RADIOMETRIC CHARACTERISTICS OF KOMPSAT-2 HIGH RESOLUTION IMAGES

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ABSTRACT KOMPSAT-2, the first Korean high resolution earth observing satellite, continuously acquires high resolution images since July 2006. The quality of satellite images should be geometrically and radiometrically ensured before distribution to users. This study focused on absolute radiometric calibration which is a prerequisite procedure to ensure the radiometric quality of optical satellite images. In this study, we performed reflectance-based vicarious calibration methods on several uniform targets collected through several field campaigns in 2007. The radiative transfer model, MODTRAN, was used to estimate the amount of energy received at the sensor. The energy reached at the sensor are affected by several factors such as reflectance of targets, atmospheric condition, geometry condition between Sun and the sensor, etc. This study proposes the absolute radiometric calibration coefficients of KOMPSAT-2 MSC images combining several types of collected data through field works and tried to compare dynamic range of sensor-detected energy with other commercial high resolution sensors.

KEY WORDS: KOMPSAT, High Resolution Image, Calibration, Radiometric Characteristics

1. INTRODUCTION

1.1 KOMPSAT-2

Along with the KOrea Multi-Purpose SATellite (KOMPSAT-1), the first earth observing satellite in Korea, KOMPSAT-2 was successfully launched in July 2006. Multi-Spectral Camera (MSC) loaded on KOMPSAT-2 images the earth in sun-synchronous orbit by push-broom scanning method with 15 km swath width at 685 km altitude and continuously acquires 1 m panchromatic images and 4 m multi-spectral images.

1.2 Absolute Radiometric Calibration

The quality of optical images should be measured by three methods, such as geometric accuracy, radiometric quality, and spatial resolution. The radiometric characteristics of optical images could be estimated by the relationship between digital numbers (DN) of pixels in image and the corresponding targets' radiance at sensor. 'Absolute Radiometric Calibration' is to establish this relationship for the background of quantitative radiometric characteristics and the measurements of image quality (Chi, 2007). Generally, absolute radiometric calibration is performed with pre-launch laboratory, post-launch on-board, and post-launch reflectance-based calibration (Thome, 1997). The absolute radiometric calibration in this study was performed using post-launch reflectance-based vicarious calibration methods on several uniform targets collected through several field campaigns in 2007, because KOMPSAT-2 does not have on-board calibrators.

The absolute radiometric calibration explains the relationship between DNs of images and estimated radiance at sensor-received by a simple linear equation as show Figure 1. In Figure 1, gain coefficient, the slope of the line, means how well the DNs react to the radiance of targets. The linear equation explains the radiometric quality of the sensor using the gain coefficient.

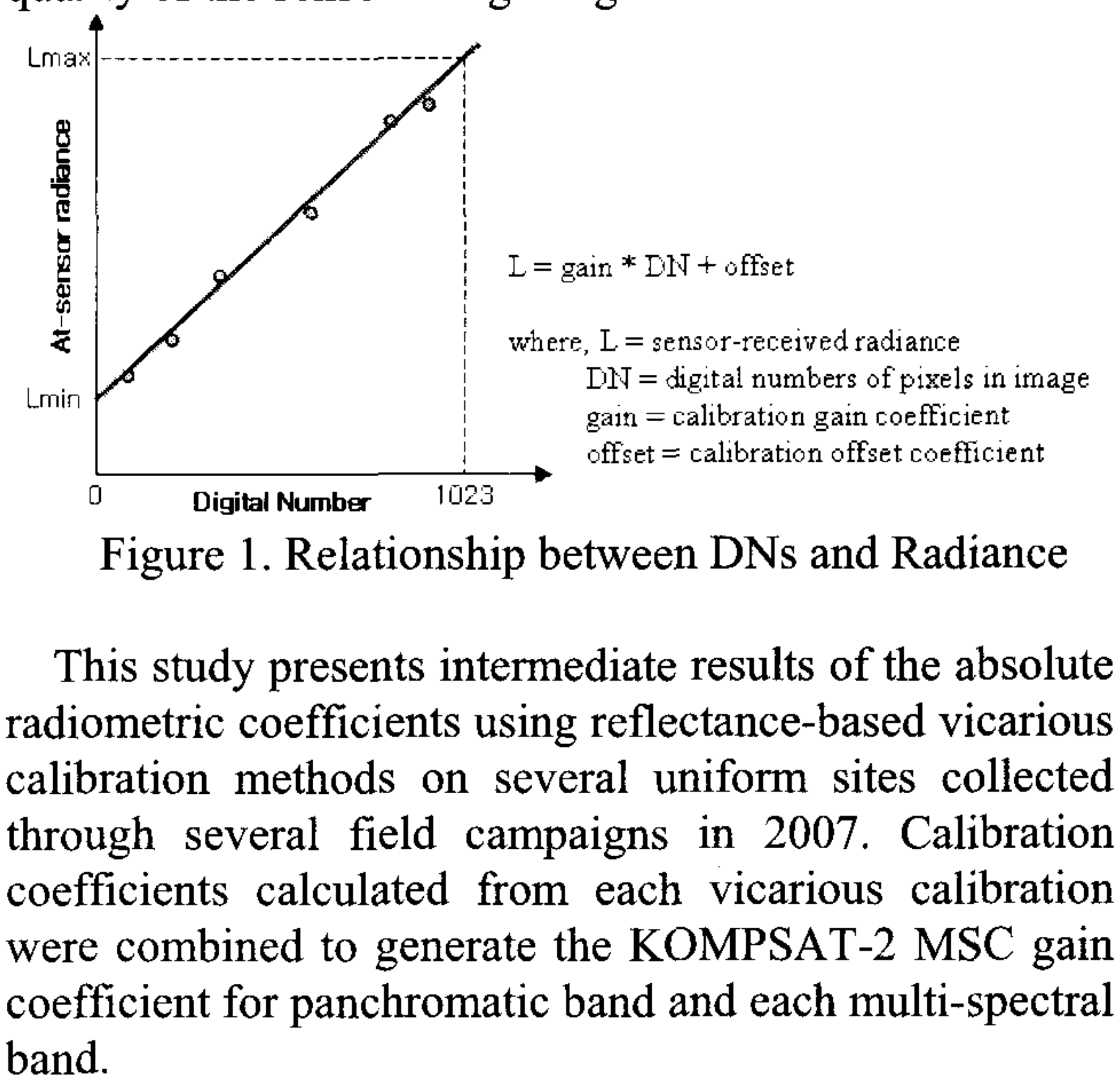


Figure 1. Relationship between DNs and Radiance

This study presents intermediate results of the absolute radiometric coefficients using reflectance-based vicarious calibration methods on several uniform sites collected through several field campaigns in 2007. Calibration coefficients calculated from each vicarious calibration were combined to generate the KOMPSAT-2 MSC gain coefficient for panchromatic band and each multi-spectral band.

2. METHODS

Figure 2 illustrates the procedure of absolute radiometric calibration carried out in this study. Since the absolute radiometric calibration established the relationship between DNs of ground targets on an image and radiance from the corresponding targets detected at sensor, radiance at sensor should be estimated. Because electromagnetic energy goes through atmosphere two times from Sun to sensor, interaction in atmosphere should be considered. To estimate the effect of atmosphere, a radiative transfer code is used, especially Moderate Resolution Transmittance (MODTRAN) in this study.

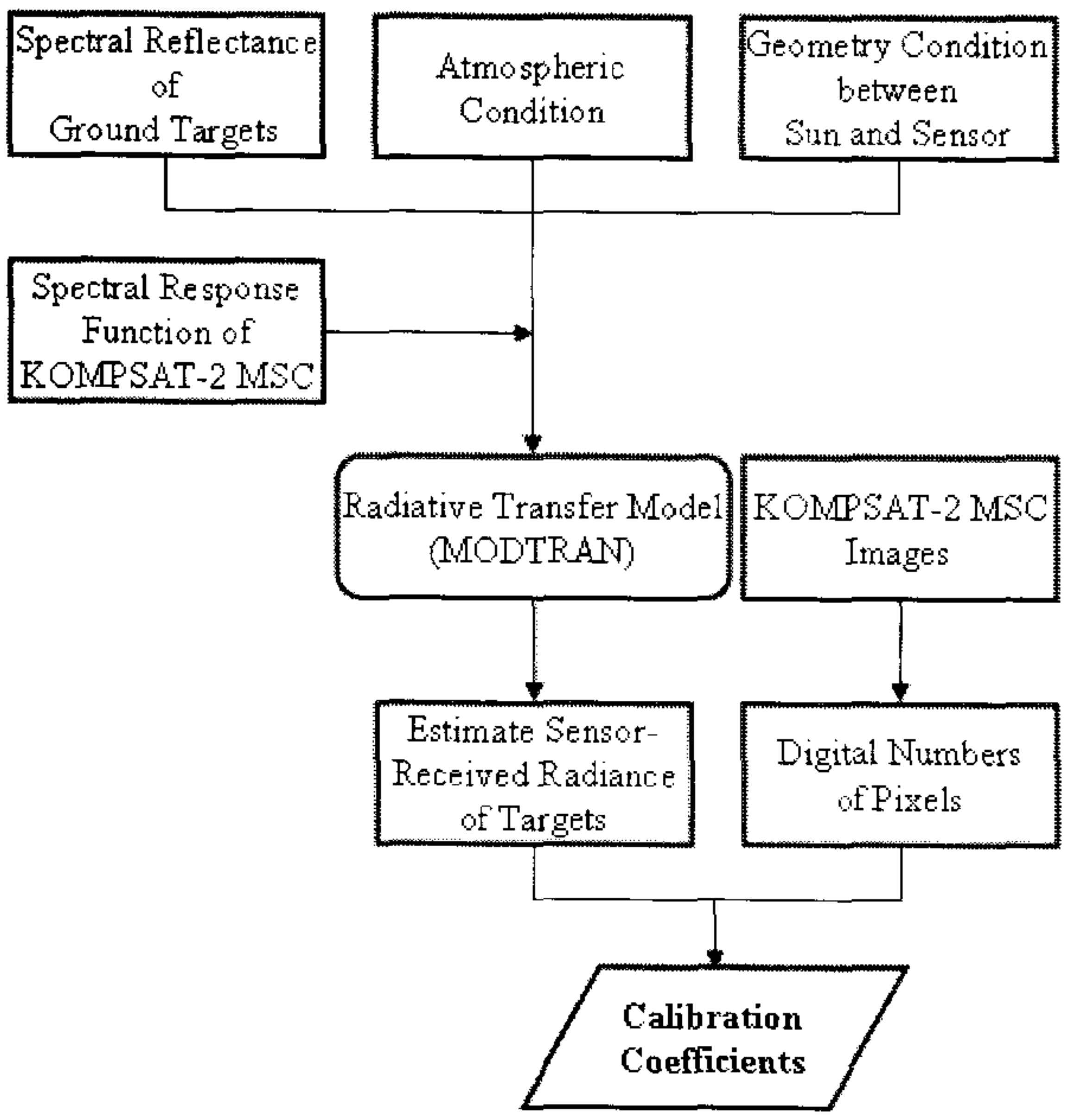


Figure 2. Procedure to estimate the coefficients

Calculation of radiance through MODTRAN is eventually important for the whole absolute radiometric calibration. For MODTRAN to calculate the radiance, spectral reflectance of ground targets, atmosphere conditions and geometry between Sun and the sensor were necessary. The spectral reflectance of ground targets was measured by a portable spectro-radiometer at the same time the satellite was passing over the ground targets. As input parameters of the radiative transfer mode, atmosphere condition is a complex part because many mixed factors are affected, while the geometry between Sun and the sensor is straightforward.

2.1 Ground Data

Field campaigns were performed seven times at different sites since April 2007. GER-2600 measured the reflectance of various ground targets from dark to bright, such as tarps of different reflectance, concrete, asphalt, grass, and soil, etc. GER-2600 is the spectro-radiometer to measure spectral reflectance of targets in the 400 nm to 2,500 nm spectral range. The ground targets were divided into three groups by the quality of each target on 4 m multi-spectral images of KOMPSAT-2, such as good, medium, and poor quality. Targets in good quality group have comparatively homogeneous surface and enough size to discriminate in multi-spectral images. Medium quality targets can discriminate in a degree in multi-spectral images, but it is hard to get correct DN value of pixels. Targets in the poor quality group are impossible to distinguish in images.

2.2 Atmospheric Conditions

In this study, MODTRAN, developed by the United States Air Forces, was used to estimate the amount of ground-target's radiance recorded at a sensor. The radiance at-sensor is usually quite different from the radiance returned from the ground-targets because energy is lost by atmospheric attenuation. Radiative transfer models such as MODTRAN and 6S are used to predict amount of atmospheric attenuation in a particular day. Among the numerous constituents of atmosphere, water vapor (H_2O), ozone (O_3), nitrous oxide (N_2O), carbon monoxide (CO), methane (CH_4) and carbon dioxide (CO_2) are radiatively active molecules. Since most of other gases are not dramatically changed in the atmosphere, the effect of the gases can not be considered. Especially, oxygen and nitrogen are almost constantly preserved, so those gases do not have to be seriously considered for the analysis (Yoon, 2006).

To estimate atmospheric effects on electromagnetic energy, vertical information of aerosol and atmosphere are necessary for the use of MODTRAN. MODTRAN provides six standard and general models such as tropical, mid-latitude summer, mid-latitude winter, subartic summer, subartic winter, and 1976 US standard atmosphere. In addition, users can be defined atmosphere models using radiosonde data (PcModWin Manual, 2004). In this study, the radiosonde data of the closest station to field campaign area were used and the data were provided by the department of atmosphere science, university of Wyoming. Our previous study (Yoon, 2006) has reported aerosols are critical and sensitive factors to estimate the amount of radiance at-sensor. For a radiative transfer model to estimate radiance at-sensor, the necessary data is vertical distribution of aerosol. The efficient way to measure vertical profiles of aerosol is lidar, however, the instrument was not prepared for the absolute radiometric calibration. As the aerosol source of vertical distribution by lidar, the data measured from the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation, as called CALIPSO, can be useful if the time and location of data acquisition are identical. CALIPSO provides public release of the data as of June 2006. The dates of field campaigns in 2007 are not matched with the CALIPSO data so far. If the remaining planned field campaigns will be matched with CALIPSO data, it can be possible to use the accurate data. At this time, as an alternative way, aerosol data from Aerosol Robotic Network (AERONET) were used. AERONET is a worldwide network of ground measurement stations to provide atmospheric data supported by NASA.

2.3 Geometric Conditions

Geometry conditions between sun and sensor are generally provided with information of satellite images. Altitude of instrument, azimuth angle, elevation angle, and spectral range of each band, etc are necessary for geometric conditions. Since an optical sensor is usually not sensitive 100% energy through full spectral range, the characteristics of responsibility of each band should be considered (Kim, 2002). Figure 3 represents the relative spectral response function of KOMPSAT-2 MSC. Usually, the center of spectral range has the highest sensitivity, but the energy of sensitivity will be lower on the end of spectral range. The amount of radiance recorded by sensor will be more accurately estimate when the sensitivity of each band are considered.

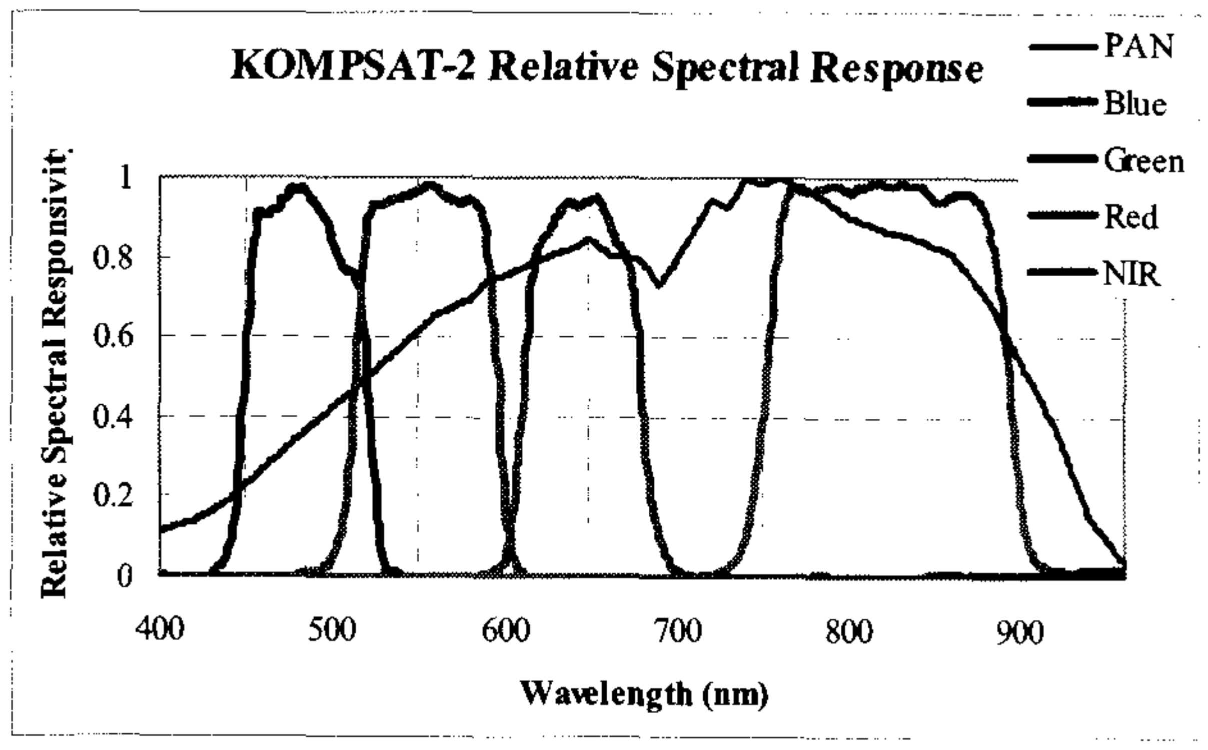


Figure 3. Relative Spectral Response Fuction of MSC

3. RESULT

3.1 Estimation of Calibration Coefficients

Field campaigns for the absolute radiometric calibration of KOMPSAT-2 have been carried out 7 times at different sites and dates since April 2007. Figure 4 shows the simple relationship between DN values of pixels and at-sensor radiance in a panchromatic image of KOMPSAT-2 MSC. The left picture in Figure 4 is using all targets of our field campaigns, but there are some targets to make distribution larger. Right one of Figure 4 is just shown targets from the group of good quality with uniform surface and enough huge to be distinguishable in multi-spectral images. Figure 5 shows the result of multi-spectral bands of MSC.

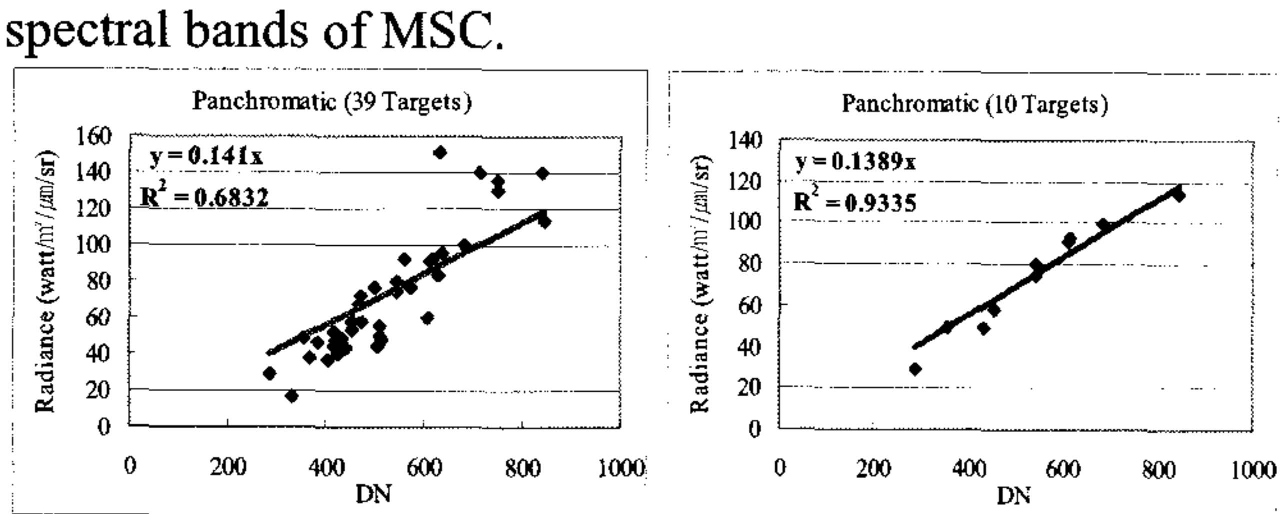
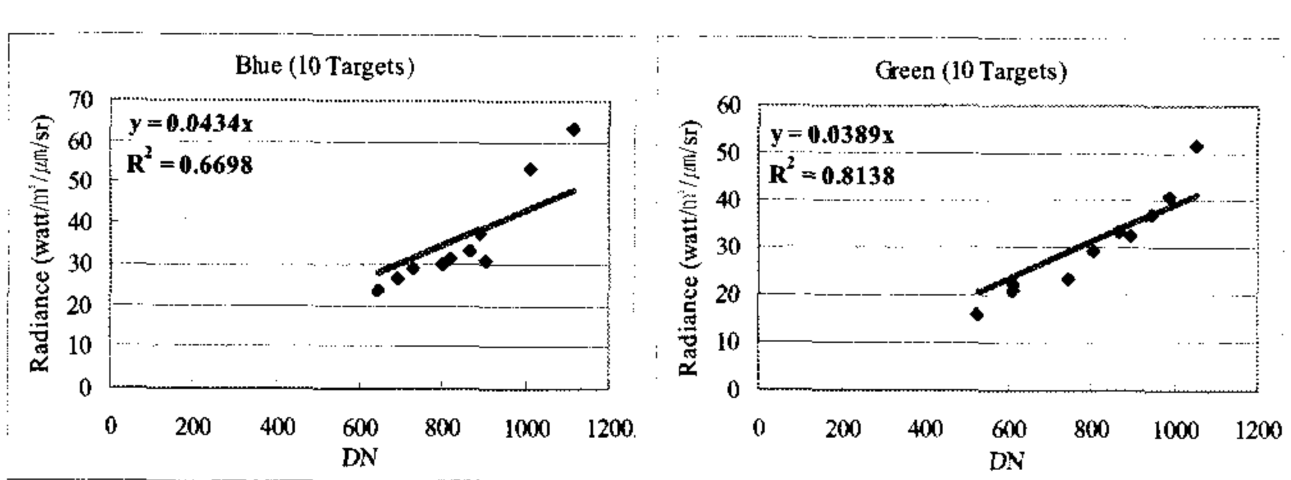


Figure 4. Relationship between DNs and Radiance In Panchromatic Band



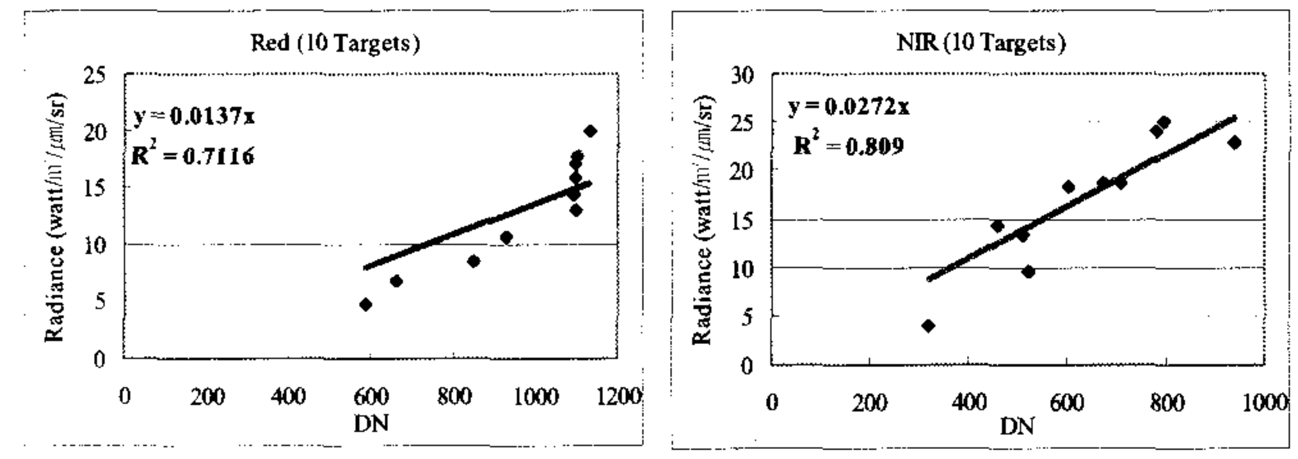


Figure 5. Relationship between DNs and Radiance In Multi-Spectral Band

According to atmospheric models, aerosol models, quality of targets, several combinations of different input parameters could be used to establish the linear relationship between radiance and DNs. Table 1 shows the statistics showing variations of the gain coefficient. In this study, we did not determined the gain coefficients yet because several field campaigns will be carried out in fall season with clear atmospheric condition.

Table 1. Statistics of Coefficients in Each Band

	PAN	Blue	Green	Red	NIR
Mean	0.1378	0.0445	0.0394	0.0132	0.0271
Stdev	0.0066	0.0046	0.0034	0.0012	0.0020
Min	0.1199	0.0376	0.0322	0.0106	0.0222
Max	0.1436	0.0497	0.0438	0.0151	0.0297

3.2 Comparison with Other High Resolution Sensors

Nowadays, there are many high resolution satellite systems. We were tried to compare dynamic range of sensor-responsed with other commercial high resolution sensor such as IKONOS, and QuickBird. KOMPSAT-2 MSC images are recorded in 10 bits radiometric resolution (0 to 1023), but IKONOS and QuickBird are recorded in 11 bits depth DN values (0~2047). It is easy to calculate capability of sensor-recorded energy using the calibration coefficients and radiometric depth.

The IKONOS and QuickBird were high resolution and well-calibrated sensor radiometrically. If we will compare the maximum radiance recorded by KOMPSAT-2 MSC using our calibration coefficients estimated with those sensors, we can judge our coefficients are correct or not. On the below graph in Figure 6, there are not much difference among the sensors. Therefore, our absolute radiometric calibration coefficients are somewhat correct.

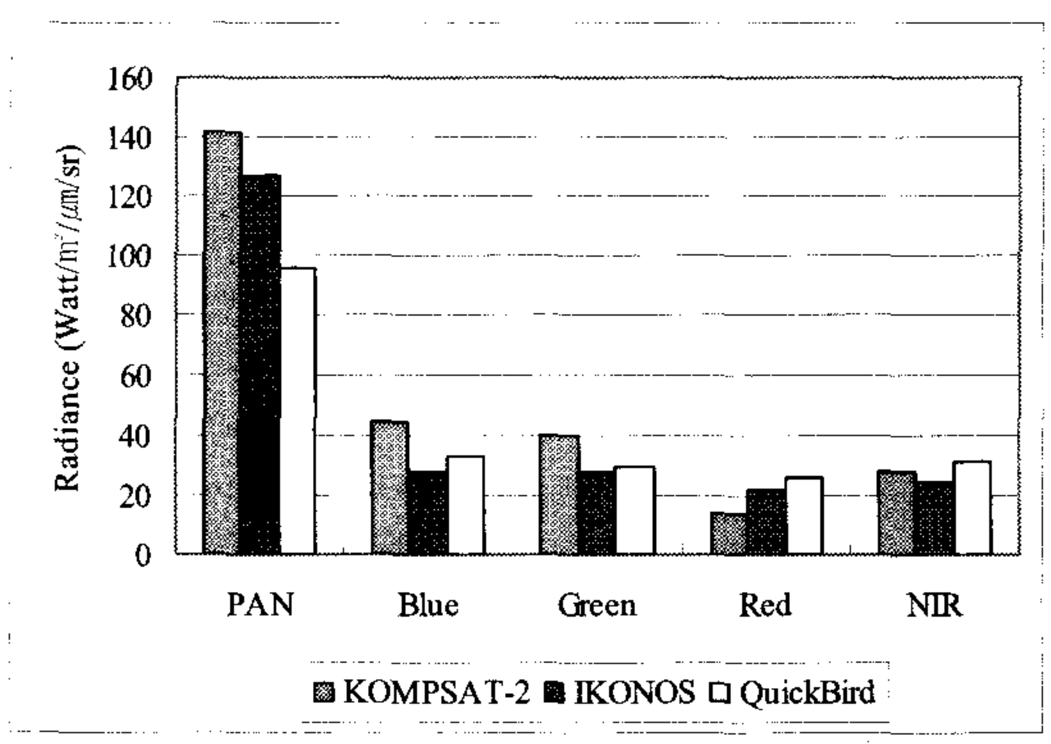


Figure 6. Dynamic Range Comparison with High Resolution Sensor

4. CONCLUSIONS

This study presented intermediate results of field campaigns in 2007 for the absolute radiometric calibration of KOMPSAT-2 MSC. Because more field campaigns will be continuously performed in fall season with clear atmosphere, it is possible for the gain coefficient to be improved more accurately. In addition, as another atmospheric information source, CALIPSO data can be considered if the identical time and location are prepared. For the atmospheric information, we can obtain them by several indirect methods, such as ground measurements provided by AERONET, vertical measurements by laser of satellite and estimation by optical satellite like MODIS. The methods are considered in the respects of location and data resolution if the time is identical. The comparisons of the methods effecting on the radiative transfer model will be an interesting part in future study. This study did not determine the gain coefficient yet, but proposed methodology to compare the combinations of input parameters with different results. In later field campaigns, more accurate input parameters will be considered to precisely estimate radiances at-sensor.

5. REFERENCE

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