POST-LAUNCH RADIOMETRIC CALIBRATION OF KOMPSAT2 HIGH RESOLUTION IMAGE

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ABSTRACT Radiometric calibration of optical image data is necessary to convert raw digital number (DN) value of each pixel into a physically meaningful measurement (radiance). To extract rather quantitative information regarding biophysical characteristics of the earth surface materials, radiometric calibration is often essential procedure. A sensor detects the radiation of sunlight interacted atmospheric constituents. Therefore, the amount of the energy reaching at the sensor is quite different from the initial amount reflected from the surface. To achieve the target reflectance after atmospheric correct, an initial step is to convert DN value to at-sensor radiance. A linear model, the simplest radiometric model, is applied to averaged spectral radiance for this conversion. This study purposes to analyze the sensitivity of several factors affecting on radiance for carrying out absolute radiometric calibration of panchromatic images from KOMPSAT2 launched at July, 2006. MODTRAN is used to calculate radiance at sensor and reflectance of target is measured by a portable spectro-radiometer at the same time the satellite is passing the target for the radiometric calibration. As using different contents of materials composing of atmosphere, the differences of radiance are investigated. Because the spectral sensitivity of panchromatic images of KOMPSAT2 ranges from 500 to 900 nm, the materials causing scattering in visible range are mainly considered to analyze the sensitivity. According to the verified sensitivity, direct measurement can be recommenced for absolute radiometric calibration.

KEY WORDS: Radiometric calibration, vicarious calibration, radiance, KOMPSAT, MODTRAN

1. INTRODUCTION

Along with the Korea multi-purpose satellite (KOMPSAT1), the first earth observing Korean satellite, KOMPSAT2 was successfully launched in July, 2006. While the electro-optical camera (EOC) of KOMPSAT1 acquires images with approximate 6.6 m/pixel resolution, multi-spectral camera (MSC) loaded on KOMPSAT2 acquires sub-meter panchromatic and 4 m/pixel multi-spectral images. Optical images should be undergone the calibration and validation procedure to verify the quality of images before distribution to users.

The radiometric calibration is performed with the pre-flight laboratory works, the post-launch on-board calibration, and post-launch ground reference calibration (Thome et al., 1997). The post-launch ground reference calibration, also called 'vicarious calibration', is traditionally performed, which relate theoretical radiance by a radiative transfer model to digital numbers (DN) of pixels in satellite images at the same time. The relation between radiance and DN is established by a simplest linear model as shown in equation 1. Sensor-received radiance is estimated by a radiative transfer model considering atmospheric condition and geometry between Sun and the sensor, etc. Therefore, several parameters should be considered to estimate the radiance at sensor (L in equation (1)) such as geometric information of the sensor and Sun, reflectance of objects, atmospheric condition and aerosol at the same time acquiring images.

$$L = C_1\,DN + C_0 \qquad (1)$$

where, L = sensor- received radiance
DN = DN of corresponding object on an image
C_1 = calibration gain coefficient
C_0 = offset coefficient

Y-S Kim and C-H. Kang (2001) calculated total radiance receiving at MSC of KOMPSAT2 using MODTRAN (Moderate Resolution Transmittance Code) with simulated condition, and compared the radiance with the provided total radiance in the MSC contracts. As the precedent research, calibrations EOC images of KOMPSAT1 were performed by J.H. Kim et al. (2002). They obtained the calibration coefficients of EOC by the radiative transfer model of LOWTRAN and the DN from EOC data.

This research ultimately purposes to perform the absolute radiometric calibration (vicarious calibration) for MSC panchromatic images of KOMPSAT2. MODTRAN will be used to calculate radiance at sensor and reflectance of target will be measured by a portable spectro-radiometer at the same time the satellite is passing the target. Otherwise, tarps with constant reflectance are used as reference targets. For the ultimate goal, this study purpose to analyze the sensitivity of several input parameters of MODTRAN affecting on radiance to prepare the absolute radiometric calibration. According to the sensitivity, critical factors among the numerous input parameters are determined and seriously considered for the radiometric calibration. Through the sensitivity analysis of input parameters, this study can recommend the desirable and effective management of radiative transfer model, MODTRAN, for the absolute radiometric calibration of panchromatic images of KOMPSAT2.

2. METHOD

A radiative transfer model theoretically calculates the amounts of the solar energy attenuating through interactions with atmosphere, the gases of air. It is used to calculate transmittance and radiance considering the atmospheric condition such as scattering, clouds, fogs, rains, pressure, temperatures, amounts of gases within air etc. Those factors are variable with the weather condition, season, and location. It is quite complex to provide adequate input parameters without direct measurement at the time of acquiring the images. Therefore, several input parameters of a radiative transfer model, MODTRAN, are tested and compared with other conditions. Since the panchromatic images of KOMPSAT2 are spectrally ranged from 500 nm to 900 nm, the activities of visual spectrum in the atmosphere are mainly considered in this study.

2.1 Radiative transfer model - MODTRAN

MODTRAN is one of radiative transfer models developed by the United States Air Forces. MODTRAN4, the latest version of MODTRAN used for this study is significantly improved for the accuracy of radiance calculation from the previous version (MODTRAN 3.7) (Berk et al. 1998). The model estimates the amounts of solar energy receiving at an imaging sensor through interactions with atmosphere such as scattering, absorption, and refraction. The atmosphere is mainly composed of four stratified layers (figure 1). The four groups are boundary layer from 0 to 2 km, upper troposphere layer from 2 to 10 km, lower stratosphere layer from 10 to 30 km and stratospheric (mesospheric) layer from 30 to 100 km(PcModWin manual, 2004). The solar energy is going in and out the atmosphere to reach to a sensor as shown in figure 1. During the trip, the solar energy is attenuated by interactions, scattering, absorption and reflection.

For the calculation of the solar energy of receiving at the sensor, the input parameters for MODTRAN can be divided three groups: atmosphere and aerosol, geometry of Sun and the sensor, and surface parameters. Other parameters are considered constant values except atmosphere and aerosol models for the sensitivity analysis of input parameters. Therefore, the geometry between sun and a sensor and object's reflectance are not changed for the comparison of atmosphere models and aerosol models.

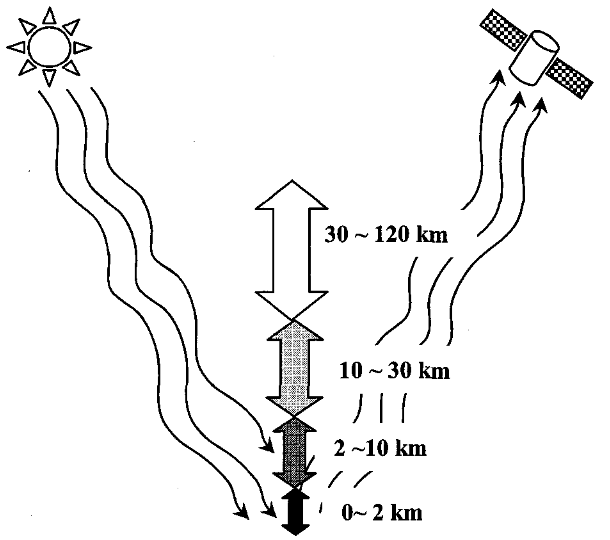

Figure 1. Path length of solar energy from Sun to a sensor

2.2 Atmosphere model and aerosol

Since the solar energy is going through the atmosphere, the solar energy attenuates during the path length. The atmosphere strongly affects the results of the radiative transfer model. Among the numerous constituents of atmosphere, water vapour (H_2O), ozone (O_3), nitrous oxide (N_2O), carbon monoxide (CO), methane (CH_4) and carbon dioxide (CO_2) are radiatively active molecules (Anderson et al., 1986). Most of other gases are not dramatically changed in the atmosphere. Especially, oxygen and nitrogen are almost constantly preserved, so those gases do not have to be seriously considered for the analysis.

Users of MODTRAN can define atmospheric model through two ways. One way is to use six standard and general atmospheric models provided by MODTRAN such as tropical (15° N), mid-latitude (45° N) summer, mid-latitude (45° N) winter, 1976 US standard etc. The other is users can be defined the atmosphere using direct measurements or radiosonde data. The atmosphere model is stratified the four groups of atmosphere in figure 1 into dozens of layers, usually 33 or 34 layers from 0 km to 100 or 120 km above the earth surface. Depending on the altitude, the altitude profiles of each gas are defined. The atmospheric models contain approximately estimated the seasonal amounts of gases in local area by latitude. Therefore, the models use average values of the contents, so those are not quite precise. In this study, mid-latitude summer and winter models are used to calculate total radiance.

Together with atmospheric models, aerosols are critical factors existing within atmosphere. Aerosols are particles suspended in the atmosphere (PcModWin manual, 2004) including industrial soot, dust, sea spray, etc. Aerosols related to the purity of air are too versatile to estimate and model. MODTRAN provide several aerosol models such as rural and urban model depending on visibility. In this study, rural model with 23-km and 5-km visibility and urban model with 5-km visibility are used.

3. RESULT

According to the combination of the atmospheric models and aerosol models, the radiative transfer model calculates the total radiance from 450 nm to 900 nm in the visual spectrum. Table 1 shows the integrated total radiance in all of the tested cases. Several distinctive points can be observed from table 1. Under the same aerosol model, for example rural 23 km, the total radiance does not show big differences between mid-latitude summer model and mid-winter winter model. It is noticed that the total radiances show big difference between rural aerosol with 23-km visibility and urban aerosol with 5-km visibility. Therefore, the aerosol model affects the total radiance more than the atmosphere model. As the atmosphere is not clear and pure in the order of rural model with 23-km visibility, rural model with 5-km visibility and urban model with 5-km visibility, the total radiance receiving at sensor is noticeably reduced. Hence, it is said that the total radiance is more sensitive to the aerosol models rather than the atmosphere models.

These points are illustrated by figure 2 and figure 3. The integrated total radiance in table 1 is the area under total radiance lines in figure 2 and figure 3. Figure 2 shows the total radiance at the wavelength between 450 nm and 900 nm. Figure 2a is the total radiance with mid-latitude summer atmospheric model with rural aerosol 23-km visibility vs. urban aerosol 5-km visibility. The total radiance shows large difference as the numerical values shown in table 1 between rural model with 23-km visibility and urban model with 5-km visibility. This means since the atmosphere of urban area is not pure, the visibility is low, 5-km, and the atmosphere has more molecular causing scattering effect. Figure 2b is the total radiance with mid-latitude summer with rural 23km vs. rural 5km, and figure 2c is the total radiance with mid-latitude winter with rural 23km vs. rural 5km. The difference between rural aerosol with 23km and urban aerosol with 5km (figure 2a) is the largest. Through the figures, the aerosol between rural area and urban area is quite different and sensitively affect the total radiance.

Table 1. Integrated total radiance (watts/cm^2·ster) between 450 nm to 900 nm in visible spectrum according to atmospheric models and aerosol models.

	Mid-latitude Summer	Mid-latitude Winter
Rural 23km	0.007234	0.007021
Rural 5km	0.006288	0.006144
Urban 5km	0.003641	0.003622

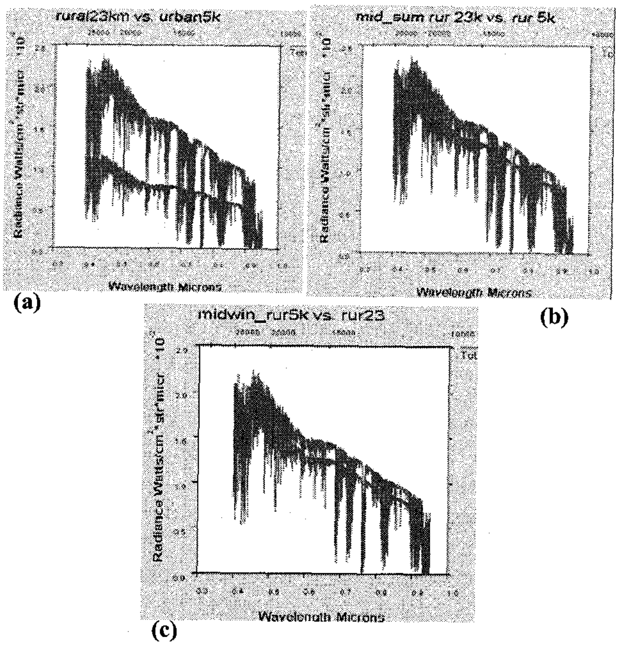

Figure 2. Total radiance of mid-latitude summer with rural aerosol with 23 km visibility vs. with urban aerosol with 5 km visibility (a), mid-latitude summer with rural aerosol with 23km visibility vs. rural aerosol with 5km visibility (b), mid-latitude winter with rural aerosol with 23 km visibility vs. rural model with 5km visibility (c)

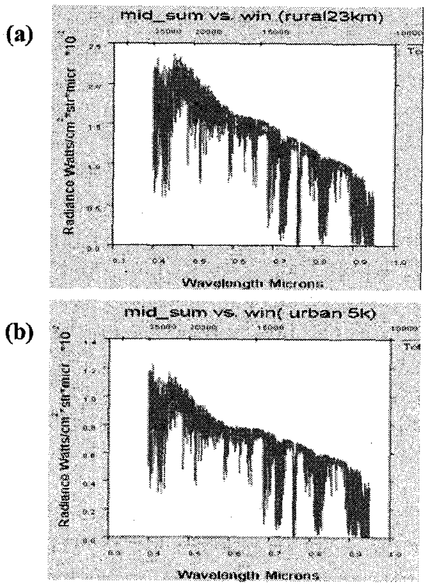

Figure 3. Total radiance of rural aerosol with 23-km visibility with mid-latitude summer vs. mid-latitude winter (a), total radiance of urban aerosol with 5-km visibility with mid-latitude summer vs. mid-latitude winter (b)

Figure 3 shows the comparison with atmosphere models, mid-latitude summer and mid-latitude winter. The difference between atmosphere models is not much larger than the difference between aerosol models. The total radiance of mid-latitude winter is slightly smaller than the total radiance of summer model.

4. CONCLUSION

Planning the absolute radiometric calibration of KOMPSAT2, this study analyzes the sensitivity of input parameters for performing MODTRAN. With the fixed condition of geometry between Sun and the sensor and surface parameters (temperature and reflectance), the atmospheric models and aerosol models are used to calculate total radiance receiving at the sensor. Consequently, aerosol models affect the total radiance more than atmospheric models. Especially, the total radiance using rural aerosol with 23-km visibility are quite different form that of urban aerosol with 5-km visibility. Therefore, the aerosol model should be seriously considered in the post-launch radiometric calibration. Since aerosol is versatile, it is quite difficult to model the contents of the constituents. Direct measurement in field at the time performing the post-launch radiometric calibration campaign is recommended as the best way for the accurate calibration.

5. REFERENCES

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