THE EFFECT OF TOPOGRAPHIC FACTOR IN ATMOSPHERIC CORRECTION FOR HYPERSPECTRAL DATA

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ABSTRACT

In this study, two MODTRAN-based software packages (FLAASH and ATCOR-4) were employed to conduct atmospheric correction on a hyperspectral dataset, collected by a Itres CASI-1500 in Southern Taiwan with a spectral range of 367 – 1047 nm and a spectral resolution of 9.6 nm. ATCOR-4 is capable of including topographic effect (such as slope and aspect) in atmospheric correction when a DEM or DSM is provided. The effect of topographic factor was demonstrated by comparing the results obtained from FLAASH and ATCOR-4 with in-situ measurements, using a PSR-1100 spectroradiometer, respectively. The preliminary results showed that ATCOR-4 produced the best result when a smoothed DSM is provided. However the processing time for obtaining such result in significantly longer than FLAASH.

Keywords: Atmospheric correction, Hyperspectral image, Radiative transfer model,

INTRODUCTION

Hyperspectral images have been widely used for land use classification, change detection and so on (Teng et al.2008). However, the radiance received at the sensor is different with the radiance leaving from the Earth surface due to the interference by the atmosphere. Therefore, the atmospheric effect has to be corrected prior to any applications utilizing the spectral information to lead a more accuracy result.

There are many atmospheric correction approaches were developed, such as scene-based empirical line, radiative transfer modeling and so on. Scene-based empirical line approach (Conel et al., 1987) requires in-situ measurements of spectral reflectance. This approach was based on the linear regression of hyperspectral images and in-situ measurement, and requires at least one bright target and one dark target to achieve. On the other hand, radiative transfer modeling is using a theoretical modeling technique to simulate the absorption and scattering effects of atmosphere in order to correct the spectral values. There exists several different modeling, such as 6S, LOWTRAN and MODTRAN. In this study, two MODTRAN-based software packages (FLAASH and ATCOR-4) were tested to correct the atmospheric effect on the same hyperspectral images. Furthermore, topographic effects are considered in ATCOR-4, includes the slope, aspect, sky view factor and cast shadow which are obtained from digital elevation model.

The main objects of this study are (1) Comparing the atmospheric correction results between two software packages in a single flight-line. (2) Comparing the correction result in the overlap area of multiple flight-lines to evaluate the consistency between flight-lines.

MATERIAL

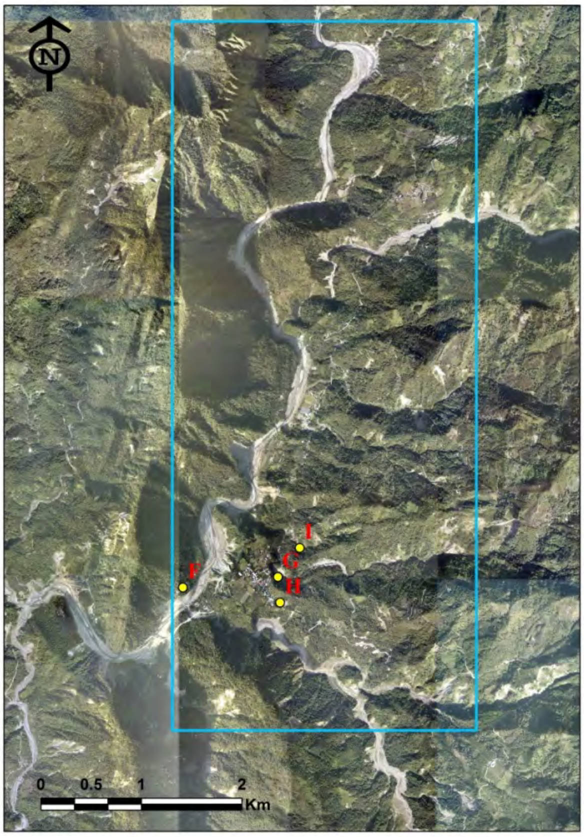
The study area (Figure 1a) is near Tsengwen Reservoir, southern Taiwan. And the materials contain hyperspectral images, Digital Elevation Model (DEM), Digital Surface Model (DSM) and in-situ measurement of spectral reflectance.

The 72-band hyperspectral data were obtained by an Itres CASI-1500 on 13th September 2012. The spectral range of Itres CASI-1500 is between 367 nm and 1047 nm with 9.6 nm interval. And the image pixel resolution is 1 meter.

The DEM and DSM were generated from LiDAR data which was obtained by Optech ALTM Prgasus on 2nd September 2012. And the grid size is 1 meter, which is the same pixel resolution with the hyperspectral image. It is an important requirement of ATCOR-4 due to the pixel by pixel process.

In order to verification the results of the atmospheric correction, this study collected in-situ measurement of spectral reflectance. The reflectance was acquired by using PSR-1100 field portable spectroradiometer. And the locations of site are shown in figure 1a denoted as yellow points F, G, H and I. The land cover of these four sites is asphalt-paved surface (Figure 1b). And the spectrometer was placed horizontally on the tripod and then measured the spectral reflectance (Figure 1c).

(a)



(b)

(c)

Figure 1. (a) The study area is denoted as the blue line, and the yellow points indicate the location of in-situ measurement. (b) It shows the surrounding of the in-situ measurement. (c) It shows the method of measuring the reflectance.

Two MODTRAN-based software packages were adopted in this study, FLAASH (Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes) and ATCOR-4 (Atmospheric/Topographic Correction -4). FLAASH is based on a standard equation (ENVI, 2009) for spectral radiance L at a sensor pixel. The equation is:

$$L = \left(\frac{A\rho}{1-\rho_e S}\right) + \left(\frac{B\rho_e}{1-\rho_e S}\right) + L_a \quad (1)$$

Where ρ is the pixel surface reflectance, ρ_e is an average surface reflectance for the pixel and a surrounding region, S is the spherical albedo of the atmosphere, L_a is the radiance back scattered by the atmosphere and A and B are coefficients that depend on atmospheric and geometric conditions but not on the surface. It is worth mentioning that FLAASH neglects the topographic effect during the process. Instead of considering the surface elevation, it assumes the terrain as a flat surface.

In opposite, ATCOR-4 additionally includes a correction of topographical effects. It allows user to input the information of DEM or DSM to obtain the topographic factor (slope, aspect, sky view factor and cast shadow). The main steps (Richter and Schlapfer, 2012) are showing in the figure 2. And the correction cannot start until all the data were fully prepared.

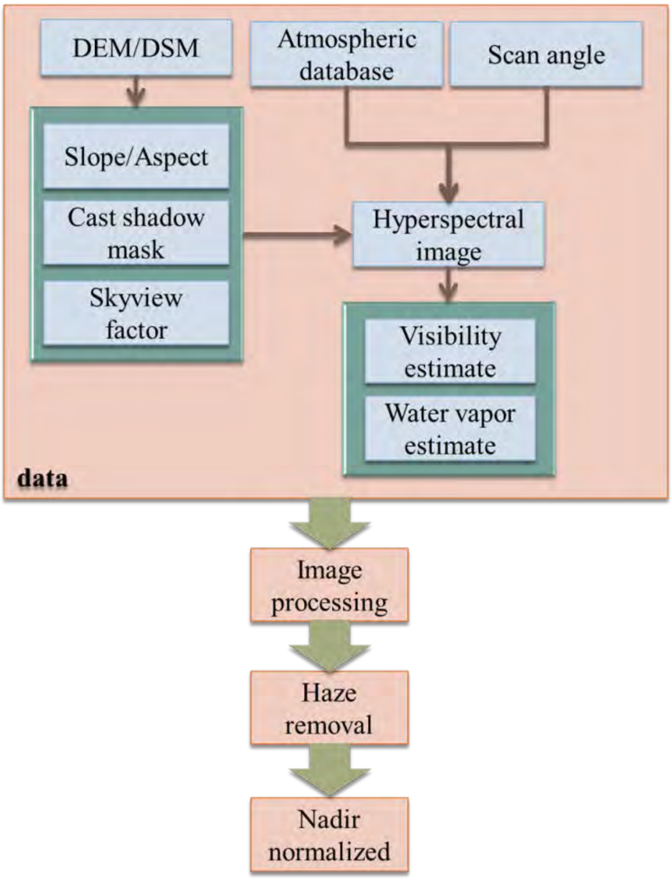


Figure 2. The flow chart of using ATCOR-4.

EXPERIMANT

Since ATCOR-4 is able to input topographic information, two different of elevation models are tested, which are DEM and smoothed DSM. It is due to the DSM contains detail surface features, which leads to a rough surface that makes the corrected result contains null values. This study additionally tested the effect of the number of null values while applied different kernel sizes of smooth filter. And this study also used ATCOR-4 and FLAASH to do atmospheric correction without elevation information, which means assuming the surface is flat when conduct atmospheric correction. According to above, there are four different cases of the correction results (Figure 3). Compare these four results of atmospheric correction with the in-situ measurement, and analyzed which one is the closest to the in-situ measurement.

According to above atmospheric correction in single flight-line, this study chose a better performance of corrected result from ATCOR-4 to compare with the corrected result from FLAASH in multiple flight-lines. No matter in which flight-line, the same target should perform similar spectral reflectance curves. So this study chose four kinds of land feature, including vegetation, river, bare soil and asphalt, and each land feature random chose ten targets. This study compared the correction result in the overlap area of multiple flight-lines to evaluate the consistency between flight-lines.

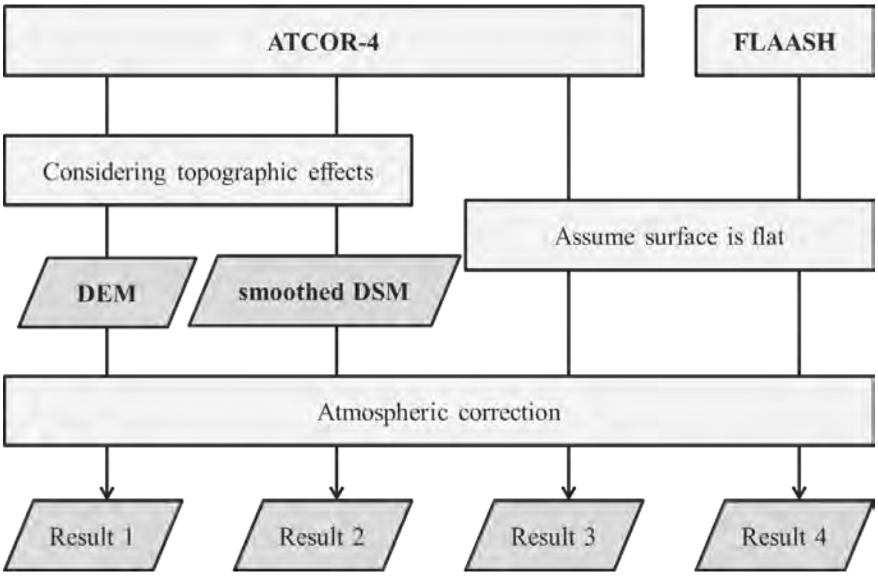


Figure 3. The flow chart of experiment.

RESULTS AND DISCUSSION

(1) Atmospheric correction in single flight-line

Frist, this study tested the effect of the number of null values while applied different kernel sizes of smooth filter. The tested kernel sizes are 5, 9, 13, 17 and 21 pixels, respectively. The corrected results were shown in figure 4. It is noted that the number of null pixel is dramatically decrease while applied a smooth filter to DSM. In the case that ATCOR-4 using DSM performs the worst correction result, which is shown in figure 4a. Due to the DSM contains detail surface features, which leads to a rough surface that makes the corrected result contains null values. According to the result, it is suggested that the smooth operation on DSM is necessary in ATCOR-4. And according to figure 4, this study chose the result of applied 13×13 kernel to represent the result 2 (figure 3) because there are hardly exists null pixel.

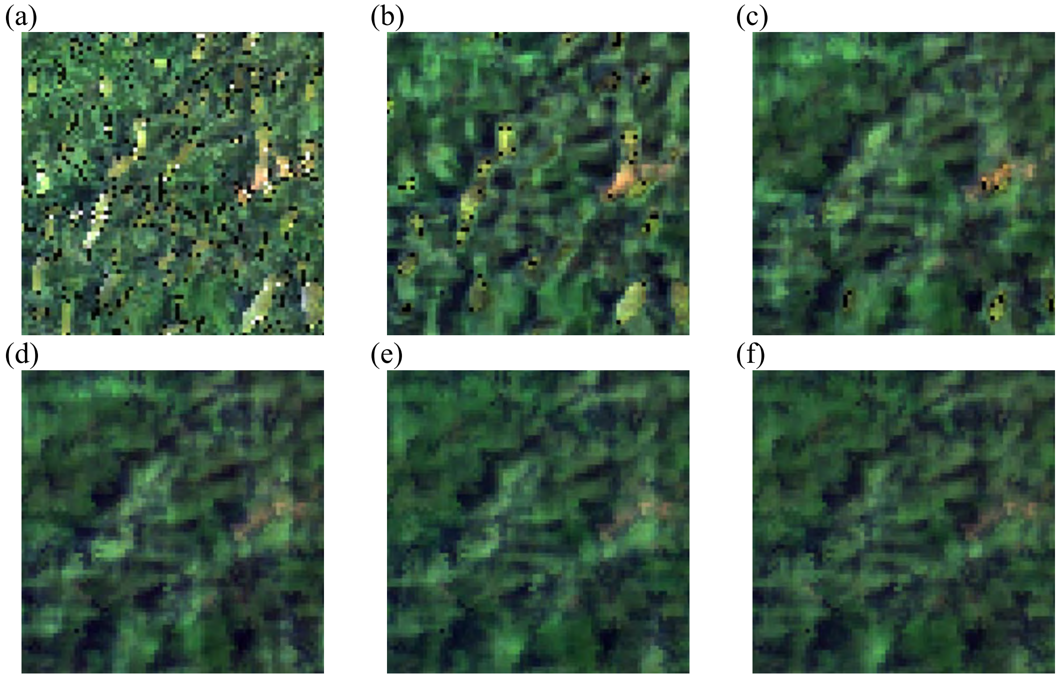


Figure 4. A close-up view of the correction result of applied different kernel sizes of smooth filter to DSM in ATCOR-4. The black pixels indicate the pixels of unsuccessful correction that present as null pixels. (a) with no smooth filter (b) 5×5 kernel size (c) 9×9 kernel size (d) 13×13 kernel size (e) 17×17 kernel size (f) 21×21 kernel size

According to figure 3, there were four different atmospheric correction results. This study compared the corrected reflectance with in-situ measurement, and then analyzed which is the closest to the in-situ measurement. The location of the in-situ measurement is shown in figure1a denoted as yellow points which are point F, G, H and I. Figure 5 shows the comparison of four correction cases and the in-situ measurement. It is obviously that the result of FLAASH is unstable between 850nm to 1050nm, and its reflectance contains negative values. And it is noted that no matter which result, the reflectance is far below to in-situ measurement in blue band.

However, it is hard to evaluate the atmospheric correction results according to Figure 5. So we further calculated the absolute difference between the corrected reflectance and in-situ measurement in each band, and averaged the difference which is listed in the Table 1. And the asterisk mark denotes the minimum difference among each method, it is noted that the results of using ATCOR-4 with smooth DSM is the closest to the in-situ measurement.

Table 1. The averaged absolute difference of spectral reflectance compared to in-situ measurement (unit: %, the minimum difference is marked by *)

Site	ATCOR-4			FLAASH
	DEM	smoothed DSM	flat	
F	2.07	1.52*	2.53	1.86
G	2.67	2.45*	2.70	3.62
H	2.48	2.40*	2.58	3.04
I	6.81	6.69	6.09*	7.52

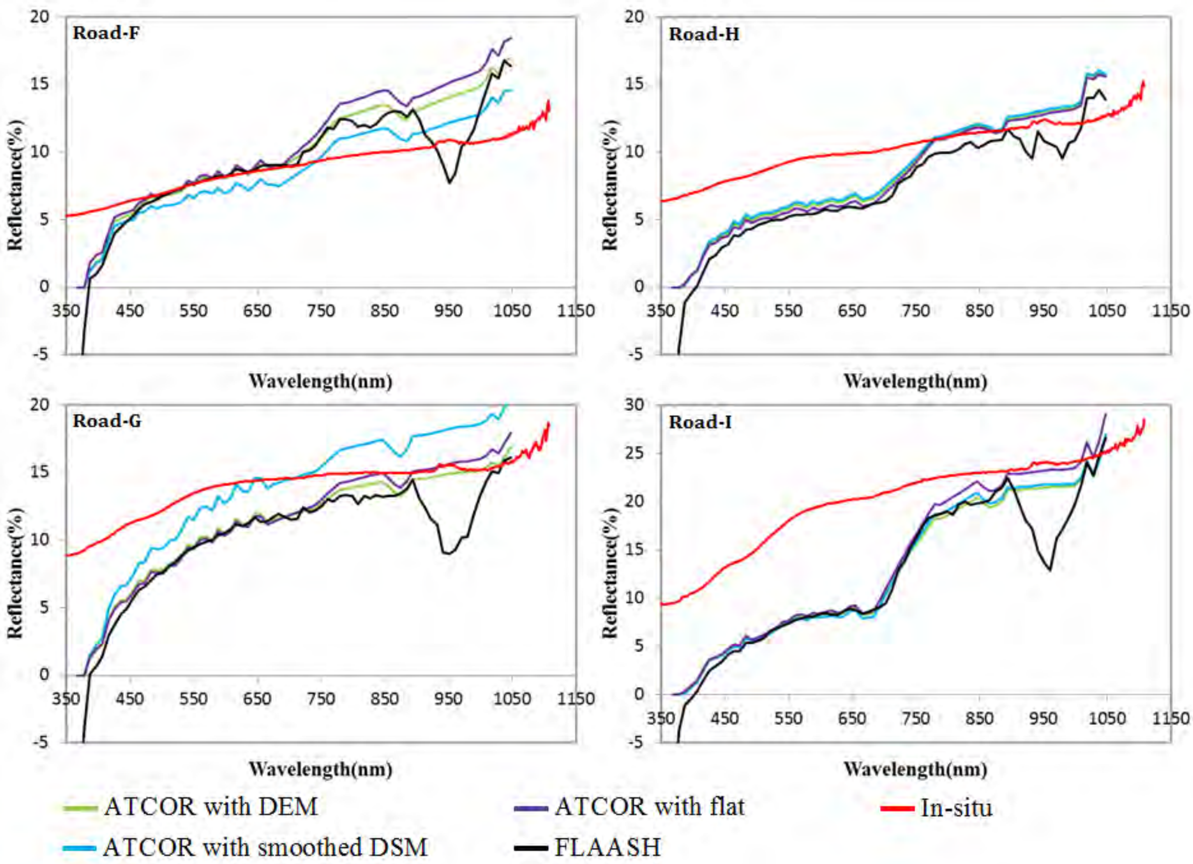


Figure 5. The corrected spectrum of each method and in-situ measurement.

(2) Atmospheric correction in multiple flight-lines

Since the ATCOR-4 with smooth DSM perform the most similarity to the in-situ measurement, the result is considered a reference to compare with the result of FLAASH of multiple flight-lines. As mention before, the same target should perform similar spectral reflectance curves. This study compare corrected reflectance of same target in the overlapping areas between flight-lines. The four kinds of land feature are vegetation, river, bare soil and asphalt. Each land feature random be chose ten targets. And the corrected reflectance of one flight-line minus the other flight-line by each target, and then calculate the average and standard deviation of the minus results by each land feature (Figure 6). And we can find out the stability in multiple flight-lines is no obvious difference by using ATCOR-4 or FLAASH.

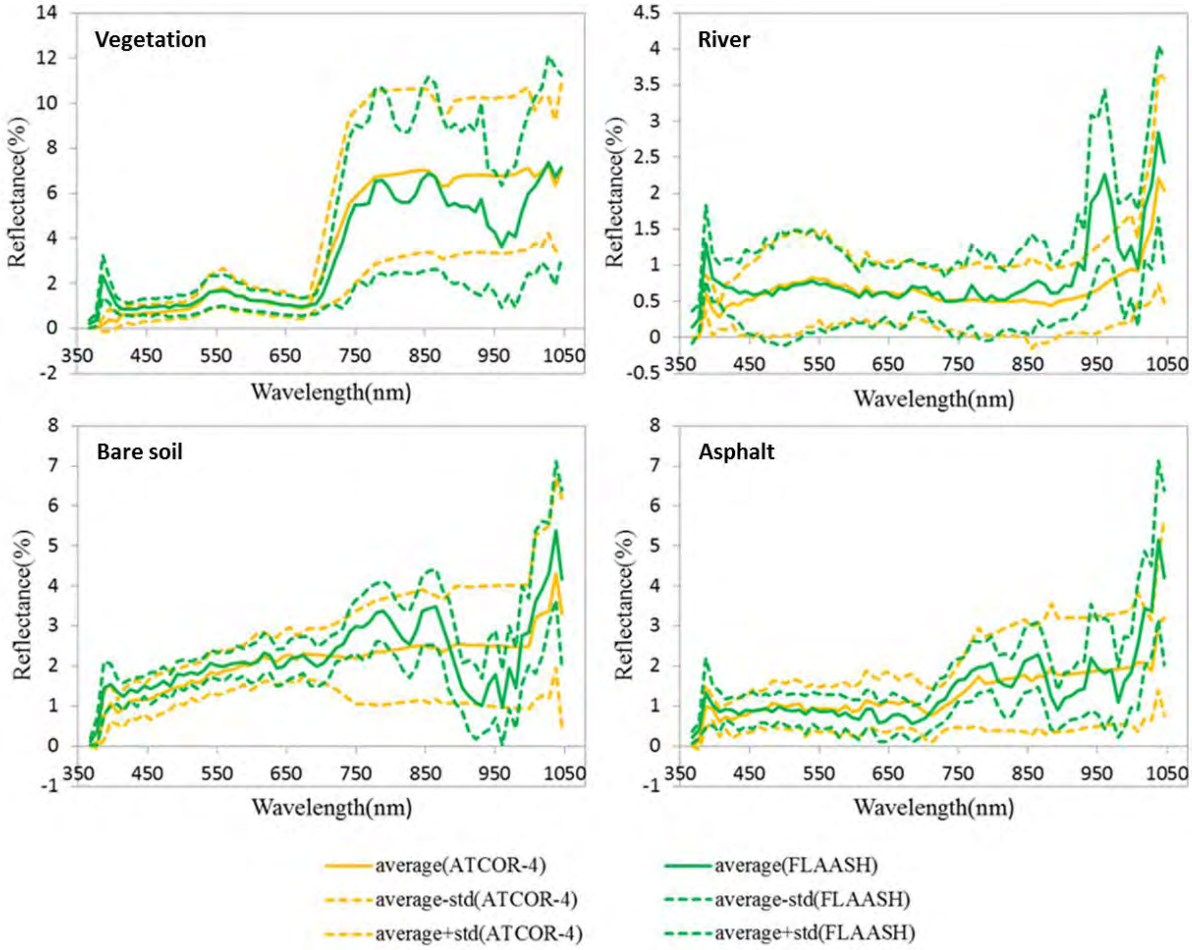


Figure 6. This is a comparison chart, and shows the stability in multiple flight-lines.

CONCLUSION

This study using FLAASH and ATCOR-4 to do atmospheric correction for hyperspectral image. And compare the corrected result by single flight-line and multiple flight-lines. The following are some conclusions:

1. Using FLAASH to do atmospheric correction is unstable between 850nm to 1050nm, and its reflectance contains negative value. And no matter use FLAASH or ATCOR-4, the reflectance is far below to in-situ measurement in blue bands.
2. The result suggests that using smoothed DSM in ATCOR-4 performs the best atmospheric correction. And directly use DSM in ATCOR-4 is not recommended due to the null pixels (Figure 5).
3. In the comparison of single flight-line, ATCOR-4 with smooth DSM has least difference compared to in-situ measurement, which shows that it’s significant to consider the topographic effects.
4. The comparison of multiple flight-lines shows that the stability on multiple flight-lines is no obvious difference by using ATCOR-4 or FLAASH.

In summary, although there is no obvious difference in the comparison of multiple flight-lines, the result of using FLAASH is not stable between 850nm to 1050nm in the comparison of single flight-lines. Thus the point view of this study is that ATCOR-4 is stable than FLAASH.

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