Extraction of vegetation state using ADEOS-II/GLI data

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Key words: ADEOS-II/GLI, Vegetation index, Vegetation coverage

I Introduction

Japan Aerospace Exploration Agency (JAXA) launched the Advanced Earth Observing Satellite II (ADEOS-II) on December 14, 2002. ADEOS-II have five sensors on board, and one sensor is a multi-spectral global imager (GLI). One of scientific purposes of the mission is monitoring vegetation state such as coverage, biomass, activity, and the net primary production of vegetation. GLI data from Apr. 2003 to Oct. 2003 is available. In this study, we present results of the extraction of vegetation information using ADEOS-II/GLI data in an experimental field of ADEOS-II Mongolian Plateau EXperiment for ground truth (AMPEX) around Mandalgobi in Mongolia.

II Study area

The experimental field is one of the validation sites of soil moisture estimation algorithms from ADEOS-II/AMSR data and Aqua/AMSR-E. It lies approximately 235 km south-southwest of Ulaanbaatar, capital of Mongolia. The experimental site is located in a semiarid and sparsely vegetated area. The dominant vegetation types are short-type grass, long-type grass such as *Achnatherum splendens* and shrubs such as *Caragana microphylla* and *Caragana pygmaea*.

The GLI image of the area is shown in Fig. 1. The area is 60 Km by 60 Km and with it's start point at Mandalgobi (M.G.) city as shown with the southwest edge's cross in Fig. 1. The field survey was carried out at the each grid point, at intervals of 10 km. The grid point at Mandalgobi is defined as “A0” and the other grid points every 10 Km are defined as “A, B, C, D, E, F, G” in the west east direction and “0, 1, 2, 3, 4, 5, 6” in the south north direction.

The field survey was carried out in the experimental area on and around the Aqua satellite over-pass day from August 7 to 10, 2003. Fig. 2 shows the vegetation coverage and plant biomass for each point. To determine the vegetation coverage on the each point, the vegetation coverage (%) and natural height (cm) were measured twice randomly for each species, using a 50 cm by 50 cm quadrate, for short-type grass. For long-type grass and shrubs, the vegetation coverage was measured by a line method in three directions, and natural height (cm) and crown and base area were measured twice randomly for each species.

III ADEOS-II/GLI data

ADEOS-II/GLI has 30 bands of 1 km spatial resolution and 6 bands of 250 m spatial resolution in VNIR[1], SWIR[2] and MTIR[3]. Global mosaic data of GLI has 12 bands for VNIR, SWIR and 5 bands for MTIR and it's spatial resolution is 1 km. We use 9 bands in VNIR and SWIR for global mosaic data analysis as shown in Fig. 3 and Table 1. Precipitation data provided by Institute of Meteorology and Hydrology, Mongolia (IMH) is used to compare the precipitation and cloud frequency.

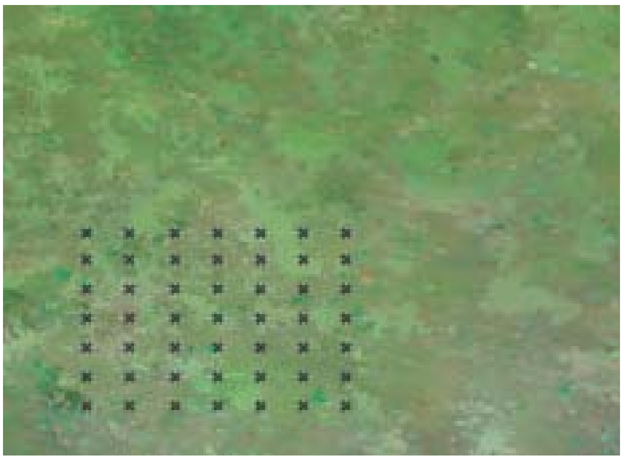

Fig. 1 ADEOS-II/GLI image of the experimental area.

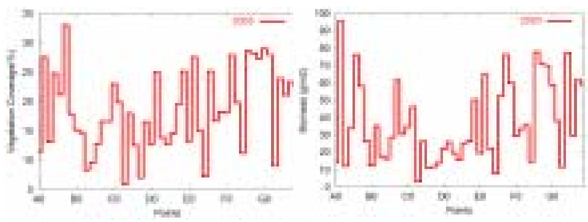

Fig. 2 The result of field survey of vegetation coverage and biomass for each grid.

[1] : Visible and near-infrared region.
[2] : Short-wave length infrared region.
[3] : Middle and thermal infrared region.

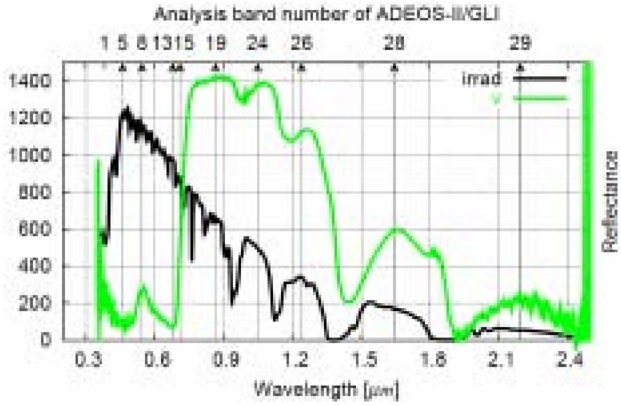

Fig. 3 ADEOS-II/GLI 1 km spatial resolution Band numbers used in this study.

Table 1 ADEOS-II/GLI 1 km spatial resolution data spectral bands and band number defined in this study.

Band Number of SatelliteSensor	Center wavelength [μm]	BandNumber Defined inThisStudy
5	0.4593	1
8	0.5440	2
13	0.6786	3
15	0.7101	4
19	0.8657	5
24	1.0486	6
26	1.2410	7
28	1.6449	8
29	2.1938	9

IV Analysis Methods

We analyzed the spectral reflectance data measured by GLI sensor using the Universal Pattern Decomposition Method (UPDM) (Zhang, 2004). The method is based on the pattern decomposition method (PDM) (Fujiwara, 1996; Muramatsu, 2000; Daigo, 2003). In the PDM framework, the normalization of standard patterns depends on how many bands and which wavelengths the sensor observes. As the results the obtained pattern decomposition coefficients may differ for each sensor such as TM or GLI, even when the same sample is observed. Since the same normalized spectral patterns for any sensor is used in UPDM. In the UPDM, the same value of the coefficients can obtained for measured results by different sensor such as TM or GLI. The method is briefly explained in this section.

The set of spectral reflectance values (R_1, R_2, ..., R_n) of n bands for a pixel is transformed into four coefficients such as water (C_w), vegetation (C_v), soil (C_s) and supplementary of a yellow-leaf (C_4) with four standard spectral shape patterns. In the four standard spectral shape patterns, three are correspond to typical ground objects, namely water (P_{iw}), vegetation (P_{iv}) and soil (P_{is}), and one is a supplementary standard pattern (P_{i4}). The general equation of universal PDM was as follows:

$$R_i \rightarrow C_w P_{iw} + C_v P_{iv} + C_s P_{is} + C_4 P_{i4} \qquad (1)$$

In UPDM, the standard pattern was defined using the continuous spectral function from 350 nm to 2,500 nm, as follows:

$$\int \left| P_k(\lambda) d\lambda \right| = \int d\lambda \quad (k = w, v, s) \qquad (2)$$

Here $\int d\lambda$ refers to integration of the total wavelength range, and $P_k(\lambda)$ is defined as

$$P_k(\lambda) = \frac{\int d\lambda}{\int \left| R_k(\lambda) \right| d\lambda} R_k(\lambda) \quad (k = w, v, s) \qquad (3)$$

For each sensor band, the standard patters are defined by

$$P_{ik} = \frac{\int_{\lambda_{si}}^{\lambda_{ei}} P_k(\lambda) d\lambda}{\int_{\lambda_{si}}^{\lambda_{ei}} d\lambda} \quad (k = w, v, s) \qquad (4)$$

where λ_{si} and λ_{ei} are the start and end wavelength for band *i*, respectively and $\int_{\lambda_{si}}^{\lambda_{ei}} d\lambda$ is the wavelength with of band *i*. The supplementary pattern is defined as

$$P_4(\lambda) = \frac{r_4(\lambda) \int d\lambda}{\int \left| r_4(\lambda) \right| d\lambda} \qquad (5)$$

where $r_4(\lambda)$ is the residual yellow-leaf value relative to *i* bands:

$$r_4(\lambda) = R_4^{yl}(\lambda) - \left\{ C_w^{yl} P_w(\lambda) + C_v^{yl} P_v(\lambda) + C_s^{yl} P_s(\lambda) \right\} \qquad (6)$$

Here, $R_4^{yl}(\lambda)$ is the measured spectral reflectance of yellow-leaf sample, and $r_4(\lambda)$ is the residual value. The decomposition coefficients were obtained for each sensor by the least squares method using eq. (1).

$$\text{VIUPO} = \frac{\left(C_v - 0.17 C_s - C_4 \right)}{C_w + C_v + C_s} \qquad (7)$$

It is determined to have linear relationship with vegetation cover and with the quantity of photosynthesis. (Zhang, 2004)

V GLI data analysis

The spectral reflectance measured by GLI sensor for the grid point A1, F4, G5 and G6 on Aug. 13 is shown in

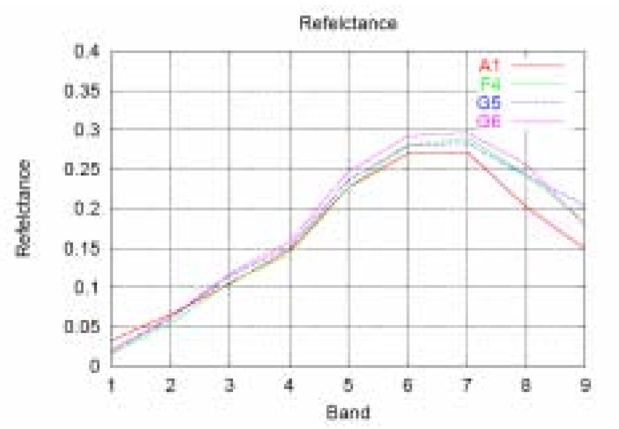

Fig. 4 Spectral reflectance of the grid in the experimental area by GLI.

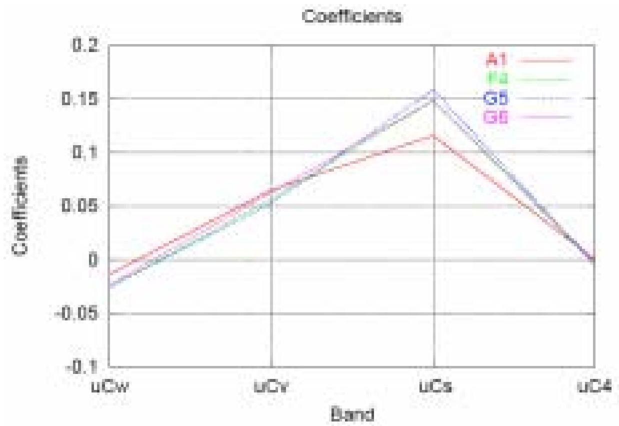

Fig. 5 UPDM coefficients for the spectral reflectance in Fig. 4.

Fig. 4. In these area, *Caragana microphyllais* dominant. The spectral pattern is similar to soil. Four UPDM coefficients for the samples are shown in Fig. 5. The coefficients of soil and vegetation are around 0.15 and 0.06, respectively. Although the spectral pattern is similar to soil, information of vegetation was extracted as C_v coefficient.

1. Vegetation coverage and VI-UPD

Using the data measured on Aug. 13 2003, the vegetation index VIUPD for the grid point was compared with the vegetation coverage measured in the field from Aug. 7 to Aug. 10 2003. Fig. 6 shows the result of the relationship between the VIUPD and the vegetation coverage. It had a linear relationship and it was

$$VC(\%) = 90.6(\pm 4.6) \times \text{VIUPO} \qquad (8)$$

The experimental linear-correlation coefficient was 0.94.

2. Vegetation coverage estimation for the experimental area

Using the relationship in eq. (8), the vegetation coverage for the experimental area was estimated. The result is shown in Fig. 7.

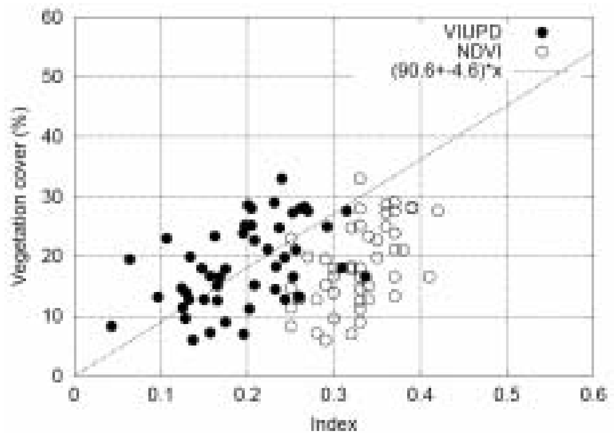

Fig. 6 The relationship between VIUPD measured by GLI on Aug. 13 2003 and vegetation coverage measured from Aug. 7 to Aug. 10 2003 in the field.

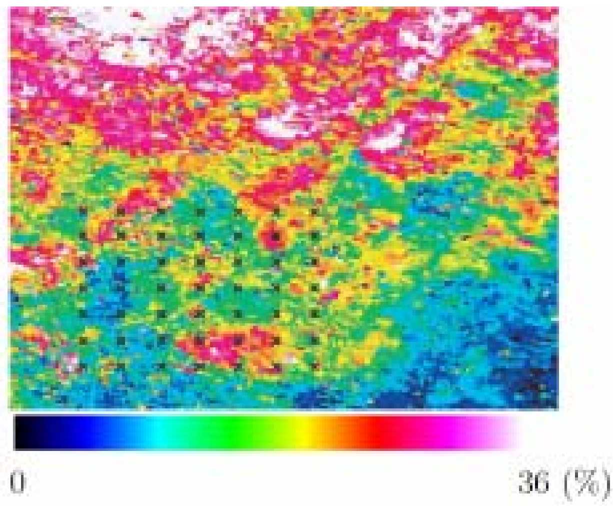

Fig. 7 Spectral reflectance of the grid in the experimental area by GLI.

VI Conclusions

The spectral reflectance measured by ADEOS-II/GLI sensor was studied with the universal pattern decomposition method (UPDM). The set of reflectance was successfully transformed into UPDM coefficients. For the sample of the grid point of being dominant of *Caragana microphylla*, the set of reflectance was transformed into UPDM coefficients. Although the spectral shape is similar to soil, the vegetation information was extracted as uC_v coefficient.

The relationship between the vegetation index (VIUPD) based on UPDM and the vegetation coverage measured on Aug. 3 to 10 2003. A linear relationship was established and the experimental linear-correlation coefficient was 0.94. Using the relationship, the vegetation coverage for the whole experimental area was estimated. We have a plan to estimate the net primary production of vegetation using this method.

Acknowledgment

ADEOS-II/GLI data was provided by JAXA.

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