P1.4 **CALIBRATION FOR THE SOLAR CHANNEL USING MODIS-DERIVED BRDF PARAMETERS OVER AUSTRALIAN DESERT TARGETS**

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1. INTRODUCTION

Communication Ocean Meteorological Satellite (COMS) to be launched at 2008 will be the first Korean geostationary satellite. The Meteorological Imager (MI) aboard the COMS will measure the reflected solar radiation within a spectral band (550 ~ 800 nm) as well as emitted infrared radiation at 4 spectral bands. The retrieval of quantitative parameters requires the absolute calibration of the radiometer and monitoring of its drift. As no in-flight calibration device will be available for the solar channel, vicarious calibration is required for producing level 1.5 data.

In this study we develop a method utilizing satellite-derived BRDF for the calculation of TOA radiance which then will be used for the COMS solar channel calibration. We chose bright desert targets that are assumed to be less influenced by clear-sky atmospheric conditions because of larger surface reflection. Spatial and temporal variations of MODIS-derived nadir bidirectional reflectance distribution function (BRDF) were examined over the Australian Simpson and Strzelecki desert, and then targets showing smallest variations were selected as test targets. At the selected targets, seasonally varying BRDFs were used as inputs to a radiative transfer model to simulate visible channel radiances. Computed radiances were then compared with MODIS-observed radiances to evaluate the degree of uncertainties of this approach because COMS will be launched in near future.

2. METHOD

There are five steps in this vicarious calibration method using desert targets: 1) sensitivity test, 2) target selection, 3) satellite-level radiance estimation 4) cloud and sand storm detection, and 5) validation.

2.1 Sensitivity test

Sensitivity studies have been carried out in order to properly evaluate the importance of input parameters when the satellite level radiance was estimated by using Second Simulation of the Satellite Signal in the Solar Spectrum (6S) model (Vermote *et al.* 1997). The sensitivity of the satellite-level radiance to various parameters is shown in Table 1. for a given reference condition. The result shows that geometry angles, water vapor, ozone and aerosol optical thickness are not dominant parameters. But the accurate knowledge of the surface reflectance is important to properly characterize the satellite-level radiance.

Table 1. 6S model input parameters used for sensitivity test for MODIS band 1. Required accuracy is that parameter change induced for +1% radiance error.

Input parameter	Reference condition	Required accuracy
Solar zenith angle (°)	33	- 0.88
Satellite zenith angle (°)	40	- 12.3
Relative azimuth angle (°)	85	- 6.94
Water vapor (g/cm^2)	3.5	- 2.7
Ozone (DU)	310	- 56
Aerosol optical thickness	0.2	+ 0.26
Surface reflectance	0.27	+ 0.003

2.2 Target selection

We have identified four criteria for target selection. The four criteria are the brightness, spatial uniformity, temporal stability and spectral stability (Mitchell et al. 1997).

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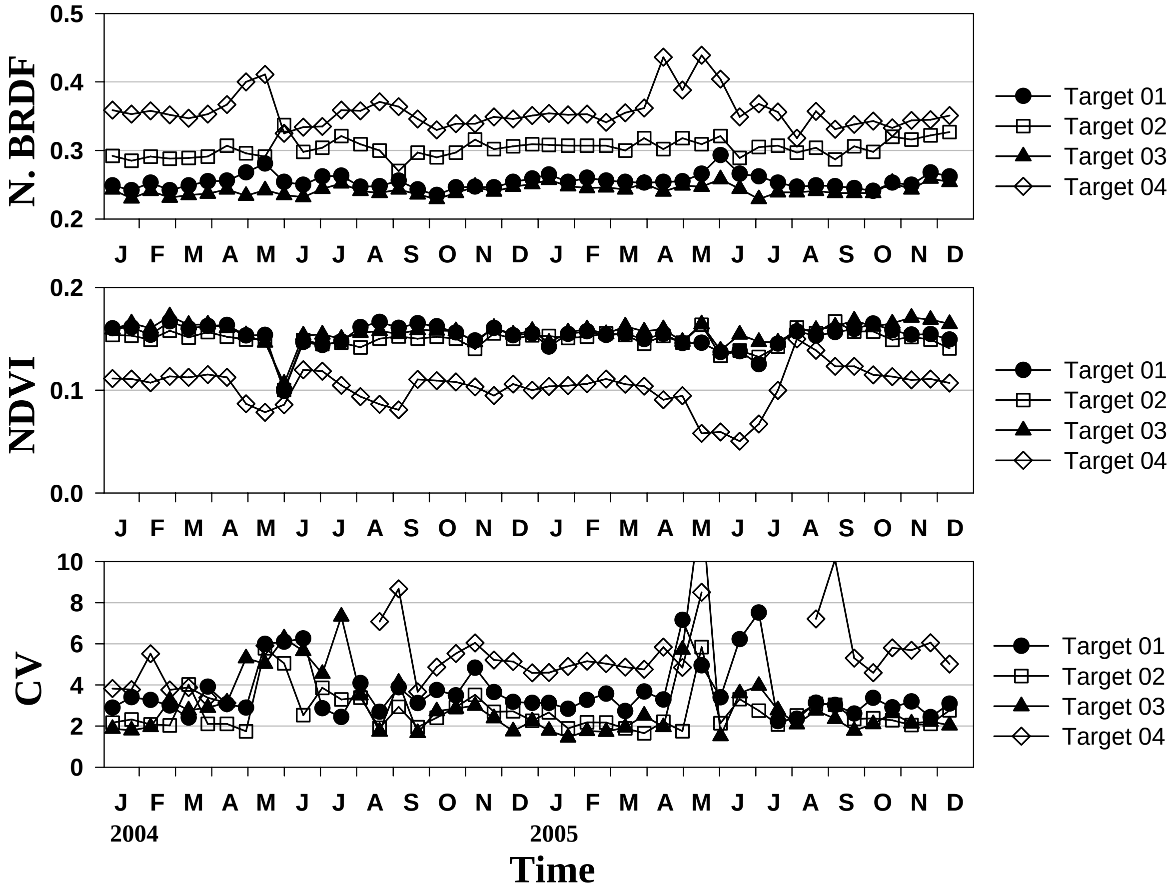

Fig. 1. Time series of surface characterization for all four calibration targets. The upper panel shows the nadir BRDF (N. BRDF) for MODIS band 1. The middle and bottom panels show NDVI and coefficient variation (CV) in MODIS band 1, resepctively.

The brightness of the target is important because the impact of uncertainties in measurement and characterization lead to a relative error that scales inversely as the brightness. The nadir BRDF (N. BRDF) is used for the brightness test. Spatial uniformity is important because unavoidable registration error introduces significant uncertainty into calibration methods when the surface is not spatially uniform. Cosnefroy *et al*. (1996) computed the coefficient of variation (CV) which is the normalized the standard deviation with the mean of the normalized TOA reflectance, both based on a moving 41 X 41 pixel sample region within a METEOSAT-4 image. In this study, we computed CV using N. BRDF at 5 X 5 grid (about 20 X 20 km). Temporal stability is critical if the site is to be used to monitor long-term sensor responsivity. Spectral stability is important in broadening spectral band from MODIS to COMS. NDVI is used for spectral stability test. The surface characteristics of 4 candidate sites are shown in fig.1.

Table 2. Location of the four candidate calibration targets.

Site	Latitude(°S)	Longitude(°E)
Target 01	25.00~25.05	137.00~137.05
Target 02	25.80~25.85	136.80~136.85
Target 03	25.10~25.15	136.55~136.60
Target 04	29.00~29.05	139.80~139.85

2.3 Satellite-level radiance estimation

The satellite level radiance was calculated with the 6S code (Vermote *et al.* 1997) accounting for surface and atmosphere properties. The atmosphere properties are not dominant parameters to retrieve the satellite-level radiance for the MODIS band 1 spectral region (see Table 1). Therefore we use a fixed reference condition for the sensitivity test. However, for the surface reflectance MODIS-derived

BRDFs are used. The global 0.05° MODIS BRDF and albedo Climate Modeling Grid (CMG) data (Version 4) are used in this study. The underlying 1-km BRDF/albedo data were derived by coupling all available cloud-free, atmospherically corrected, spectral surface reflectance observations over a 16-day period with a semi-empirical, kernel-driven BRDF model (Lucht *et al.*, 2000). The theoretical basis of this kernel-driven BRDF model is that the land surface reflectance can be modeled as a sum of three kernels representing basic scattering types: (1) isotropic scattering, (2) radiative transfer-type volumetric scattering as from horizontally homogeneous leaf canopies, and (3) geometric-optical surface scattering as from scenes containing 3-D objects that cast shadows and are mutually obscured from view at off-nadir angles (Lucht *et al.*, 2000). The 6S code has been modified to account for directional effects in case of non-constant surface spectral conditions using MODIS-derived BRDF parameters within the spectral interval of integration. Fig. 2 shows MODIS observations and model calculation for all pixels over the Target 03 from Jan. 2004 to Dec. 2005

2.4 Cloud and sand storm detection

Since only clear sky cases are simulated, the presence of sand storms, broken clouds, and cloud shadows needs to be carefully removed from the observations, to avoid the calibration bias. A specific filtering mechanism similar to Govaerts et al (1998) has been developed. The corresponding mean value $\overline{R}(t)$ and the standard deviation σ are estimated with two step procedures that reject extreme pixel values. $\overline{R}(t)$ is first estimated by accounting all the pixels. The pixels which are smaller or larger than $\overline{R}(t) \pm \sigma$ are rejected and $\overline{R}(t)$ is re-estimated. And the corresponding observation range r_d is estimated as the difference between observed maximum and minimum values. A Gaussian curve of mean μ_d and standard deviation σ_d is adjusted on the histogram of the difference $R'(t) - \overline{R}(t)$, where $R'(t)$ is model calculated radiance. A clear sky observation is assumed when $\left|(R'(t) - \overline{R}(t)) - \mu_d\right| \le \sigma_d$ and $r_d \le 2\sigma_d$. The first test rejects observations that disagree with the simulations by larger than σ_d. The second one disregards observations when the observed scene is not sufficiently homogeneous. After proceeding this filtering mechanism, the comparison results between observed and calculated radiance are shown in Fig. 3.

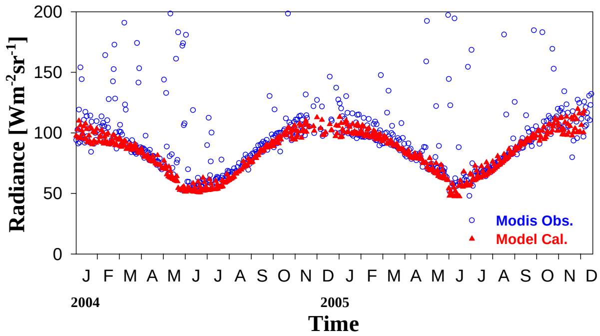

Fig. 2. Comparison between observed and calculaed radiances for all pixels at Target 03 from Jan. 2004 to Dec. 2005.

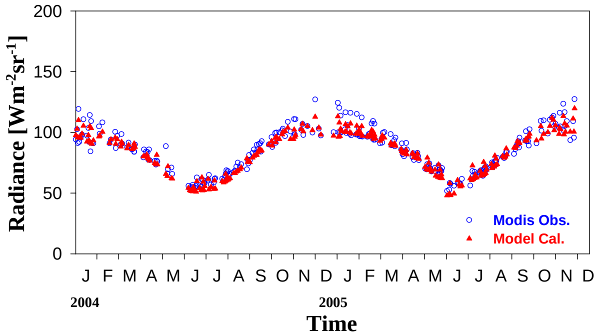

Fig. 3. The same as Fig. 2 except after proceeding filter mechanism

2.5 Radiance comparison observation and calculation

As the desert surface characteristics are supposed to be stable in time, only the instrumental radiometric noise and atmospheric parameter uncertainty are responsible for temporal random errors. The ratios between observed and calculated radiance over each target are thus averaged to reduce temporally random error for 16 days (see Fig. 4). All the ratios temporally averaged over each target are now spatially averaged, assuming that the surface characterization errors are not correlated (see Fig. 5).

3. RESULT

All candidate calibration targets offer a good temporal and spectral stability, and reasonable brightness (see Fig.1). Spatial uniformity is also good but CV appears to be larger than 5 %. A filtering mechanism for selecting the clear sky target seems to be an attractive method. After processing the filtering mechanism, cloud and sand storm contaminated targets can be removed (see Fig. 2 and Fig. 3)

The temporal average results in Fig. 4 show that the computed radiance errors are less than 10 %. But the computed radiances appeared underestimated for all targets. After spatially averaging, the errors of calculated radiance appear to be less than 5% over the most of time although there is an underestimate by about 3 %.

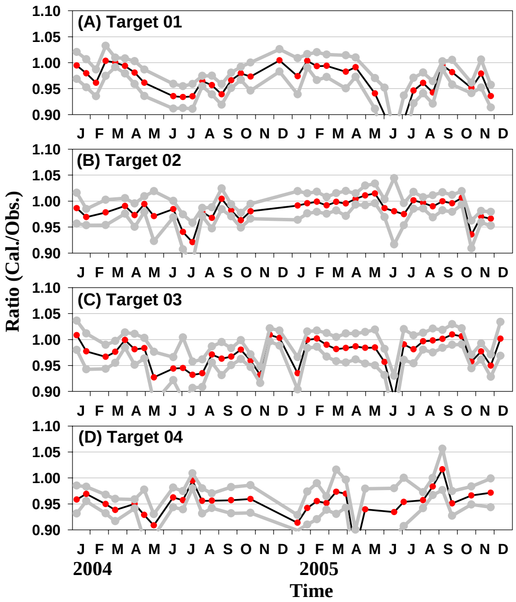

Fig. 4. The ratios between observed and calculated radiances over each target. Ratios were averaged for the 16 days. Grey line indicates the 90% confidence interval.

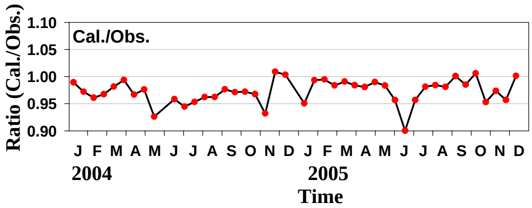

Fig. 5. The ratios between observed and calculated radiances which were spatially averaged for all targets.

4. CONCLUSION

Results suggest that the relative bias between calculated and satellite-estimated appears to be within ±5% calibration uncertainly level when a large number of pixels are averaged over all targets, suggesting that the vicarious method developed in this study is suitable for calibrating the COMS visible senor within the suggested error range.

Table 3. The ratio between observed and calculated radiances at four candidate calibration targets and spatially average for all targets.

Site	Ratio (Cal./Obs.)
Target 01	0.963 ± 0.036
Target 02	0.983 ± 0.020
Target 03	0.974 ± 0.027
Target 04	0.953 ± 0.028
Spatially average	0.973 ± 0.022

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