Retrieval of emissivity and land surface temperature from MODIS

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ABSTRACT :

In this study, emissivity and land surface temperature (LST) were retrieved using the previously developed algorithms and Aqua/MODIS data. And sensitivity of estimated emissivity and LST to the predefined values, such as land cover, normalized difference vegetation index (NDVI) and spectral emissivity were investigated. The methods used for emissivity and LST were vegetation cover method (VCM) and four different split-window algorithms. The spectral emissivity retrieved by VCM was not sensitive to the NDVI error but more sensitive to the land cover error. The comparison of LST showed that the LST was systematically different without regard to the land cover and season. And the LST was very sensitive to the emissivity error excepting the Uliveri et al. This preliminary result indicates that more works are needed for the retrieval of reliable LST from satellite data.

Key Words: Land surface temperature, emissivity, vegetation cover method, split-window lgorithm

1. Introduction

Land surface temperature (LST) plays an important role in the physics of land surface as it controls the processes of energy and water exchange between the surface and the atmosphere. However, regular observations of LST are fundamentally limited because the land surfaces are composed of significantly heterogeneous components in emissivity, thermal inertia and height. The only practical way of obtaining LST at spatial and temporal resolutions appropriate for the wide range of users, from numerical and climatologic modeler to the weather forecasters, is by means of remote sensing. Various efforts are underway to improve the quality of the retrieved emissivity and land surface temperature (LST) from satellite data (e.g., Price, 1984; Uliveri et al (LST) from satellite data (e.g., Price, 1984; Uliveri et al., 1994; Han et al., 2004).

The temporal and spatial resolution and the spectral capability of the forth coming Communication, Ocean and Meteorological Satellite (COMS) system reveal, to be especially adequate to retrieve LST. The present study has two goals: One is to estimate the LST and emissivity using the previously developed algorithms and MODIS data. The other is to investigate the sensitivity of estimated LST and emissivity to the predefined values, such as land cover, normalized difference vegetation index and spectral emissivity. This result can be used as background information for the retrieval of LST algorithm for the forthcoming COMS data.

2. Data and Methods

The data used in this study were land cover map, normalized difference vegetation index (NDVI) and MODIS CH31 and CH32 data of 2003 and 2004 received at KARI. Vegetation cover method (VCM, Valor and Caselles, 1996) was used to retrieve the spectral emissivity over Korean peninsula.

$$\varepsilon_i = \varepsilon_{i,v} \times FVC + \varepsilon_{i,g} \times (1 - FVC)$$

$$FVC = \frac{NDVI - NDVI_{\min}}{NDVI_{\max} - NDVI_{\min}}$$

ε_i : *spectral emissivity for channel I*

$\varepsilon_{i,v}, \varepsilon_{i,g}$: *spectral emissivity of vegetation and soil for channel I*

FVC : *Fraction of vegetation* cov*rage*

$NDVI_{\max}$, $NDVI_{\min}$: *NDVI for pure vegetation and bare soil for the given pixel*

Many types and methods were developed for the retrieval of LST using satellite data. Split window method was most widely used because of computational efficiency, easy of application and accuracy. We selected the four different split window algorithms among the numerous algorithms for this study:

Price(1984)

$$T_s = [T_4 + 3.33(T_4 - T_5)]\left(\frac{5.5 - \varepsilon_4}{4.5}\right) + 0.75T_5(\varepsilon_4 - \varepsilon_5)$$

Becker and Li (1990)

$$LST = 1.274 + \left(1 + 0.15616\frac{1-\varepsilon}{\varepsilon} - 0.482\frac{\Delta\varepsilon}{\varepsilon^2}\right)\frac{T_{31} + T_{32}}{2} + \left(6.26 + 3.98\frac{1-\varepsilon}{\varepsilon} + 38.33\frac{\Delta\varepsilon}{\varepsilon^2}\right)\frac{T_{31} - T_{32}}{2}$$

Uliveri et al.(1994)

$$LST = T_4 + 1.8(T_4 - T_5) + 48(1 - \varepsilon) - 75\Delta\varepsilon$$

Kerr et al.(1992)

$$T_s = f_v T_{veg} + (1 - f_v)T_{soil}$$

$$T_{veg} = T_4 + 2.6(T_4 - T_5) - 2.4$$

$$T_{soil} = T_4 + 2.1(T_4 - T_5) - 3.1$$

3. Preliminary Results

Spectral emissivity over Korean peninsula was calculated from MODIS NDVI data and land cover using VCM method. Temporal variations of spectral emissvity according to the land cover were shown in figure 1.

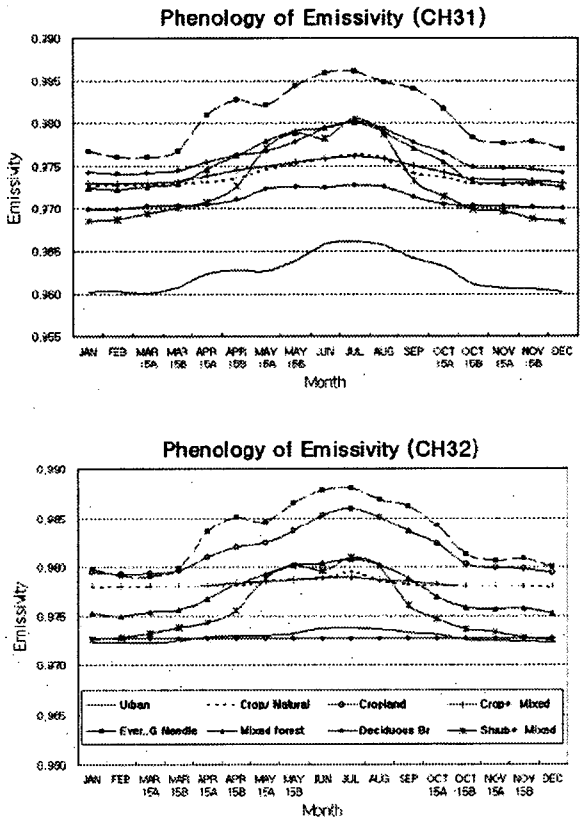

Figure 1 Temporal variations of spectral emissivity retrieved from MODIS NDVI data using VCM method.

The temporal variations of spectral emissvity were clearly dependent on the land cover type. Emissivity is a function of FVC and land cover type. So, we tested the

sensitivity of emissivity for the ±10% error in FVC and land cover classification error. While VCM showed a very stable result for the FVC error, it showed non-negligible sensitivity for the land cover error (not shown). Figure 2 shows a frequency of LST retrieved from the 4 different split window methods for 12 August, 2004. In this study, we do not eliminate the cloud-contaminated pixels during the LST retrieval, so there are number of pixels with very low temperature. LST retrieved by Becker and Li's is warmest, whereas LST by Kerr et al. is coldest. It shows that LST is clearly dependent on the retrieval methods.

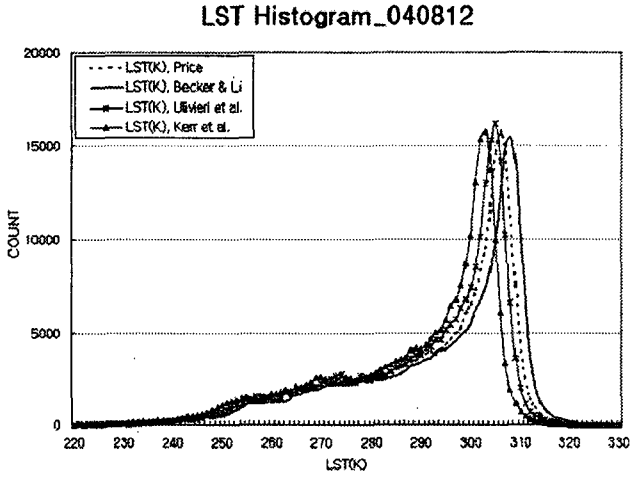

Figure 2. Histogram of LST for the four different split window algorithms

Figure 3 shows a sample image of LST retrieved from MODIS CH31 and CH32 for 12 August, 2004. LST of southern and low elevated area was generally higher than northern and mountain area. And LST of large city such as Seoul, Daegu, and Gwangju, was significantly warmer than suburban area, due to the urban heat island effects. It indicates that LST by split window method using satellite data is qualitatively reasonable.

Figure 4 shows a sensitivity of LST to the ±1% emissvity error for the wide range of emissivity with fixed brightness temperature. The sensitivity was also clearly dependent on the algorithm, especially for the Price method. It shows that accurate emissvity is prerequisite for the retrieval of reliable LST.

Figure 3. Sample image of LST retrieved from MODIS data using Price method for 12 August, 2004. Black indicates a warmer LST.

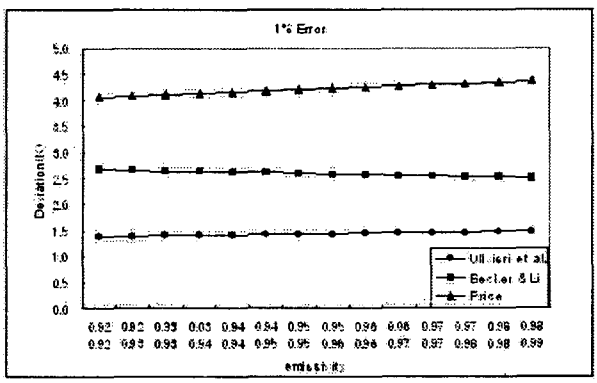

Figure 4. Sensitivity of LST to the ±1% emissvity error for the selected algorithms with fixed brightness temperature.

4. Summary

In this study, we retrieved emissivity and land surface temperature (LST) and investigated their sensitivity to the predefined values, such as NDVI or emissivity. The spectral emissivity retrieved by vegetation cover method was not sensitive to the NDVI error but more sensitive to the land cover error. And the LST was very sensitive to the emissivity error excepting the Uliveri et al. The differences among LST retrieved by the selected 4 split window algorithms were between 2K (Becker and Li – Price) and 7K (Becker and Li – Kerr et al.). And the differences were very systematic without regard to the land cover and season. This preliminary result indicates that more works are needed for the retrieval of reliable LST from satellite data.

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