DEVELOPMENT OF ATMOSPHERIC CORRECTION ALGORITHM FOR HYPERSPECTRAL DATA USING MODTRAN MODEL

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ABSTRACT: Atmospheric correction is one of critical procedures to extract quantitative information related to biophysical variables from hyperspectral data. In this study, we attempted to generate the water vapor contents image from hyperspectral data itself and developed the atmospheric correction algorithm for EO-1 Hyperion data using pre-calculated atmospheric look-up-table (LUT) for fast processing. To apply the new atmospheric correction algorithm, Hyperion data acquired June 3, 2001 over Seoul area is used. Reflectance spectrums of various targets on atmospheric corrected Hyperion reflectance images showed the general spectral pattern although there must be further development to reduce the spectral noise.

KEY WORDS: Hyperspectral, Atmospheric correction, MODTRAN, Water vapor contents

1. INTRODUCTION

Atmospheric correction of hyperspectral data is basically to remove atmospheric attenuations from the at-sensor radiance and to achieve accurate surface reflectance value that can be compared with known spectral characteristics in a spectral library for analyzing biophysical variables (Griffin and Burke, 2003). Several atmospheric correction algorithms have been developed for hyperspectral data, such as ACORN, FLAASH, HATCH that are based upon radiative transfer(RT) model (Richter and Schlapfer, 2002; Goetz et al., 2003; Griffin and Burke, 2003). Considering the large volume of hyperspectral data and complex RT model, atmospheric correction algorithm should be more accurate, simple and fast in data processing (Carins et al., 2003).

The objective of this study is to develop more accurate, simple and fast atmospheric correction algorithm for hyperspectral data by using the water vapor contents image directly from hyperspectral data itself.

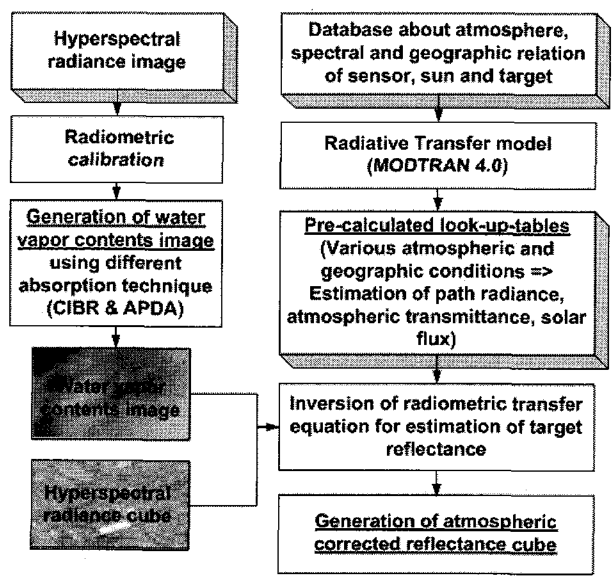

Figure 1. Atmospheric correction algorithm of hyperspectral data

2. ATMOSPHERIC CORRECTION OF HYPERSPECTRAL DATA

For more accurate and fast atmospheric correction of hyperspectral data, we attempt to generate the water vapor contents image from hyperspectral image itself and the pre-calculated LUT based on MODTRAN model. Figure 1 shows the overall procedure to the atmospheric correction algorithm of hyperspectral data suggested in this study.

2.1 Generation of water vapor contents image from hyperspectral data

For the accurate atmospheric correction, atmospheric data obtained at the time of image acquisition are necessary. Because of the difficulty for the ground measurement of atmospheric constituents and the poor spatial resolution of meteorological satellite data, atmospheric correction of high resolution satellite image has been difficulty. However, the narrow-band hyperspectral data have several absorption features and allow us to estimate atmospheric gases or water vapor contents. Using hyperspectral data, there have been a few algorithms to generate water vapor contents image: CIBR (Continuum Interpolated Band Ratio) and APDA (Atmospheric Pre-corrected Differential Absorption technique) methods. These methods use different absorption properties at an absorption bands (940nm) and a non-absorption bands (842nm, 1300nm) of atmospheric water vapor (Gao and Kaufman, 1990; Schlapfer et al., 1998). Figure 2 showed the detail specification of CIBR and APDA. methods.

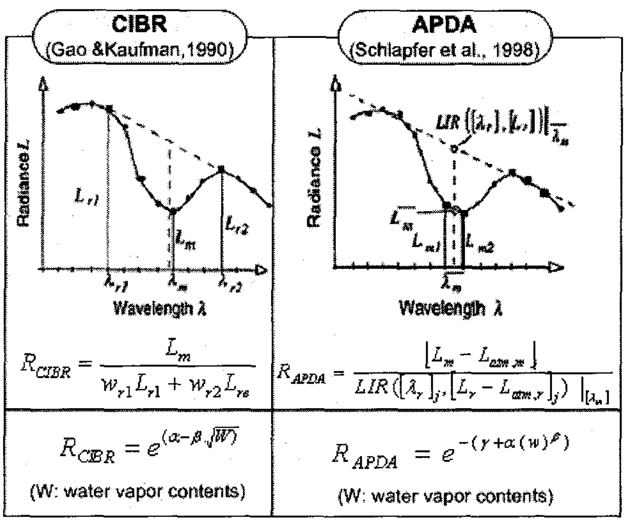

Figure 2. Concepts of CIBR and APDA methods for estimation of water vapor contents.

2.2 Pre-calculation of atmospheric look-up-table

Atmospheric radiative transfer code is a rather complex numerical model and used to calculate atmospheric scattering and absorption from at-sensor radiance and eventually to get surface reflectance. MODTRAN (MODerate resolution atmospheric radiance and TRANsmittance Model) has been a frequently used radiative transfer code for atmospheric correction of satellite imagery. In this study, the inversion mode of MODTRAN model was used to acquire surface reflectance from at-sensor radiance. For atmospheric correction, various input parameters are required, which includes atmospheric model, aerosol model, geometric information of sun-target-sensor, and sensor spectral specification. Because hyperspectral data usually have more than two hundreds spectral bands and atmospheric correction should be performed on every pixel, the atmospheric correction algorithm should be fast. We tried to implement pre-calculated LUT that include several input parameters as required in MODTRAN (Figure 3 and Table 1). LUT are composed with pre-defined values for several input parameters values and resultant reflectance value for every combination. The first sequence of LUT is used to obtain path radiance, transmittance, and global flux value for specific input parameter values of hyperspectral data. Using these information, the surface reflectance is calculated using these LUT values at next stage.

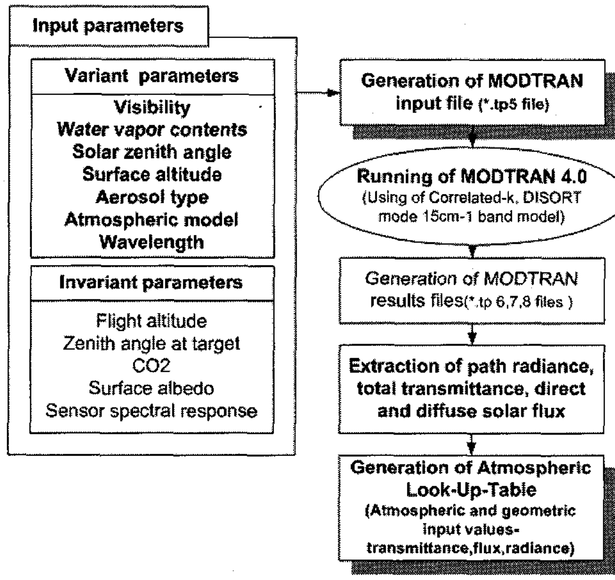

Figure 3. Flow chart to generate pre-calculated LUT.

Table 1. Input parameters and values of MODTRAN for generation of pre-calculated LUT.

Variant input parameters			
Parameters	Range	Interval	Values
Water vapor contents	0.5-4.0 gcm-2	0.5	0.5,1.0,1.5,2.0,2.5,3.0,3.5,4.0
Aerosol type	Rural, Urban	-	Rural, Urban
Atmosphere model	Mid-latitude summer, winter	-	Mid-latitude summer, winter
Visibility	5-120 km	5km/20 km	5,10,15,20,30,40,60,80,100,120
Surface altitude	0-2.5 km	0.5km	0,0.5,1.0,1.5,2.0,2.5
Solar zenith angle	0-70°	10°	0,10,20,30,40,50,60,70
Spectral bands	400-2500nm	10nm	-
Invariant input parameters			
Flight altitude			705km
CO2			365ppm
Surface albedo			0.135
Sensor spectral response			Hyperion.flt

2.3 Atmospheric correction of hyperspectral data

Equation 1 shows a general form of radiative transfer in case of Lambertian surface. In this equation, hyperspectral image's pixel value is the at-sensor radiance values. Three components (path radiance, transmittance, global flux) of atmospheric and geometric condition of hyperspectral data are calculated from MODTRAN. The surface reflectance value is then calculated by the inversion of equation 1. The inversion processing is applied to every spectral band and every pixel of hyperspectral data.

$$L(\lambda) = L_p(\lambda) + \tau(\lambda)\rho(\lambda)E_g(\lambda)/\pi \quad (1)$$

L(λ): Sensor-received radiance for each channel λ
Lp(λ): Path radiance
τ(λ): Atmospheric transmittance
ρ(λ): Surface reflectance
Eg(λ): Global flux on the ground

3. EXPERIMENT ON EO-1 HYPERION DATA

To validate the atmospheric correction algorithm, we used EO-1 Hyperion data acquired on June 3, 2001 over Seoul area. Hyperion data is satellite-borne hyperspectral data and have 242 spectral bands of spectral wavelengths ranging from about 400 to 2,500nm. Figure 4 shows two water vapor contents images generated by CIBR and APDA methods. Two water vapor contents images look very similar although the CIBR method provides a little higher values (Table 2). As seen in Figure 4, however, the water vapor contents images show clear sensor noise effects.

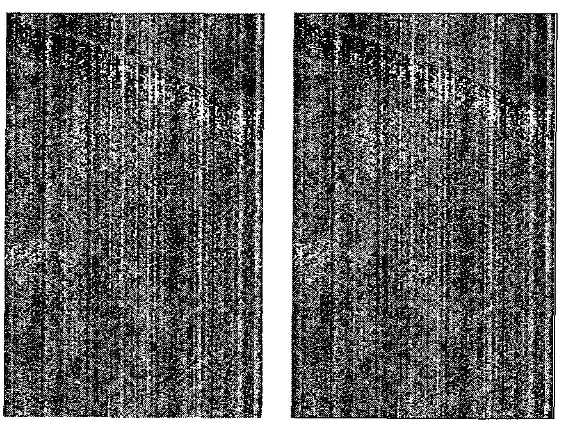

Figure 4. Water vapor contents images generated by using CIBR(left) and APDA(right) algorithms from Hyperion data.

Table 2. Statistics of water vapor contents images (unit:cm).

Statistics	CIBR	APDA
Min-Max	0.19-4.13	0.21-3.80
Mean	2.22	1.80
Std	0.52	0.44

Figure 5 shows atmospheric transmittance values extracted from pre-calculated LUT for various water vapor contents. Transmittance value on water absorption band (942nm) is decreased as atmospheric water vapor content increases. On the other hands, transmittance on the non-absorption bands (842nm, 1003nm) is insensitive by water vapor contents. As seen in Figure 5, pre-calculated LUT clearly shows the atmospheric water absorption properties.

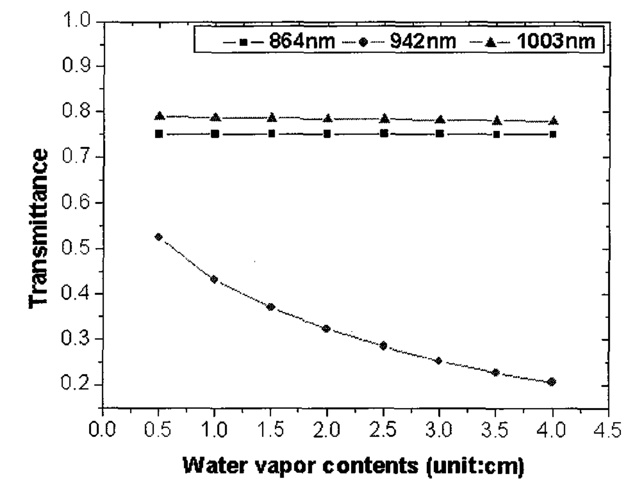

Figure 5. Transmittance values extracted from LUT for various water vapor contents at two spectral bands of water absorption band (942nm) and non-absorption bands (864nm,1003nm).

Using these water vapor contents, Hyperion radiance image was atmospherically corrected by pre-calculated LUT. Figure 6 showed spectral reflectance curves of several ground features extracted from the atmospheric corrected Hyperion reflectance image. Forest and grass showed the general spectral pattern of green vegetation, which the high reflectance at NIR region and low reflectance in visible wavelength. However the atmospheric corrected reflectance values of forest in NIR region seems to be a little low. Water has very low reflectance values over visible region and is almost no reflectance in infrared region. Spectral patterns of urban and road are similar each other. Bare soil shows the highest reflectance over all spectral range. Although these spectra match with general form of spectral reflectance, they show some noises that might come from the sensor itself. Probably, the radiometric correction of sensor data should be a pre-processing step prior to the atmospheric correction.

4. CONCLUSIONS

Although the atmospheric correction is an essential procedure for analyzing hyperspectral data, it is difficult and time-consuming job. In this study, we developed an atmospheric correction method that can be simple and fast to implement. This atmospheric correction method uses pre-calculated LUT that is based on MODTRAN model and the water vapor contents derived directly from hyperspectral image itself. The atmospheric corrected reflectance of Hyperion data correspond the general pattern of spectral reflectance of several surface materials. However, the original Hyperion sensor noise is evident on the atmospheric corrected reflectance data. Further study is planned to reduce these noise to obtain smooth atmospheric reflectance data.

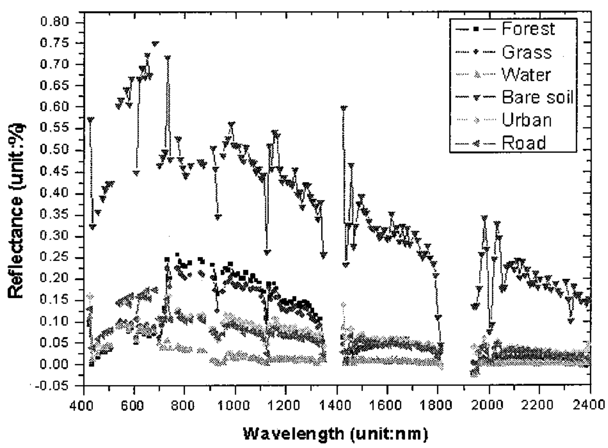

Figure 6. Spectral reflectance curves of various targets extracted from atmospheric corrected Hyperion data.

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