COMS VISIBLE CHANNEL CALIBRATION

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Abstract

COMS (Communication, Ocean, and Meteorological Satellite) has been fully operating its own missions since April 2011. COMS has Meteorological Imager (MI) for observing weather phenomena which has one visible and four infrared channels.

KMA has been conducting inter-calibration for infrared channels. The inter-calibration system using COMS for infrared radiation is based on the GSICS (Global Space-based Inter-Calibration System) Coordinate Center (GCC) Algorithm Theoretical Basis Document (ATBD). The hyperspectral Infrared Atmospheric Sounding Interferometer (IASI) on the low Earth orbit Metop-A satellite is used as reference instrument.

For visible channel calibration, KMA had developed vicarious calibration of visible channel using cloud-free ocean, cloud-free desert (Australian Simpson), water cloud (WC) and Deep convective cloud (DCC) targets. Regular observation data of MI such as Full Disk (FD), Extended Northern Hemisphere (ENH) are used for this vicarious calibration, and Radiative Transfer Model (RTM) is used for simulated results with the MODIS, NCEP, OMI data as ancillary data. The results of visible vicarius calibration from Sep. 2011 to Apr. 2013 showed that the observed values of COMS MI is corresponding to 86.5% of the valued of the simulation which is regarded as reference values. The degradation slope of VI channel is about 3.28%(2.07%/year) for one and half years from Sep. 2011 to Apr. 2013. In additons, for monitoring COMS visible channel degradation trend NMSC has been obsering moon twice a month since Feb 2011. The observed moon data have been processed by Moon Processing system in NMSC's operational Image Processing Subsystem. This Moon Processing system calculated the total irradiance of observed moon data to compare with the value of ROLO (the RObotic Lunar Observatory) model of USGS, which is an empirical model of the lunar disk reflectance as a function of its phase angle (the angle between the Moon-Sun direction and Moon-Earth direction), irrespective of the librations and the properties of the Moon surface. The visible channel degradation from Sep. 2011 to Apr. 2013 is about 4.36% and this is corresponding to 2.75%/year.

INTRODUCTION

COMS (Communication, Ocean, and Meteorological Satellite), the first Korean geostationary meteorological satellite, has been fully operating its own missions since April 2011. COMS, in longitude 128.2°E, is performing the duties of meteorological and ocean observations and communications services.

Meteorological Imager(MI) of COMS has one visible and four infrared channels. For the infrared channels, the on-board calibration is conducted from blackbody. However, there is no on-board calibration target for visible channel such as solar diffuser. Thus, ground calibration is needed for calibration and monitoring of visible channel degradation. For this, KMA chose the vicarious calibration methods using five targets: ocean, desert, water cloud (WC), deep convective cloud (DCC) and the moon, whose properties are well-known for calculating top-of-atmosphere reflectance or irradiance. As the vicarious calibration used the indirect comparison between true values and observation values, simulated values from models are assumed to be the true results. Main flow of vicarious calibration method is comprised of selecting suitable targets and applying adequate model for each targets.

DATA

The meteorological mission and data service of COMS has begun since 00UTC on 1st April 2011. Normally COMS MI measurement has two different observation modes: Full Disk (FD) and Extended Northern Hemisphere (ENH). And COMS MI produces FD imagery every 3 hours and ENH imagery every 15 minutes (Table 1).

Channel	Wavelength Range(㎛)	Center Wavelength(㎛)	Spatial Resolution(km)
Visible	0.55~0.8	0.67	1
Shortwave Infrared (IR4)	3.5~4.0	3.7	4
Water Vapor (IR3)	6.5~7.0	6.7	4
IR1	10.3~11.3	10.8	4
IR2	11.5~12.5	12.0	4

Table 1 : **Specification of MI channels.**

Besides of COMS MI data, several ancillary data are used to decide whether pixel is satisfied with the thresholds for application to calibration and as input data for models.

For selecting clear ocean targets, SeaWiFS monthly climatology, NCEP wind speed and direction, and MODIS aerosol optical thickness, are used. As for model inputs, NCEP total precipitable water, OMI column ozone amount, aerosol optical thickness and Ocean Bidirectional Reflectance Distribution Function (BRDF) are used.

For desert calibration, NCEP total precipitable water, OMI column ozone amount, ASTER spectral albedo and MODIS BRDF parameter are used as inputs for model.

For WC targets, MODIS cloud products are used to select cloud pixels and as inputs of model.

DCC method used the Brightness Temperature from COMS IR1(10.8 μm) data to select clouds overshooting tropopause layer. Both WC and DCC methods used Ocean BRDF for surface condition and tropical atmospheric profile.

Lastly, the moon is directly observed by COMS MI at twice a month, thus it is not needed the filtering correct moon target,but the supplement data: the position data of the sun, the moon, the earth and COMS at observation time.

Targets	Source	Ancillary data
Ocaen	FD, ENH	MODIS(MOD03, MOD04_L2, MOD35_L2), OMI(Ozone),

		NCEP/NCAR Reanalysis(TPW, UWIND, VWIND), CHLA(SeaWiFS monthly climatology)
Desert	FD	MODIS(MCD43C1.005(BRDF)), OMI(Ozone), NCEP/NCAR Reanalysis (TPW, Total Precipitation Water)
Water Cloud	FD, ENH	MODIS(MOD021KM, MOD06_L2)
Deep Convective Cloud	FD, ENH	COMS IR1(10.8 µm)
Moon	Direct observation at twice a month	The information data about positions of the sun, the moon and COMS

Table 2 : **Data of each target for vicarious calibration of COMS MI visible channel**

METHOD

The accuracy of simulated values is a major factor for vicarious calibration. For obtaining accurate simulated values, the targets should be restricted to have well-known properties for improving outcomes of models. And adequate model should be chosen for each target. The process of vicarious calibration can be divided into two parts: one is the selecting process of target pixels or areas from observation data for calibration, and the other is the simulating process of chosen target area. In these processes, ancillary data are needed for filtering the suitable target data from normal data and as input data of model.

The ocean targets are usually homogeneous and dark but should be considered only a clear pixel without a cloud for sensor calibration. All selected ocean pixels for KMA's calibration methods are satisfied with no cloud, no sun-glint, less than 0.1 aerosol optical thickness (AOT), and less than 7m/s wind speed. For selecting pure ocean pixels, land/sea mask of MODIS cloud products are also used. For verifying the thresholds for AOT and wind speed, MODIS AOT data and NCEP wind data are used, respectively. When the suitable ocean pixels are selected, 6S (Second Simulation of the Satellite Signal in the Solar Spectrum) radiative transfer model simulates the top-of-atmosphere (TOA) reflectance. US62 atmospheric profile is assumed. The atmospheric conditions are derived by TPW of NCEP/NCAR Reanalysis and amounts of ozone from OMI. The reflectance of ocean pixels is affected by aerosol relatively, because the surface reflectance is so small. Therefore, AOT has to be considered as an ancillary data in radiative transfer modeling. In addition, it has the advantage that radiance can be calculated without BRDF (bidirectional reflectance distribution function) because the surface reflectance of the ocean is nearly homogeneous.

KMA conducted desert calibration for 11 fixed desert targets of Simpson Desert in Australia. 6S RTM is used for simulating TOA reflectance. Model input are geometry information of the sun and COMS satellite, the atmospheric and the surface conditions at observation time. US62 vertical profile is base of the atmospheric conditions. And NCEP TPW data and OMI ozone are used. Additionally, for calculating simulated TOA reflectance in model, BRDF values with 2.5nm interval at each wavelength are needed. KMA use MODIS BRDF parameter generated every 7days. But, since this parameter only corresponds to each band, albedo data depended on surface type for each wavelength from ASTER spectral library are used with MODIS BRDF parameter for generating BRDF with 2.5nm.

For WC target, atmosphere and surface effects can be minimized in the simulation of TOA radiance due to strong reflection of cloud layer. Cloud optical thickness (COT) and cloud top temperature (CTT) are thresholds of WC pixels in WC method of KMA. The thresholds of COT is more than 5 and CTT is more than 273K in which condition, cloud is assumed to be water cloud, or less than 227K in which condition, cloud is assumed to be ice cloud. The information of COT and CTT are from MODIS cloud products. The model of WC method is SBDART (Santa Barbara DISORT Atmospheric Radiative Transfer). The cloud altitude from cloud top pressure (CTP) and particle size of cloud are used in radiative transfer modeling.

DCC target has the largest reflectance range among ocean, desert, WC and DCC. DCCs chosen by the method are assumed to be distributed from 1km to 15km. COT and particle size of the DCC are assumed to be 200 and 20, respectively. For searching these DCC, The brightness temperature from COMS IR1(10.8µm) channel data and the thresholds of the DCC are determined to be less than 190K which threshold is a narrow condition for detecting DCC. The model for DCC is SBDART same as WC method.

The moon is good source for visible calibration. Since there are no atmosphere between the moon and a satellite, the effect of atmosphere can be minimized. And the periodical characteristics of shape and brightness of the moon allows to be simulated its irradiance. But, the moon is located in outer area of the earth, and the moon is not included in the regular observation timeline. Thus, the moon needs to be observed specially by sacrificing the parts of regular observation. It is based on the lunar database provided by the RObotic Lunar Observatory (ROLO) of USGS that describes an empirical model of the lunar disk reflectance as a function of the phase angle (the angle between the Moon-Sun direction and Moon-Earth direction) and irrespective of the librations and the properties of the Moon surface.

Targets	Source	Ancillary data
Ocaen	No cloud, No sun-glint, AOT < 0.1, Wind speed < 7m/s	6S
Desert	11 fixed targets of Simpson desert in Australia	6S
Water Cloud	COT ≥ 5, CTT ≥ 273K or ≤ 227 K	SBDART
Deep Convective Cloud	$TB_{10.8}$ ≤ 190K	SBDART
Moon	Bright side of the moon	ROLO

Table 3 : **Requirements and model of each target**

RESULTS

The left panel in Figure 1 is the scatter plot by using ocean, desert, WC and DCC from Sep. 2011 to Apr. 2013. The slope of regression line is 0.864972 and the intercept is 0.024729. From the slope, we can find that the values of COMS observation are corresponding to 86.5% compared with simulated values. To confirm the stability of the values of the COMS data, time series checks were performed during same periods. The monthly time series of slopes and intercepts show that the slopes are between 0.83 and 0.9 and the intercepts are between 0.01 and 0.05. From the change of slopes, the performance degradation is clearly shown in MI visible channel.

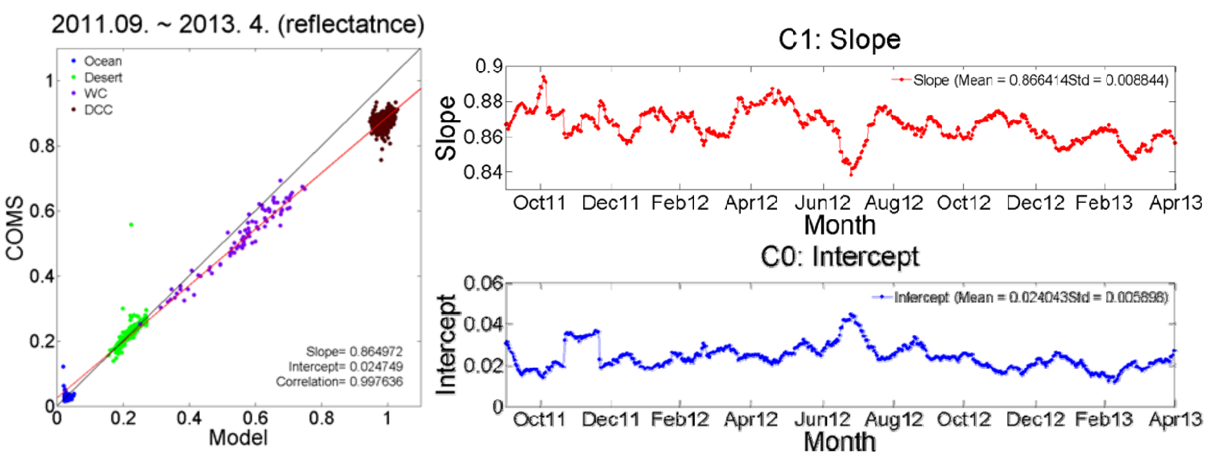

Figure 1 : **Scatter plots of observed reflectance for COMS versus the corresponding simulated reflectance from Sep. 2011 to Apr. 2012 for all targets(left) and The monthly time series of slopes and intercepts(right)**

Date	Slope	Intercept	Date	Slope	Intercept
2011.09	0.866794	0.030549	2012.07	0.847942	0.039423
2011.10	0.883913	0.015551	2012.08	0.871089	0.024997
2011.11	0.865026	0.033198	2012.09	0.870726	0.023313
2011.12	0.869005	0.020513	2012.10	0.859446	0.025622
2012.01	0.873601	0.018751	2012.11	0.873348	0.016775
2012.02	0.871341	0.025278	2012.12	0.859193	0.022906
2012.03	0.860161	0.026934	2013.01	0.856222	0.021422
2012.04	0.878237	0.024862	2013.02	0.864552	0.014774

2012.05	0.881722	0.025316	2013.03	0.854285	0.018082
2012.06	0.870585	0.027393	2013.04	0.856494	0.02709

Table 4 : **Monthly results of the slope, intercept from Sep. 2011 to Apr. 2013 for all targets**

The averaged monthly ratio between observed and simulated values from the desert target is the highest among all targets. The average of the ratio values of desert is about 101.2. And the lowest average is the DCC, of which the average is about 88.8%. From Figure 2 and Table 5, the mean values of ratio for each target are between -2.5~ -1.2%/year from Sep. 2011 to Apr. 2013. All methods for respective targets are different from each other. But, all targets have the similar trend with negative slope.

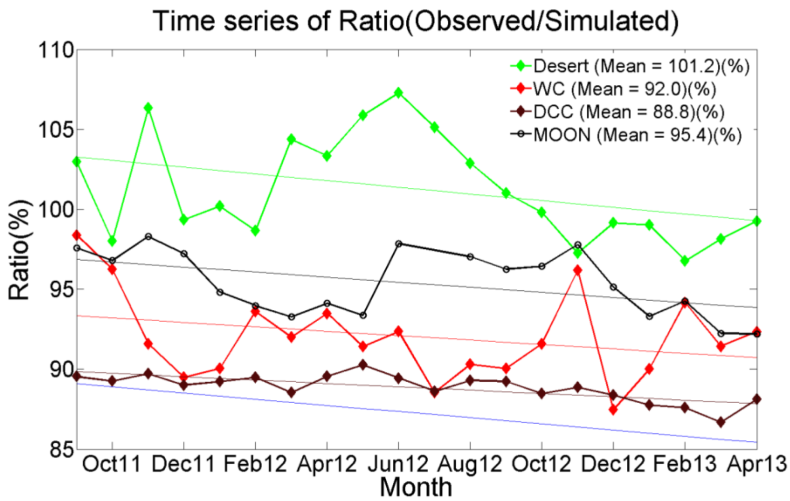

Figure 2 : **Monthly time series of ratio with observed per modeled values for desert, WC, DCC, moon targets**

	Slope	Intercept	Change of means(%/year)
Desert	-0.2093	103.2595	-2.5116
Moon	-0.1588	96.8657	-1.9056
WC	-0.1384	93.3438	-1.6608
DCC	-0.1050	89.8470	-1.26

Table 5 : **Slopes and intercepts of regression lines for each target**

Figure 3 are performance of MI visible channel. In these figure, top panel is from the moon results, calculated by the observed per simulated date, and bottom panel is obtained by the change of slopes from regression lines of monthly scatter plot generated from ocean, desert, WC and DCC. The red lines are the regression line of each figure.

The degradation are about 4.36%(2.75%/year) from the moon and 3.28%(2.07%/year) from the other 4 targets from September 2011 to April 2013. From several researches, which show about 4~5%/year degradation for visible channel, for the sensor compatible with COMS MI such as imagers of GOES series and MTSAT, we can consider that the COMS MI are stable sensor.

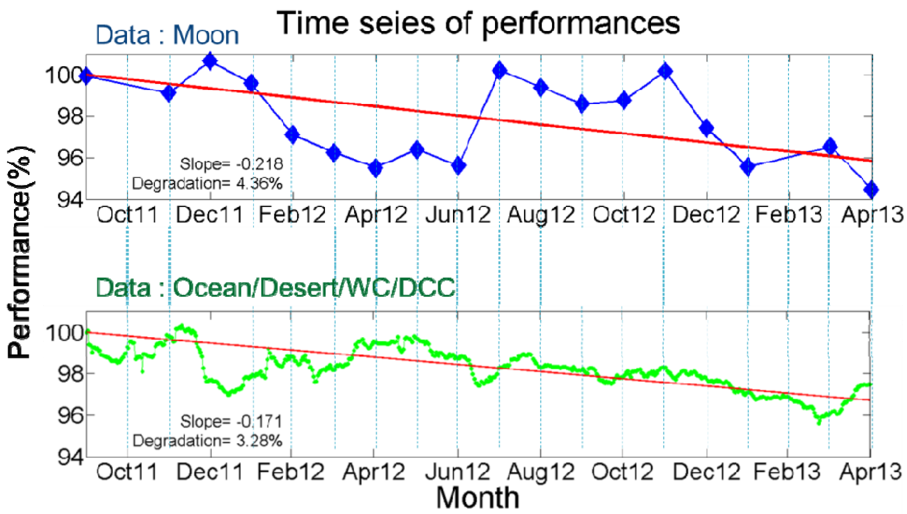

Figure 3 : **Time series of performances from Sep. 2011 to Apr. 2012 for the moon(up) and the other targets(bottom)**

Date	Moon(%)	Ocean, desert, WC, DCC(%)	Date	Moon(%)	Ocean, desert, WC, DCC(%)
2011.09	99.93	100.00	2012.07	None	98.76
2011.10	99.12	100.03	2012.08	99.38	98.89
2011.11	100.66	99.67	2012.09	98.59	98.78
2011.12	99.57	98.85	2012.10	98.76	98.72
2012.01	97.10	98.44	2012.11	100.15	99.09
2012.02	96.24	99.48	2012.12	97.43	98.38
2012.03	95.51	98.46	2013.01	95.56	97.63
2012.04	96.38	99.69	2013.02	96.53	97.87
2012.05	95.61	100.11	2013.03	94.47	96.28
2012.06	100.21	99.37	2013.04	94.44	97.60

Table 6 : **Monthly performances based on Sep. 2011 generated from the moon and the other 4 targets from Sep. 2011 to Apr. 2013 for all targets**

SUMMARY

For confirming the radiometric performance of COMS, National Meteorological Satellite Center(NMSC/KMA) has its own visible-calibration system. KMA's visible calibration system is a vicarious calibration, which is the method comparing sensor observation values and simulated values for specified targets such as ocean, desert, water cloud, deep convective cloud and the moon. The observation values for these targets are able to be simulated, because the targets have well-known properties and applicable models for simulation such as 6S, SBDART, ROLO.

According to the results from the scatter plot with ocean/desert/WC/DCC from September 2011 to April 2013, the COMS observed values are corresponding to 86.5% of the simulated values. The slopes of regression lines generated from monthly scatter plot are decreasing with time.

The mean values of ratio with all targets except ocean target are between -2.5 and -1.2 %/year from September 2011 to April 2013. The slopes of regression line of the ratios for each targets are all negative, which are within -0.2093 to -0.1050.

The analysis of the monthly slopes and the ratios with observed per simulated values shows that there is performance degradation in visible channel. The degradation of COMS visible channel is about 2.75%/year from the moon. 2.07%/year from the other 4 targets from September 2011 to April 2013.

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