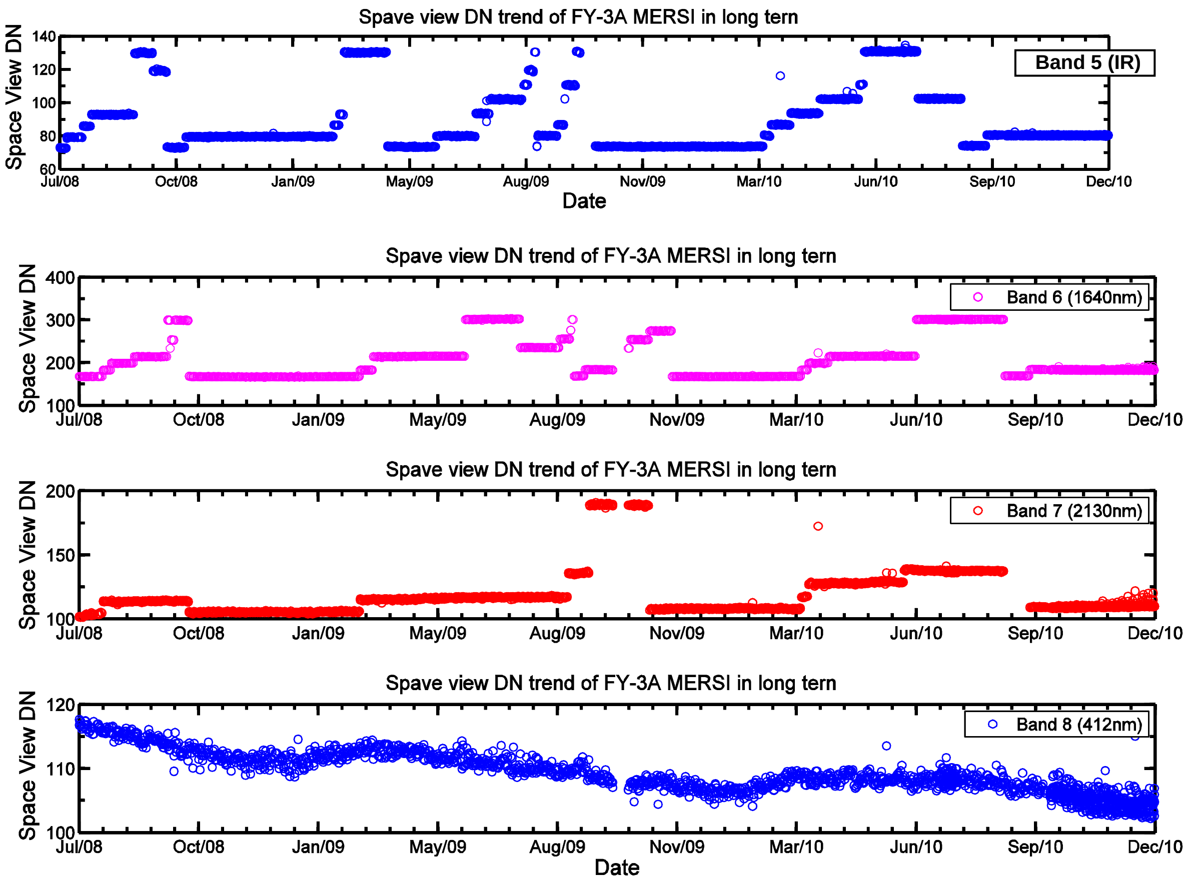


Figure 3 Scanning signal (DNsv) trend of space view of FY-3A/MERSI band 5,6,7,8. DNsv of Band 5, 6,7 have a frequent unusual fluctuation during the last years while that of band 8 has the relatively simple change trend .

The MERSI IR band monitoring based on OBC files finds that the onboard blackbody temperature has small change (about 283K) except winter in 2009 but the MERSI signal DN_{bb} appear significant fluctuation (see figure 4) similar as the band 6 and 7. This leaded to the great fluctuation of band IR calibration coefficient. but all these fluctuation can not affect the noise level of IR detector and the NEDT of band 5 (IR) is always stable at 0.35k .

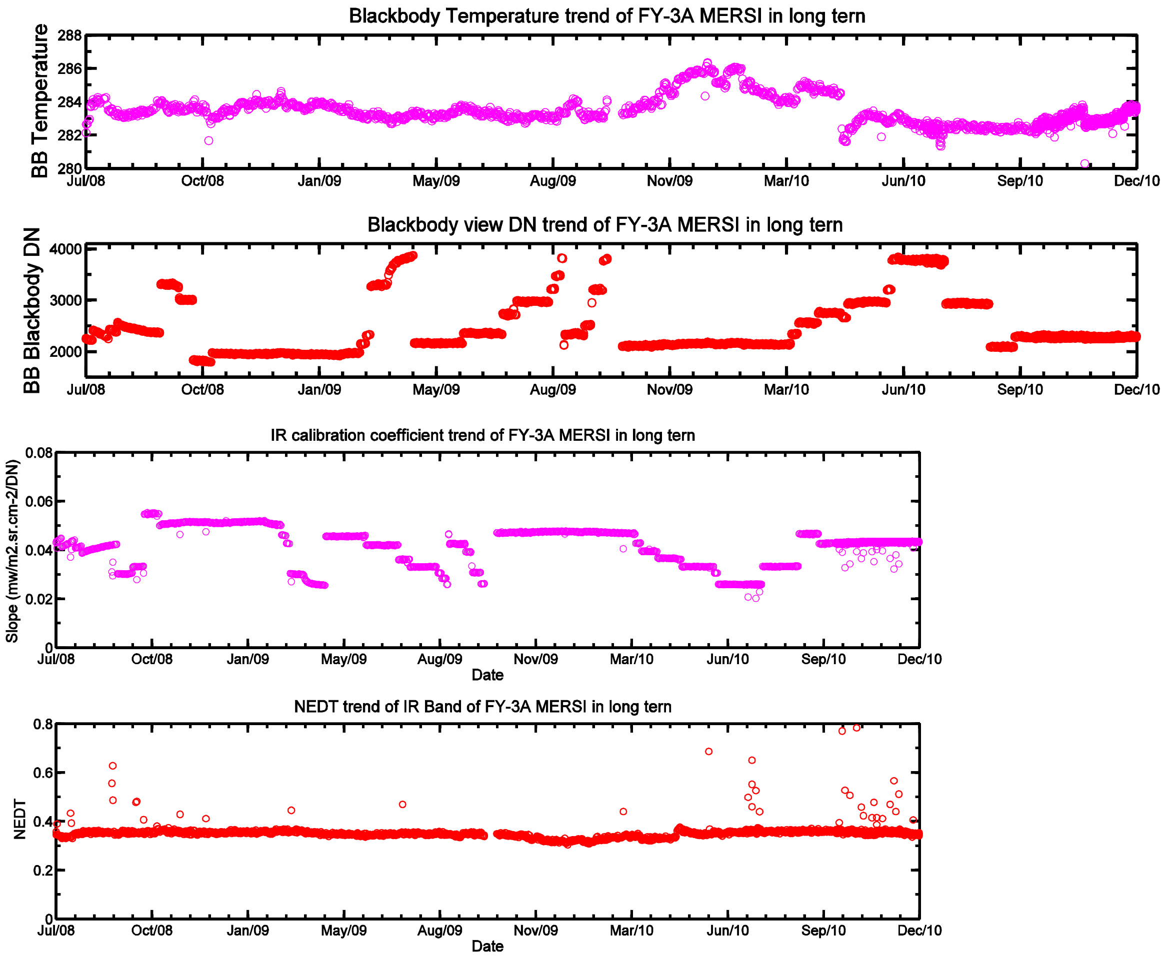


Figure 4 The performance monitoring of FY-3A/MERSI IR Band 5. (a) Blackbody temperature trend; (b) MERSI DN_{bb} scanning the blackbody; (c) calibration coefficient (slope) trend ; (d) the NEDT change trend;

3 Calibration monitoring of MERSI

3.1 SNO Cross-calibration method

The SNO method is also used for LEO-LEO intercalibration of IR bands of MERSI, VIRR and IRAS based on AIRS and IASI. The results show that the radiance of band 5 of MERSI is larger than both collocated radiance of AIRS and IASI while band 4 of VIRR was perfectly consistent with both of them and band 5 radiance was a little lower than both of them.

Except for inter-calibration for thermal emissive bands with AIRS and IASI, EOS/MODIS are used to inter-calibrate and assess the calibration of reflective solar and thermal infrared bands of MERSI/VIRR based on the global SNO observation with them. There are 18 bands of MERSI similar to MODIS's bands.

3.2 Global reference sites

To monitor the long-term stability of the calibration of MERSI/VIRR, a number of global large-area stable terrestrial sites have been employed, especially these sites advised by CEOS/WGCV . Observation data of these sites at all time are collected from MERSI/VIRR. We analysis EV signal of these sites to determine the long-term drifts in calibration of MERSI/VIRR and evaluate the suitability of the sites for calibration monitoring. Of all these sites, some perfect sites such as Sahara and Arabia deserts, ice-surfaces from Greenland and Dome C are firstly used to experimentally monitor the calibration trend.

The North African and Saudi Arabian desert sites consist mainly of san d, gravel, and rocky outcrops and are arid with little or no vegetation. The sites are uniform over a large area with variations in reflectances less than 2%. We are collecting the MERSI/VIRR observation data of all the reference sites for calibration monitoring at all the time.

Greenland and Dome C are also used to monitor calibration trend for MERSI/VIRR instruments. The reflectance prediction model consist of second order polynomial regressions of reflectance on solar zenith angle, derived from observations that are spatially uniform in all MERSI/VIRR channels over sub-regions of area 68 km by 68 km in 2008. By comparing reflectance from new observation signal (DN) in the following year with these prediction models and the beginning calibration coefficients respectively, Calibration trends are obtained in the year-round degradation rate. Figure 5 shows MERSI degradation rate at all the visible and near infrared bands monitored by Greenland and Dome C during the pass two years. The degradation rate derived from Greenland is higher than that from Dome C because the beginning data in the Greenland is earlier than in the Greenland.

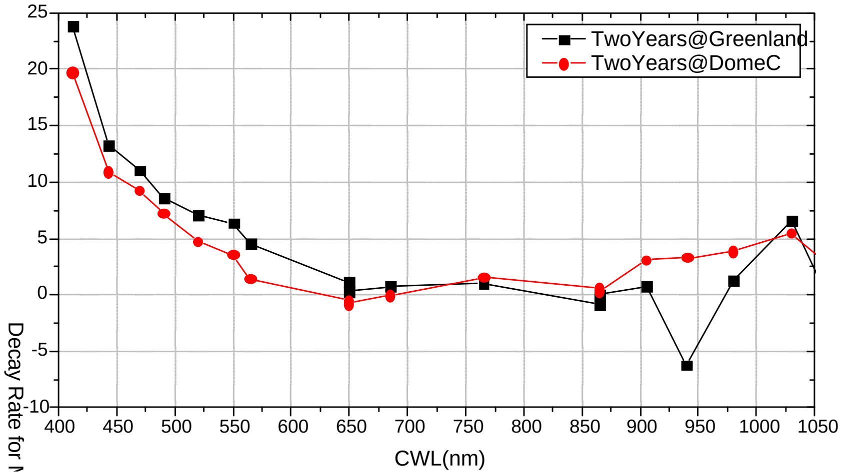


Figure 5 FY-3A MERSI degradation rate monitored through Greenland and Dome C during the pass two years

3.3 Stable bright targets monitoring

Two kinds of special moving bright targets on the earth can be used for calibration monitoring for the optical space-borne sensors. They are the deep convective cloud (DCC) and sun-glint whose reflectance is relative stable and not located in a invariant position. DCC can be identified by its infrared brightness temperature (<205K)within the intertropical convergence zone (ITCZ) near the equator. Sunglint is a phenomenon that occurs when the sun reflects off the surface of ocean at the same angle that a satellite or other sensors is viewing the surface. In the affected area of the image , smooth ocean water becomes a silvery mirror, while rougher surface waters appear dark. Figure 6 shows the DCC reflectance monitoring of FY-3A/MERSI during August 2010 to August 2010 and the degradation rates of solar reflective bands are shown on figure 7. The evident decay in band 1, 2, 8, 9,10, 20 can be found with more than 5% during the past two years. The biggest degradation in band 8 is more than 25%.

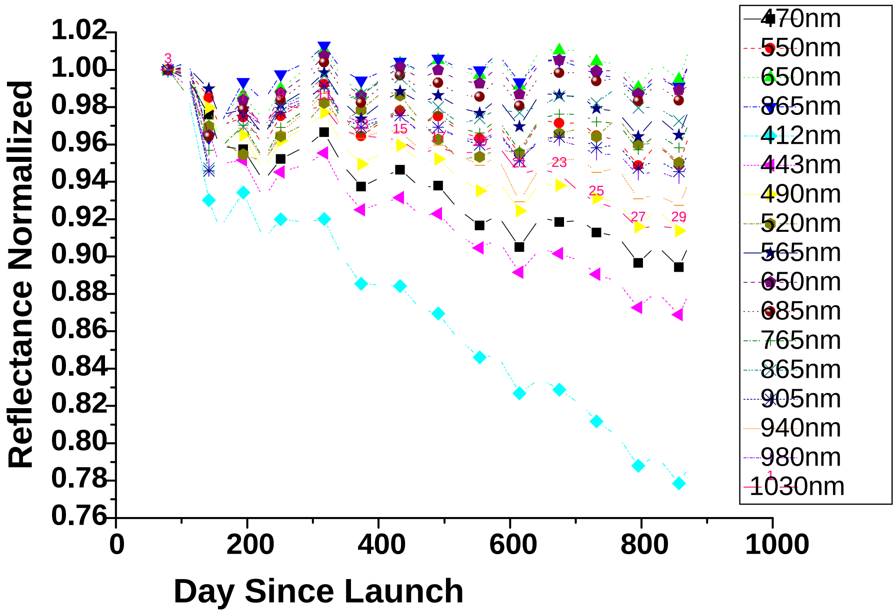


Figure 6 DCC reflectance monitoring of FY-3A/MERSI
during August 2010 to August 2010

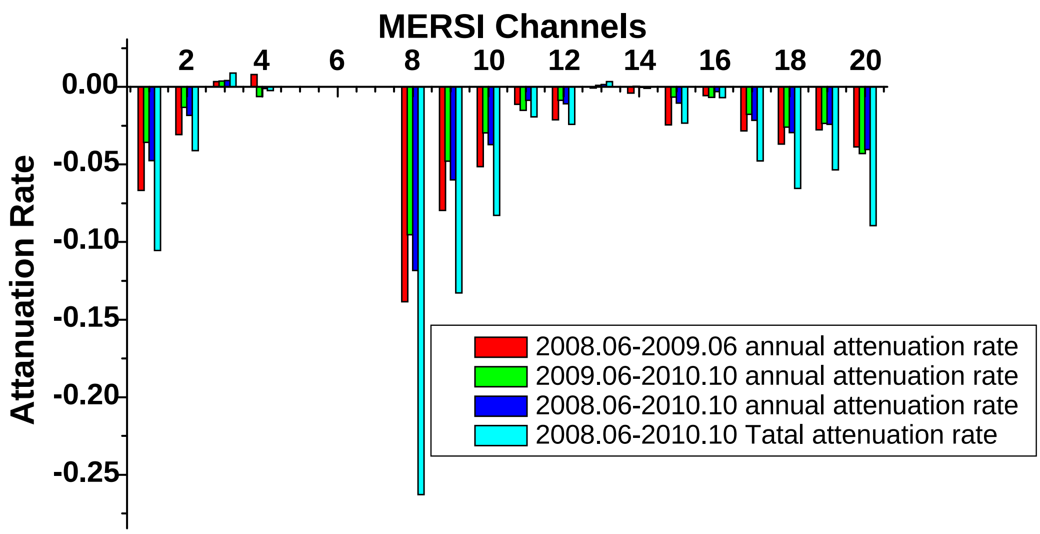


Figure 7 The degradation rate of MERSI's solar reflective bands from 2008 to 2010

4. Anomaly alert

The instrument performance monitoring shows that the DN_{sv} in three bands (band 5, 6,7) of FY-3A MERSI appear abnormal jump and lead to calibration coefficient of these bands have frequent fluctuation because of random jumping of MERSI electronic gain on orbit. IR band 5 can be calibrated using BB and SV observation in the real time. But unfortunately, band 6 and 7 can not adjust the calibration coefficient in the L1 data immediately and are needed to recalibrate them in the future.

From the calibration monitoring with several methods (see table 1)during more than two years, the shorter wavelength bands (<500nm) of the FY-3A MERSI have significant degradation performance with more than 10 and the biggest degradationin band 8 has more than 25%. The band 2, 11 and 20 have more than 5% degradation in the past. The calibration coefficients of the bands in the red and near-infrared bands (600 ~ 900nm) including band 3,4,13,14,15 and 16 almost have no change with the annual decay rate below 2%. We are giving a warning for the data users who conduct quatitative application based on these bands of MERSI (1, 2, 6, 7, 8, 9, 10, 11 and 20).

Table 1 the calibration degradation rate comparison of FY-3A/MERSI from four methods during two years

	VOC Monitoring		**Site vicarious cal**		**Cross-Cal**		**DCC Monitoring**	
Band	09/08	10/08	09/08	10/08	09/08	10/08	09/08	10/08
01	10.224	13.096	5.272	12.964	6.622	7.740	6.67	10.55
02	0.941	4.7872	5.662	7.520	1.763	2.434	3.08	4.1
03	-0.662	-0.3908	1.256	-0.14	-1.384	-2.435	-0.34	-0.89
04	-2.687	-3.7548	-1.547	-0.921	-2.127	-1.992	-0.8	-0.2
08	20.211	27.483	16.505	27.678	10.680	23.832	13.8	26.3
09	12.112	13.737	8.112	16.978	9.323	10.696	8.0	13.3
10	7.547	10.731	5.821	11.344	4.681	6.017	5.1	8.3
11	2.317	6.5656	7.362	10.176	3.224	4.218	1.1	1.9
12	1.117	2.4132	4.286	5.201	0.860	1.077	2.1	2.4
13	1.117	0.7347	0.588	-1.049	-0.757	-1.757	0.07	-0.3
14	1.269	1.3062	2.241	0.522	-0.659	-1.680	0.4	0.083
15	0.845	0.8270	2.951	2.774	0.527	0.632	2.4	2.3
16	0.516	0.9826	0.394	0.801	-1.358	-1.068	0.56	0.69
17	0.923	3.0015	0.844	3.582	3.467	6.482	2.8	4.8
18	0.198	3.0861	-4.919	2.693	11.250	21.491	3.7	6.6
19	0.067	2.3056	3.256	7.335	3.512	7.726	2.8	5.3
20	1.971	4.8511	2.720	7.5562	2.490	8.033	3.9	9.0

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