CGMS

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PROGRESS IN CALIBATIOAN OF FY-3A OPTICAL PAYLOADS

Summary of the Working Paper: The paper introduced the methods that being used 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**). To acquire accurate calibration, several measures are taken for instance to use the China Radiometric Calibration Sites (CRCS), the inter-calibration based on GSICS SNO method and sites cross-calibration method, and calibration degradation monitoring from CEOS/WGCV global reference sites. In response to recommendation from the CGMS-36, the instrument performance is monitored by the Instrument Performance Monitoring (IPM). The paper gives some preliminary results for MERSI calibration.

Progress in Calibration of FY-3A Optical Payloads

1 INTRODUCTION

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

Several calibration methods for these instruments are performed, and instruments' performance is being monitored by the Instruments Performance Monitoring (IPM). Various measures are applied to try to improve the calibration accuracy, for instance, using the China Radiometric Calibration Sites (CRCS), inter-calibration based on GSICS SNO method and sites cross-calibration method, calibration degradation monitoring from CEOS/WGCV global reference sites.

An integrated calibration system based on above methods is designed and being established in 2009. Figure 1 is the framework of FY-3A Data Quality Control System (QCS) functional requirement design for MERSI/VIRR L1 data quality assessment.

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 global reference sites image of these three sensors. This is an important database for FY-3A Optical instruments Radiance-based Calibration and Validation.

Table 1 FY-3A Optical sensors' calibration and validation activity

Instruments	Pre-flight Calibration & Characterization	On-board Calibration (OBC)	In-flight Vicarious Calibration
VIRR	-Solar-based VIS-NIR Cal. -Integrating Sphere Cal. -Thermal vacuum chamber Cal. -Spectral Response test	-Black Body -Space View	-CRCS sites Cal. -Cross calibration: AVHRR, MODIS -Intra-Calibration with VIRR
MERSI	-Solar-based VIS-NIR Cal. -Integrating Sphere Cal. -Lab thermal vacuum chamber TIR Cal. -Spectral Response test	-VIS/NIR Onboard calibrator -Black Body -Space View	-CRCS sites Cal. -Cross calibration: MODIS, MERIS -Intra-Calibration with MERSI
IRAS	-Vacuum Test -Integrating Sphere Cal.	-Black Body -Space View	-Cross Calibration: HIRS, AIRS, IASI

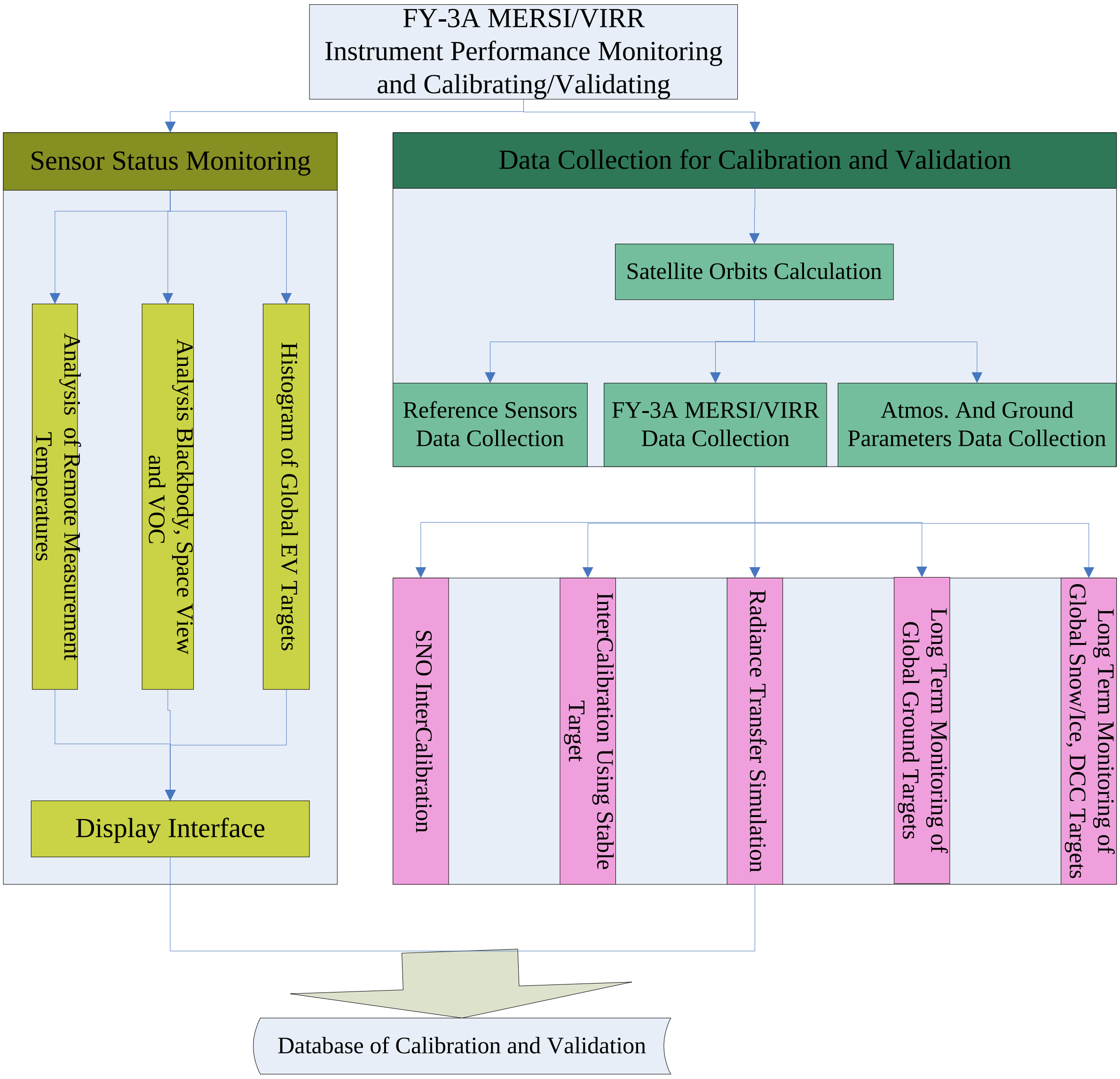


Figure 1. Optical instruments Radiance-based Calibration and Validation System Framework of FY-3A QCS

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.

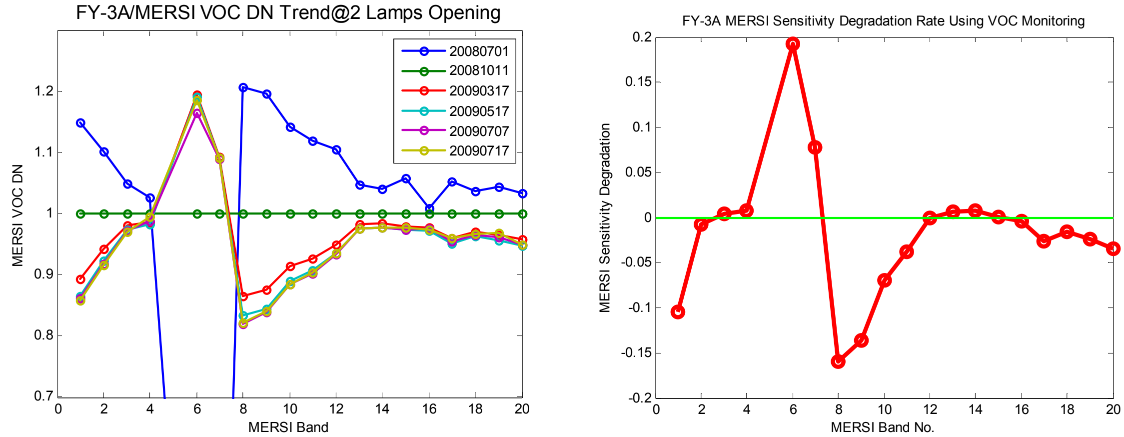
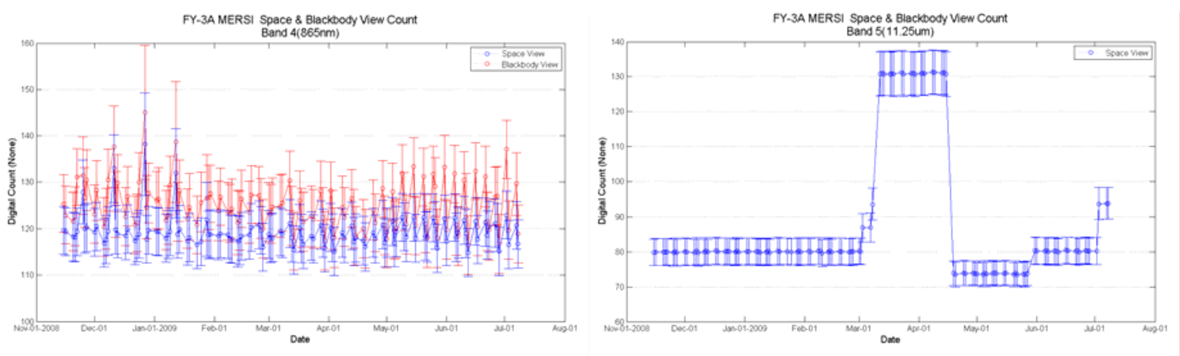


Figure 2 MERSI VOC DN at different time (left) and derived sensitivity degradation rate of 19 reflective solar bands (right)

Figure 2 (left) has shown the signal DN voc of MERSI scanning VOC at different time. The interior lamp illumination degradation was detected by the trap detectors. Finally, sensitivity degradation rate of 19 solar reflectivity bands of MERSI was derived from the scanning DN and lamp illumination degradation. It is shown at figure 2 (right). We can find the great sensitivity degradation of band 1,8,9 10 of MERSI since launch. The greatest degradation is band 8 (412nm), more than15% during one year.

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 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. IR band 5 can be calibrated using BB and SV observation at the real time. But band 6 and band 7 have to adjust the calibration coefficient based on the electronic gain level.



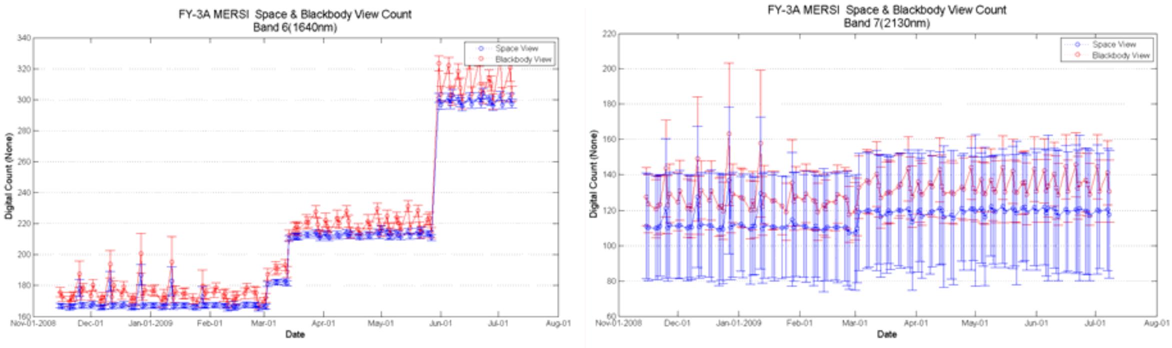


Figure 3 Scanning signal trend of space view and black body of MERSI band 4,5,6,7

3 Various calibration based on CRCS

Database of several field campaign measurements experiments in CRCS sites is already established and collected all the data of historical Cal/Val experiments in Dunhuang and Qinghai Lake. These measurements are important to calibrate and validate the L1B radiance and L2 retrieval products of satellite data.

In September,2008 and August, 2009, the ground-based synchronous experiments at the two CRCS sites (Dunhuang Gobi, Qinghai Lake) were conducted for vicarious calibration and validation for these three sensors.

We also verified the radiometric response degradation based on these two vicarious calibration analysis during 2008 and 2009.

4 Cross-calibration

4.1 SNO method

CMA GSICS Processing and Research Center (GPRC) located at NSMC is being constructed since June, 2008. Firstly it's goal is running the common GSICS GEO-LEO algorithm for FY-2C/2D. This algorithm is also used for reference for LEO-LEO IR bands of MERSI, VIRR and IRAS using AIRS and IASI. The algorithm experiment of GSICS LEO-LEO was tested for these FY-3A's optical sensors in July, 2009.

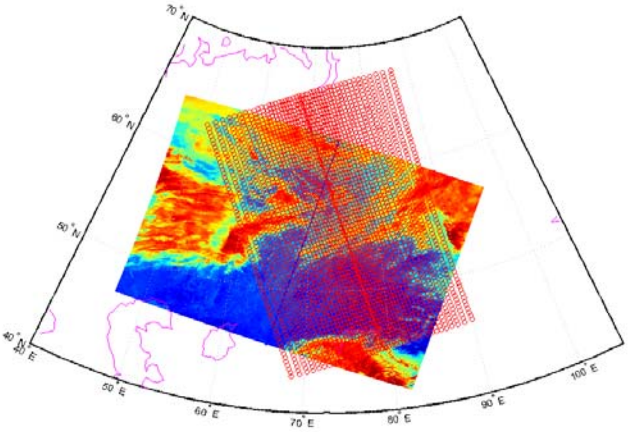


Figure4 Collocation map of VIRR(bottom image) and AIRS (overlay Grid)

We collected some L1 data of AIRS, IASI with FY-3A simultaneous nadir observation (SNO). Figure 5 gave the result of inter-calibration of Band 5 of MERSI and band 4-5 of VIRR. It found that the radiance of band 5 of MERSI is larger than both collocated radiance of AIRS and IASI . The result of VIRR IR bands shown that band 4 was perfectly consistent with both of them, but band 5 radiance was a little lower than both of them. The next step of this job will be done operationally automatically after it is tested successfully.

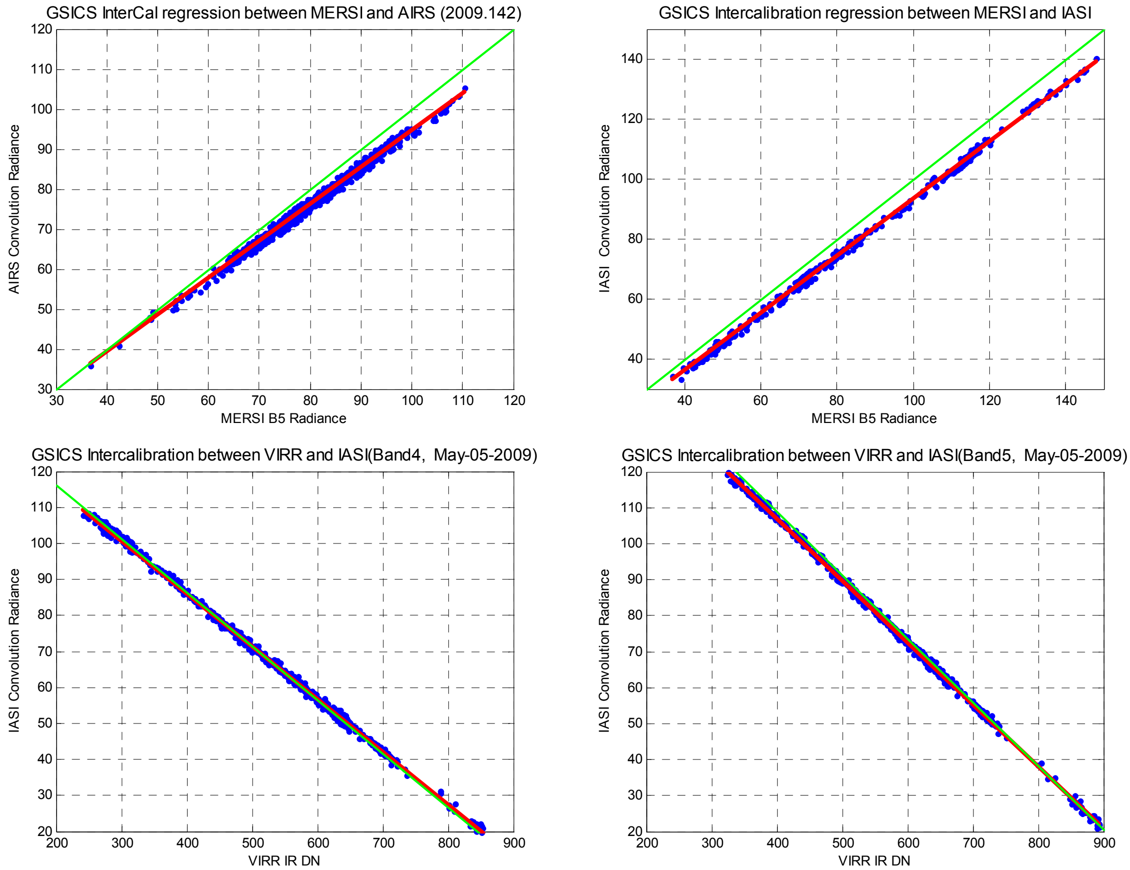


Figure 5 GSICS LEO-LEO inter-calibration for MERSI (top) and VIRR(bottom) with AIRS and IASI

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 bands of MERSI/VIRR based on the global SNO observation with them. To reach the goal, the orbit prediction of FY-3A and Terra/Aqua is the firstly job and the location and time of their SNO give the guide of data collection for SNO inter-calibration. There are 18 bands of MERSI similar to MODIS's bands. SNO method is used to assess MERSI radiance accuracy.

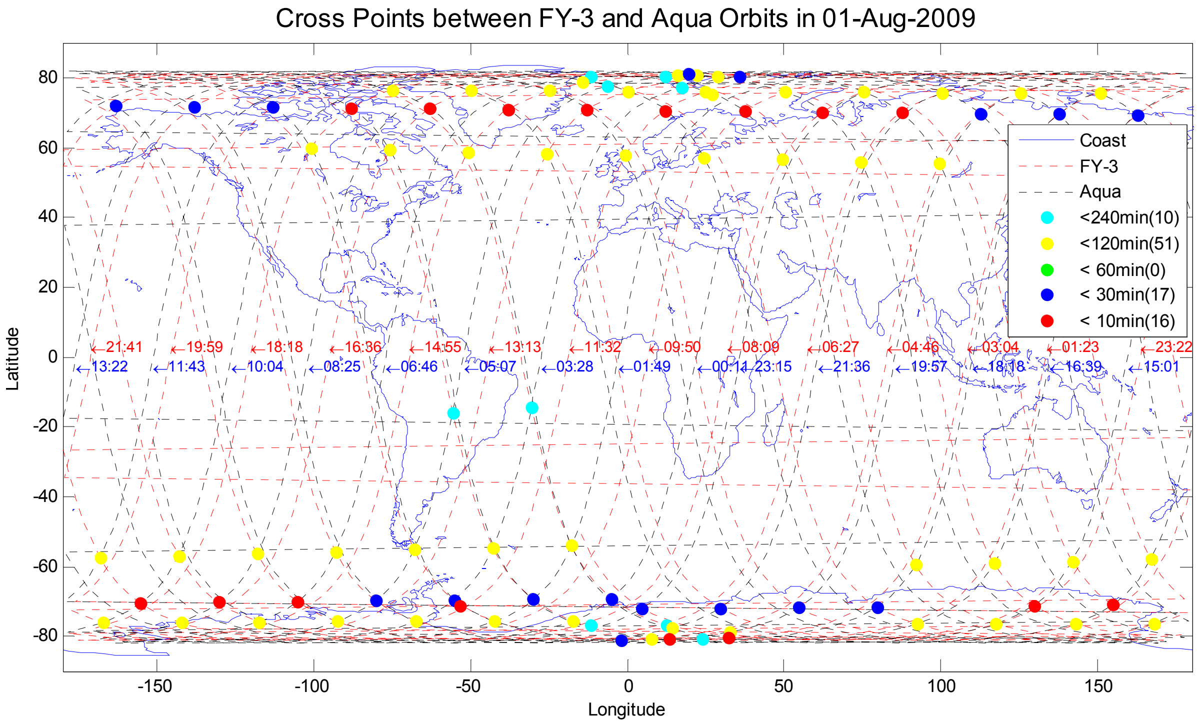


Figure 6 SNO Cross Point between FY-3 and Aqua orbit in Aug. 01, 2009

4.2 Sites Cross calibration

An inter-calibration method was proposed by J. J. Liu et al. (2004), and is solar bands. Essentially, the Earth Observing System (*EOS*) *Terra* MODerate resolution Imaging Spectroradiomter (MODIS) was used as a reference sensor, because of its excellent calibration accuracy and local overpassing time similar to *FY-3A*. During July 2008 and June 2009, clear sky measurements over the Gobi Desert Dunhuang site were collocated from MODIS and MERSI. Using the 6S radiative transfer model, MODIS reflectance measured at the top-of-the atmosphere (TOA) is converted into surface reflectance. They were corrected to the viewing geometry of the MERSI using the bidirectional reflectance distribution function (BRDF) measured on the ground. The BRDF-corrected surface reflectance data were interpolated with a spline function to obtain a continuous surface reflectance spectrum. With the MERSI spectral response function, the BRDF-modified and interpolated spectral reflectances were further converted to TOA values from the 6S radiative transfer model and the same atmospheric conditions used for MODIS. Using observations of dark space from the MERSI as another point, the sensor gains of all 19 reflective solar bands were computed for all the matched data.

As a typical example, apparent reflectance calibration result(*Scale* and *Offset*) for MERSI Band 8 are showed in Figure 1The data at 27 June 2008 is the pre-launch calibration data. It can be found that this band's response gain (1/*Scale*) has obviously degraded through the past year. If we assume that this kind of degradation is nearly linear, the linear regression of *Scale* reflects the sensors degrading rate, and the fluctuation of *Scale* around the linear regression line (standard deviation, σ) reflects the uncertainty of the calibration. These analysis data are show on the upper-left corner of the figure. It can be seen from Table 1 that, apart from bands 6 and 7 (the SWIR bands) and bands 17, 18, and 19 (bands around water WIR band's response gains, during the past year because of unknown reasons. Thus, their calibration uncertainties and degradation rates determined using regression become meaningless. As for the water vapor absorption bands (bands 17, 18 and 19), the uncertainty of this kind of inter-calibration method is still too high to be accepted. Bands 8 and 9 have the biggest degradation rates of 17% and 8% per year, respectively. Bands 1, 2, 7, 10 and 11 have medium degradation rates, ranging from the other bands, except the two SWIR bands (bands 6 and 7) and three water vapor absorption bands (bands 17, 18, and 19) have a near stable gain with the degradation rates less than 2% per year.

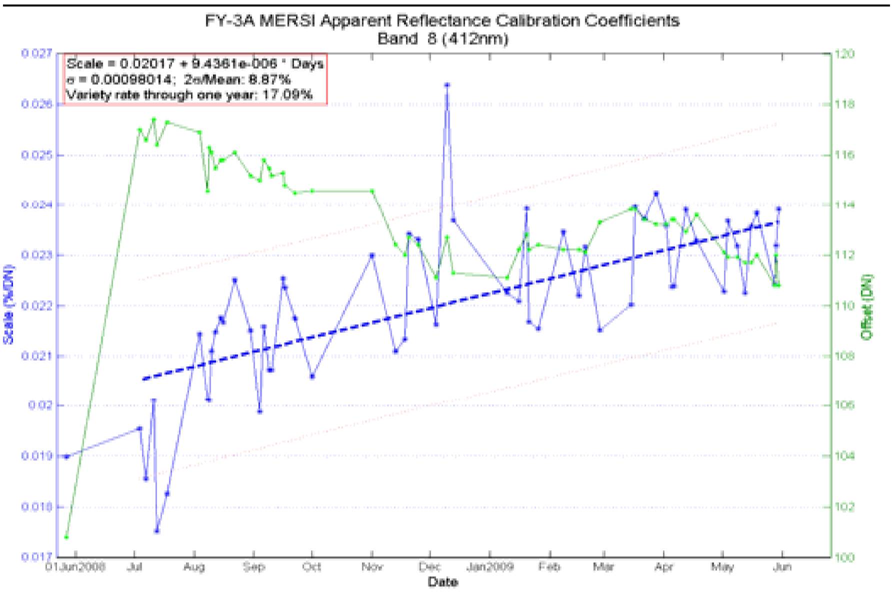


Figure 7 Calibration coefficient trend of band 8 of MERSI from site cross-calibration using Dunhuang

Table 1: FY-3A MERSI reflective solar band calibration result

Apparent Reflectance = Scale * (DN_EarthView - DN_SpaceView) (%)						
Scale = (a + b * Days) = a*(1 + RatePerDay/100 * Days) (%/DN)						
Band	a (%/DN)	b (%/DN/Days)	Sigma	2*Sigma /Mean (%)	Degrading rate per year (%)	Degra p b/a
Band1 (470nm)	0.030118	4.572529E-06	0.001173	7.56	5.55	
Band2 (550nm)	0.029632	2.065158E-06	0.000925	6.16	2.55	
Band3 (650nm)	0.024527	-8.941898E-07	0.000680	5.59	-1.33	
Band4 (865nm)	0.030311	-2.980523E-06	0.000701	4.72	-3.59	
Band6 (1640nm)	0.027445	-5.305546E-06	0.003603	27.32	-7.06	
Band7 (2130nm)	0.021856	2.211232E-06	0.001362	12.21	3.70	
Band8 (412nm)	0.020170	9.436122E-06	0.000980	8.87	17.09	
Band9 (443nm)	0.022917	5.312842E-06	0.001248	10.40	8.47	

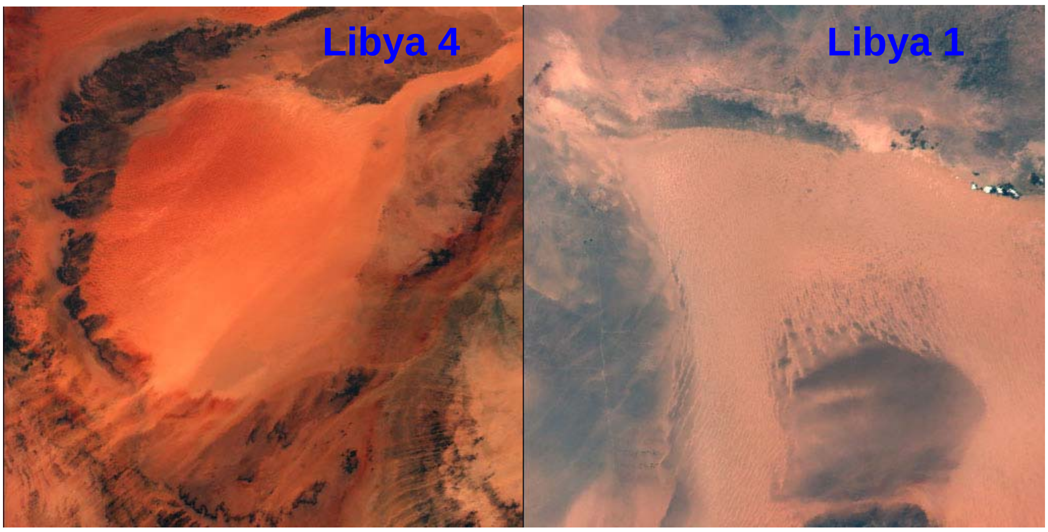
Band10 (490nm)	0.023948	2.614209E-06	0.000809	6.61	3.99
Band11 (520nm)	0.019706	2.051222E-06	0.000641	6.37	3.80
Band12 (565nm)	0.023638	7.285297E-07	0.000732	6.16	1.13
Band13 (650nm)	0.022591	-1.309099E-06	0.000669	5.99	-2.12
Band14 (685nm)	0.021496	-6.089693E-07	0.000630	5.89	-1.03
Band15 (765nm)	0.026490	1.332078E-06	0.000718	5.36	1.84
Band16 (865nm)	0.021895	-3.680938E-07	0.000518	4.75	-0.61
Band17 (905nm)	0.026756	-5.523997E-06	0.001429	11.15	-7.54
Band18 (940nm)	0.041539	-3.265701E-05	0.005676	32.54	-28.71
Band19 (980nm)	0.025491	-5.625800E-06	0.001345	11.04	-8.06
Band20 (1030nm)	0.027750	1.358855E-06	0.000688	4.91	1.79

5 Calibration monitoring using 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.

5.1 Deserts reference sites

The North African and Saudi Arabian desert sites consist mainly of sand, 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.



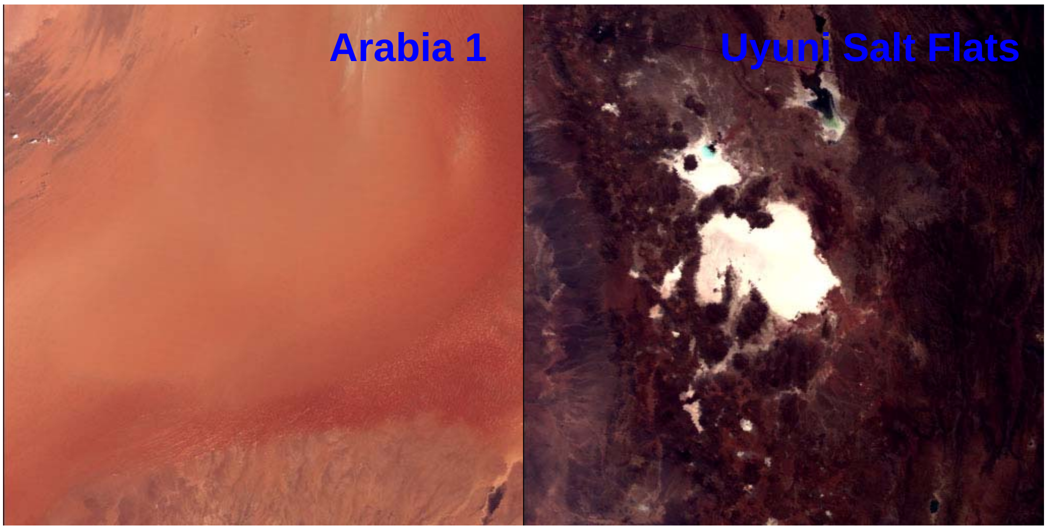


Figure 8. Some reference Sites RGB images of MERSI

5.2 Snow Ice sites

The approach (N. G. LOEB, 1997)involves using calibrated AVHRR near-nadir reflectances over spatially and temporally uniform ice-surfaces from Greenland and Dome C to produce 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 reflectances from new observation signal (DN) in the following year with these prediction models and old calibration coefficients in 2008, respectively, Calibration trends are obtained in the year-round degradation rate.

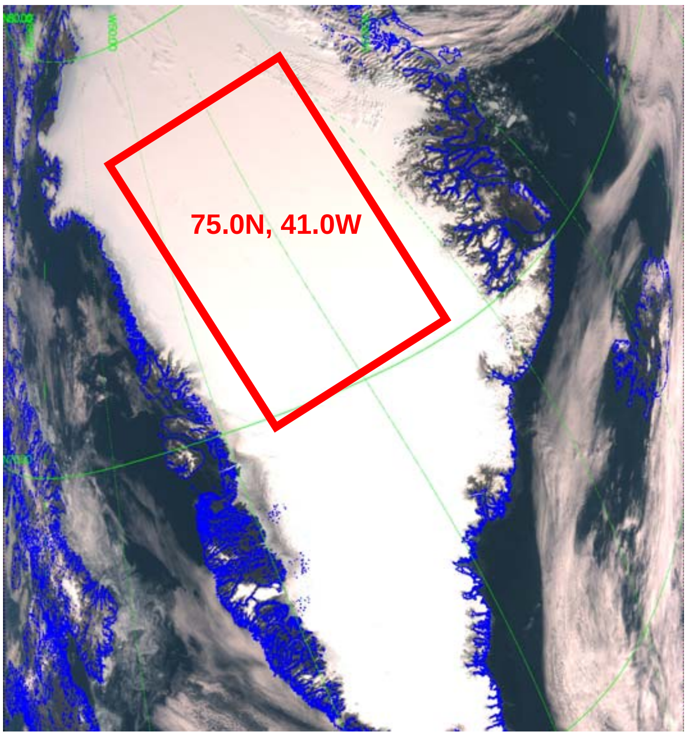


Figure 9. Greenland image of MERSI and analysis area (red square)

for calibration monitoring

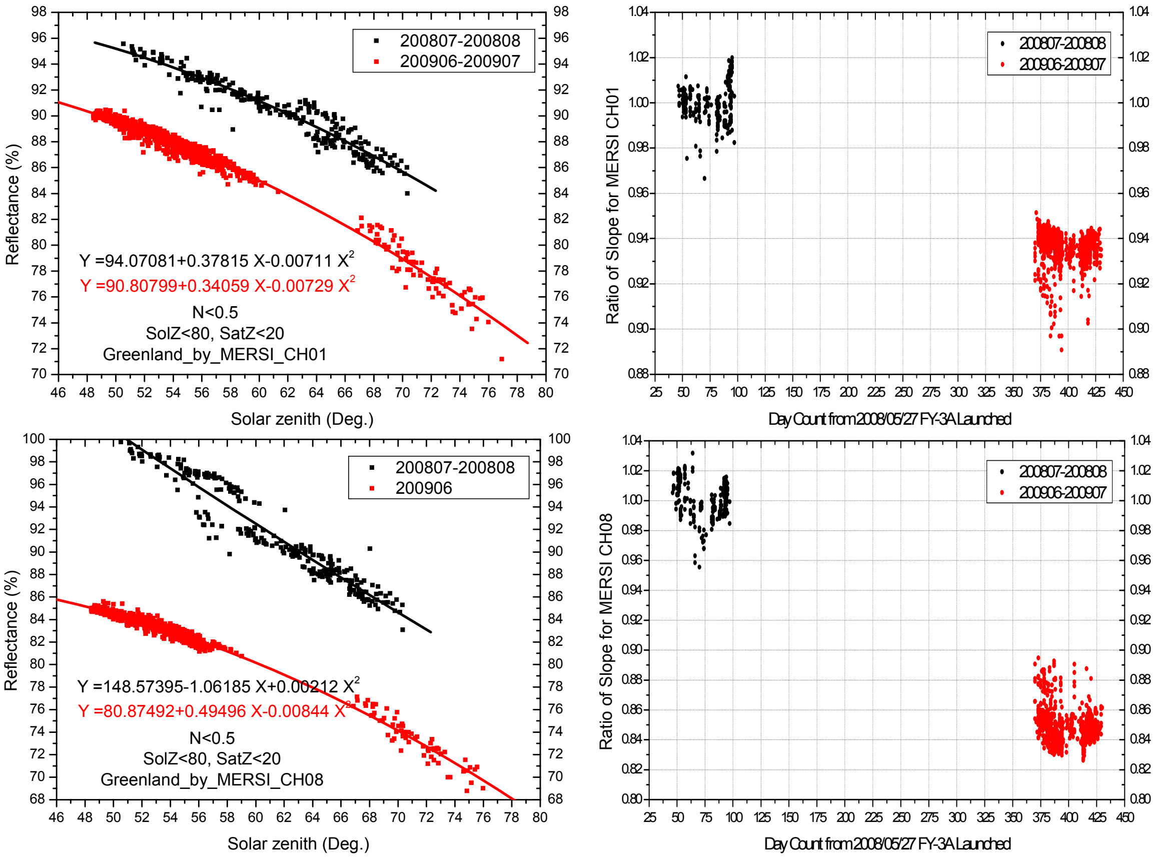


Figure 10 MERSI Calibration year-round degradation rate using Greenland observation during 2008 to 2009

Table 2 MERSI calibration degradation rate from 2008 to 2009 using Greenland observation

Band	Degradation Rate％	Band	Degradation Rate％
01	-6.38	11	-4.32
02	-3.52	12	-2.18
03	+0.13	13	-1.01
04	+1.12	14	-0.99
05	/	15	+0.19
06	179.61?	16	-0.23
07	-14.72	17	-1.22
08	-15.04	18	+1.29
09	-8.51	19	-0.96
10	-4.90	20	-4.37

6 Action Plan in the near future

CSTOI of FY-3A in NSMC/CMA will continue to monitor and assess the calibration accuracy and provide the update of calibration coefficient of FY-3A's optical instruments. Under QCS of FY-3A and CMA GPRC, The priority of next job will realize IR GSICS calibration for MERSI/VIRR/IRAS into routine operation. It is also important for establishing a near real-time monitoring system of instrument performance of FY-3A optical sensors (IPM-FY3). At the same time, global reference sites image Database (Similar SADE) from MERSI/VIRR is very necessary and useful for calibration monitoring based on these reference sites.

Table 2 Timetable of Actions to Implement GSICS for FY-3A in NSMC

Action	Responsibility	Target Date
Realize IR GSICS calibration for MERSI/VIRR/IRAS into routine operation	NSMC	Jun., 2010
Establish a near real-time monitoring system of instrument performance of FY-3A optical sensors	NSMC	Dec., 2010
Establish SADE global database from MERSI/VIRR	NSMC	Dec., 2010
Calibration monitoring method based on WGCV reference sites	NSMC	Jun., 2010

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