Spectral Band Adjustment Factor of KOMPSAT Series for Agriculture Remote Sensing

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ABSTRACT: As the number of multispectral satellites increases, it is expected that it will be possible to acquire and use images for periodically. However, there is a problem of data discrepancy due to different overpass `time, period and spatial resolution. In particular, the difference in band bandwidths became different reflectance even for images taken at the same time and affect uncertainty in the analysis of vegetation activity such as vegetation index. The purpose of this study is to estimate the band adjustment factor according to the difference of bandwidth with other multispectral satellites for the application of KOMPSAT satellite in agriculture field.

KEY WORDS: SBAF, KOMPSAT, NDVI, Agriculture

1. INTRODUCTION

Relative radiometric calibration (hereafter cross-calibration) is to normalize multi-temporal data taken on different dates to selected reference data at specific time. In order to eliminate the need for both radiative transfer codes and atmospheric optical properties that are difficult to acquire particularly for historic satellite data, many investigator have resorted to relative radiometric normalization. Cross-calibration between the sensors is critical to bring the measurement from different sensors to a common radiometric scale. This techniques use a well calibrated sensor as a transfer radiometer to achieve characterization of other sensors using near-simultaneous observations of the Earth (El Hajj et al, 2008).

However, an integrated global observation framework requires an understanding of how land surface processes are seen differently by various sensors. Different applications and technology developments in EO require different spectral coverage. Thus, even for the spectral bands designed to look at the same region of the electromagnetic (EM) spectrum, sensor response can be substantially different because their analogous bands may have different relative spectral responses (RSRs) (Chander et al, 2010).

The need of spectral band adjustment factors (SBAFs) as an important tool to reduce the cross-calibration uncertainties that arise because of the spectral differences between the analogous bands of the multispectral sensors. The main contributions of this paper are as follows:

(1) The differences in spectral responses between KOMPSAT-3 and Landsat-8, we applied the SBAF using the EO-1 Hyperion.
(2) To validate the calibration coefficients, their interconnectedness and accuracy were analyzed by performing comparisons based on TOA reflectance, with reference to Landsat-8.

2. METHOD

2.1 Image Selection

For accurate cross-calibration between two sensors, the uncertainty arising from their RSR differences needs to be resolved. A compensation for differences in spectral response functions can be made after having some prior knowledge of the spectral signature of the ground during the overpass time. This compensation factor used to compensate for the spectral band differences is known as SBAF (Chander et al, 2013).

The Hyperion data provide an opportunity to account for the spectral band differences as described earlier and provides an alternative to simultaneous ground measurement which is often impossible for remote inaccessible areas. We obtain the EO-1 Hyperion Image at the same day KOMPSAT-3, Landsat-8 for SBAF in Lybia-4 Site. The dates and viewing geometries of the scenes are shown in table 1.

Table 1. Image Metadata

Use	Site	Sensor	Date	Time (UTC)	Earth-sun distance	Solar		Sensor	
						Zenith	Azimuth	Zenith	Azimuth
Spectral Band Adjustment Factor	Libya 4	KOMPSAT-3	14/7/6	11:39:27	1.016	15.9	263.0	1.9	80.7
		HYPERION		8:05:26		32.8	92.5	13.6	98.0
		LANDSAT-8	14/7/8	8:55:00	1.016	22.2	100.9	Nadir	
		HYEPRION		8:03:06		32.9	92.3	12.2	98.0
Cross Validation	North Virginia	KOMPSAT-3	13/10/20	18:40:46	0.995	51.2	206.8	25.1	261.7
		LADNAST-8	13/10/21	15:54:50		51.6	159.1	Nadir	

2.2 Spectral Band Adjustment Factor

EO-1 Hyperion sensor images were used to derive the spectral band adjustment factor (SBAF) to compensate for the differences in the RSR between the sensors. Although SBAF is discussed briefly in this section, readers are directed elsewhere for the detailed mathematical expressions for SBAF. The suitability of the Hyperion sensor for the assessment of spectral band differences has also been addressed elsewhere in the literature (Henry et al., 2013). SBAF can be calculated using the following formula by utilizing the integral values of the RSR(Chander et al, 2013):

$$\overline{\rho_\lambda}(sensor) = \frac{\int \rho_\lambda * RSR_\lambda d\lambda}{\int RSR_\lambda d\lambda} \qquad SBAF = \frac{\overline{\rho_\lambda}(A)}{\overline{\rho_\lambda}(B)} \qquad \overline{\rho_\lambda}(A*) = \frac{\overline{\rho_\lambda}(A)}{SBAF}$$

Here, RSR_λ is the RSR of the sensor, ρ_λ is the hyperspectral TOA reflectance profile, $\overline{\rho_\lambda}(A)$ is the simulated TOA reflectance for sensor A, $\overline{\rho_\lambda}(B)$ is the simulated TOA reflectance for sensor B, $\overline{\rho_\lambda}(A*)$ is the compensated TOA reflectance for sensor A when using the SBAF to match sensor B TOA reflectance.

2.3 Cross Validation of TOA Reflectance

When comparing the radiometric quality obtained from the other sensors, the cosine effect of the different solar zenith angles due to the differences in time in obtaining materials could be removed if TOA reflectance was used instead of the TOA radiance. The equation to calculate the TOA Reflectance (ρ) of KOMPSAT-3 and Landsat-8 is as follows:

$$\rho_\lambda = \frac{\pi \cdot L_\lambda \cdot d^2}{ESUN_\lambda \cdot cos\theta_s}$$

Here ρ_λ is planetary reflectance, L_λ is spectral radiance at the sensor aperture (either KOMPSAT-3 or Landsat-8 (W/m2 ㎛ sr), $ESUN_\lambda$ is the band dependent mean solar exoatmospheric irradiance (W/m2 ㎛), θ_s is the solar zenith angle (radians), and d is the earth sun distance (astronomical units).

3. RESULT

3.1 Spectral Band Adjustment Factor (SBAF)

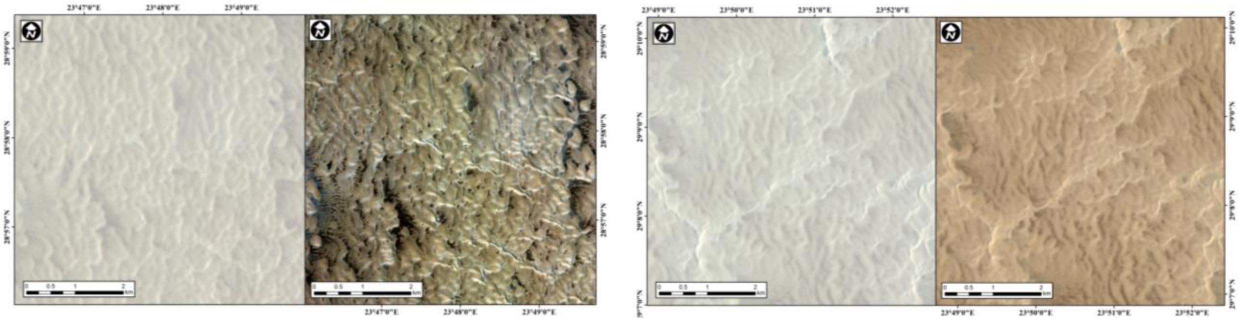

Figure 1. KOMPSAT-3, Landsat-8 and EO-1 Image for SBAF in Libya-4 Site

The SBAF was calculated using KOMPSAT-3 and EO-1 on July 6 2014, and using Landsat-8 and EO-1 on July 8 2014(Figure 1). The SBAF before (S.Ref) and after (M.Ref) KOMPSAT-3 reflectance increased by 5.45%. Landsat-8 reflectance increased by 5.06%, which is very similar. The correlations between S.Ref (L8) and M.Ref (L8) was 0.987, and between S.Ref (K3) and M.Ref (K3) was 0.974, and hence was slightly higher for Landsat-8. Therefore, if the value of the SBAF is reflected, the repetition capacity will be similar.

Table 2 shows the largest difference (14.91%) in the SBAF for the KOMPSAT-3 and OLI band combination occurred in the NIR and blue, green, and red bands, whereas a difference of -2.2~2.1% can be expected in the other bands when imaging a bright desert. The uncertainties were higher in the NIR bands, but were all about ±1%. If this is not accounted for, there will be a systematic error in the cross calibration.

There was a similar pattern in the % DIFF after SBAF values, with little differences between the bands, except for the NIR band. The spectral bandwidth and overlap ratio for KOMPSAT-3 and Landsat OLI was only 16%. The NIR difference was consistent between different bands, with the TOA reflectance reported by OLI being generally higher. The NIR band was anomalous, with the two sensors disagreeing by 5.89%

Table 2. Effect based on EO-1 Hyperion 10nm derived SBAF

Band	S.Ref[1)] (K3)	S.Ref[2)] (L8)	SBAF	Stdev (SBAF)	M.Ref[3)] (K3)	M.Ref[4)] (L8)	A.Ref[5)] (K3)	% Diff SBAF	
								After[6)]	Before[7)]
Blue	0.245	0.250	0.978	0.43	0.256	0.255	0.262	0.39	2.65
Green	0.368	0.363	1.014	0.45	0.348	0.332	0.343	4.82	-3.37
Red	0.486	0.475	1.021	0.34	0.481	0.451	0.470	6.65	4.20
NIR	0.673	0.551	1.221	0.30	0.609	0.530	0.499	14.91	-5.89

1) K3 Simulated TOA Ref. from EO-1, 2) L8 Simulated TOA Ref. from EO-1, 3) Measured TOA Ref. on L8, 4) Measured TOA Ref. on K3 5) Adjusted TOA Ref. (SBAF), 6) (M.K3-M.L8)/M.L8*100, 7) (A.K3-M.L8)/M.L8*100

3.2 Cross Validation of TOA Reflectance

To validate the radiometric coefficient in the calibration process used in this study, the images of the multi spectral sensor of Landsat-8 OLI and the KOMPSAT-3 images over the same period (2~3 days) were used, as is common worldwide. Generally, the cross validation method requires monitoring for at least one year. However, KOMPSAT-3 has been few images that were obtained on the same date as Landsat-8 are available. Therefore, we obtained images from North Virginia, USA(Figure 2).

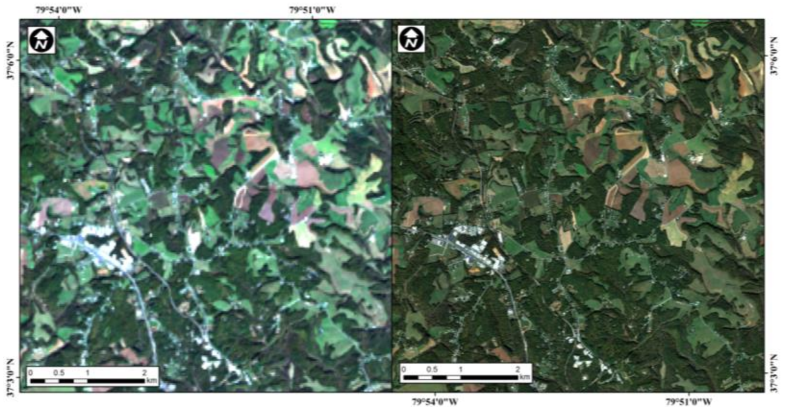

Figure 2. KOMPSAT-3 and Landsat-8 Image for Cross Validation

Table 3 show The difference in TOA reflectance Each Band. Landsat-8 and KOMPSAT-3 based on the absolute calibration was 1~2% in the blue, green, and red bands, whereas there was a 4% difference in the NIR. The differences in standard deviation were 0.61% (blue), 0.92% (green), 1.24% (red), and 4.72% (NIR).

Table 3. Validation Result each band (TOA Reflectance :%)

Band				**Blue**	**Green**	**Red**	**NIR**
Landsat-8 (Absolute Cal.)			**TOA.Ref**	**9.82**	**8.16**	**6.65**	**28.3**
KOMPSAT-3	Before SBAF	Absolute Cal[1)]	TOA.Ref.	11.48	9.40	7.58	24.4
			Diff	1.66	1.24	0.93	-3.90
			Stdev	0.61	0.92	1.24	4.72
		Cross Cal.[2)]	TOA.Ref.	11.34	9.44	8.13	29.45
			Diff	1.52	1.28	1.48	1.15
			Stdev	0.60	0.92	1.34	5.50
	After SBAF	Abs.K3 With SBAF[3)]	TOA.Ref.	11.58	9.31	7.75	24.09
			Diff	0.10	-0.09	0.16	-0.31
			Stdev	0.01	0.01	0.05	0.08
		Cross.K3 With SBAF[4)]	TOA.Ref.	11.23	9.53	7.97	29.79
			Diff	1.41	1.37	1.32	1.49
			Stdev	0.59	0.93	1.31	5.56

1) Absolute Cal. K3 and Absolute Cal. L8, 2) Cross Cal. K3 and Absolute Cal. L8, 3) Absolute Cal. K3 and after consider SBAF K3, 4) Cross Cal. K3 and after consider SBAF L8

As a result, the differences after SBAF compensation (Abs. K3) were within 1% and the Stdev was under 0.1%, which indicates a very high similarity. The differences after SBAF compensation (Cross K3) were under 1.5% and the maximum Stdev was more than 5%. The differences in the cross calibration between Landsat-8 and KOMPSAT-3 were less than ± 1.5% in all bands, therefore if SBAF is applied, the difference due to the spectral characteristics of the different bands should be improved.

Table 4. NDVI Validation Result

SBAF	Sensor	Average	Min	Max	Stdev	Diff.	Diff. Std	Gain	Bias
	Landsat-8	0.61	-0.02	0.85	0.12				
Before	Absolute Cal.	0.51	-0.08	0.80	0.15	0.10 1)	0.1024 1)		
	Cross Cal.	0.55	-0.02	0.82	0.14	0.06 2)	0.0969 2)		
After	SBAF Abs.K3	0.49	-0.11	0.79	0.15	0.02 3)	0.0127 3)	1.0260	0.0355
	SBAF Cross.L8	0.57	0.01	0.83	0.13	0.02 4)	0.0125 4)	1.0115	-0.046

1) Absolute Cal. L8 subtract absolute. Cal. K3, 2) Absolute Cal. L8 subtract Cross cal. K3, 3) Absolute. Cal. K3 subtract after consider SBAF K3, 4) Cross. Cal. K3 subtract after consider SBAF L8

Table 4 show the difference average NDVI Landsat-8 and KOMPSAT-3. The average NDVI for Landsat-8 based on absolute calibration was 0.61, but for KOMPSAT-3 the average was 0.51. After SBAF compensation this was improved to 0.59 and the Stdev changed from 0.1 (before) to 0.02 (after). The difference in NDVI at Landsat-8 and KOMPSAT-3 based on Absolute Calibration improved from 0.10 (before) and 0.03 (after), and Stdev improved from 0.10 (before) to 0.01 (after).

Cross calibration resulted in a considerable improvement in the differences in NDVI between Landsat-8 and KOMPSAT-3, with values of 0.06~0.10 (before) and 0.02~0.03 (after). The SBAF was low in the blue and green bands, but was rather high in the red and NIR. Therefore, it varied according to the target object.

4. CONCLUSION

The Spectral band adjustment factor (SBAF) were calculated using the hyperspectral satellite images acquired in the desert area. As a result of applying SBAF to the main crop area, the vegetation index showed a high agreement rate of relative percentage difference within 5%. For the estimation of SBAF, this study used only one set of images, which did not consider season and solar zenith angle of SBAF variation. Therefore, long-term analysis is necessary to solve SBAF uncertainty in the future.

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