Atmospheric Correction of SPOT5 Land Surface Imagery

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Abstract—**High spatial resolution satellite images are playing the more and more important role in real-time monitoring on earth surface conditions. But haze and cloud reduce those application capabilities, especially in south of China. Thus, atmospheric correction is necessary for extracting quantitatively information from high spatial resolution satellite images. SPOT5 imagery is selected as the data source. In terms of multi-spectral imagery, in order to remove hazy regions and get the surface reflectance imagery, an improved homomorphic filter is combined into the matching mean reflectance in both hazy/clear regions method. Based on band characteristic of SPOT5, visible bands take part in classifying after haze removal using the improved homomorphic filter in process. Both aerosol optical depth and surface reflectance images are retrieved using MOTRAN 4.0. What' more, in terms of panchromatic imagery, authors use MOTRAN 4.0 remove atmospheric effect by means of the retrieved aerosol optical depth. The two retrieved surface reflectance images are both obviously better than original images. When more bands of SPOT5 take part in classifying, it can improve the accuracy of clusters in both hazy & clear regions, so it is helpful to make up the disadvantages of mean reflectance matching method in both hazy/clear regions. Meanwhile, the method in paper can be used other high spatial resolution satellite images.**

Keywords-high spatial resolution satellite remote sensing; SPOT5; atmospheric correction; hazy removal

I. INTRODUCTION

In recent years, high spatial resolution satellite imagery promotes the application field of remote sensing technique, for example SPOT5, IKONOS, Quickbird and so on. But it depends usually on the weather condition to get the proper imagery. However, Cloud and haze are the main factors to reduce the imagery quality and application effect. This phenomenon is especially common in South of China. As well known, the cloud and haze will reduce the accuracy of target recognition and classification, even making wrong results. Thus to extract quantitative information from high spatial resolution satellite imagery, atmospheric correction is necessa--ry. SPOT5 is selected as the data source in this paper.

It is a relatively long history of the quantitative atmospher--ic correction of remote sensing imagery, but little method is founded in terms of SPOT5. There are two types methods of atmospheric correction, and one is relative method, only improving visual effect not removing atmospheric radiance effect, such as Tasseled Cap Transformation (K-T Transformation)[1], homomorphism filtering[2], substitution[3,4]. Tasseled Cap Transformation performs an orthogonal linear transformation on multi-band images, and it is based on sensor properties, only being applicable to Landsat imagery. Homomorphism filter is a method based on the distribution characteristic of cloud. This method is simple, but it may cause the wrong result for clear regions in imagery. In the same time, the Fourier Transformation result is a floating point complex array, so it needs many computer resources in process. Substitution method replaces image the cloud regions with corresponding regions of clear image. Then precise image registration and color adjustment have to be done before substitution. Moreover, it is difficult to do with the edge of the cloud region, and appropriate substitution images are more difficult to obtain.

The other is absolute correction method based on radiance transformation model, for instance 6S[5], MOTRAN[6],SHDOM[7] and so on. This method consists of two major steps: parameter estimation and surface reflectance retrieval [8]. As long as necessary atmospheric parameters are known, retrieval of surface reflectance is relatively straightforward if the surface is assumed to be Lambertian. It is always to assume that aerosol distribution is homogenous in one scene and has stable simple surface target for simple atmospheric correction so as to reduce atmospheric effect based on imagery themselves[9-13]. In fact, obtaining accurate atmospheric parameter is so difficult. There are cloud and haze in most of images. Moreover, it is not always right for the assumption of standard Lambertian. So we need study on atmospheric correction based on nonhomogenous aerosol spatial distribution.

This work was supported by Project of China Geological Survey (NO.1212010911082).

Multi-spectral and panchromatic imageries are corrected separately in this paper. In terms of the former, an improved homomorphism filter method[14] (Fig. 1)is combined into mean reflectance matching of each cluster in both clear& hazy regions[8] based on the band characteristic of SPOT5. *F(x, y)* is the original multi-spectral imagery. Then there are four transformations or process in the following. *F'(x, y)* is the improved imagery. In terms of panchromatic image, MOTRAN 4.0 is used by means of the retrieval aerosol depth.

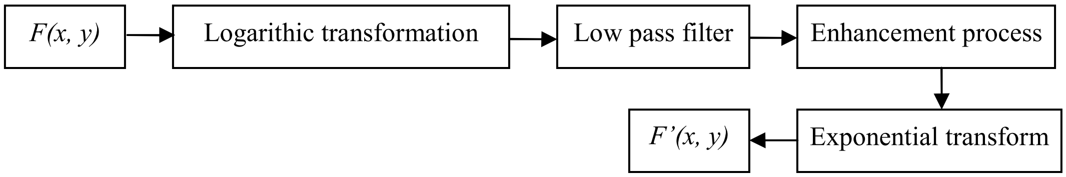

Figure.1. An improved homomorphism filter method working in spatial domain.

II. THE METHOD

A. Atmospheric Correction of SPOT5 Multi-spectral Imagery

As well known, the reflectance of radiance transform model is surface reflectance in clear regions when there having hazy regions in imagery, while it is mixed reflectance of surface and haze or thin cloud in hazy regions. Liang introduces and appraises mean reflectance matching of each cluster in both clear & hazy regions special for ETM+ imagery in order to rescue the surface reflectance of hazy regions. First of all, hazy & clear regions are recognized, then classifying for each pixel. Finally, mean reflectance of the same surface clusters are matched in both hazy & clear regions. It is a method that can remove hazy regions and, in the same time, get the surface reflectance in recent years, which has been applied successfully to MODIS, Landsat, SeaWiFS and CBERS-02 satellite imagery[8,15,16].

Liang's method needs enough infrared bands for satellite remote sensing data so as to improve classification accuracy and to describe accurately surface cover types. However, SPOT5 has not such bands as ETM+, and the effectiveness is not good to use his method for SPOT5. So hazy regions in visible band imagery are removed using an improved homomorphism filter, and then taking part in classifying in order to improve accuracy for high spatial resolution imagery such as SPOT5.

1) Determining hazy & clear regions. Determining hazy & clear regions is very important to the effective of atmospheric correction. There are some hazy regions detection techniques at present, such as Tasseled Cap Transformation method, band ratio method, classification method for visible bands and so on. Band ratio determines the spatial distribution of hazy regions using reflectance ratio between blue band and near infrared band integrating thermal infrared bands. However, the result is not very good if using one of these methods. In addition to, some methods are not applicable for high spatial resolution imagery. Because haze & cloud cause the almost same absorption and reflectance of different bands. Thus, thresholds are set to compute hazy regions using different bands, but only not-adjustable threshold will be inaccuracy. Not-adjustable threshold and man-machine interactive are used to determine
hazy & clear regions in this paper.

2) Determining reflectance of hazy & clear regions. Digital values of each pix will be converted into radiance value of sensor $L(k)$(W • m^2 • μm^{-1}) (after radiance correction[16].

$$L(k) = c_0(k) + c_1(k)\mathrm{DN}(k) \tag{1}$$

Where k is bans number, and c_0 , c_1 are bias and gain separately.

Under the condition of plat Lambertine and uniform atmospheric condition in horizontal direction, the surface reflectance is the following [16].

$$\rho = \frac{\pi[d^2(c_0 + c_1\mathrm{DN}) - L_p]}{E_0\tau_v\cos\theta_s} \tag{2}$$

Where L_p is path radiance; τ_v is the total atmospheric transmissivity from surface to sensor, θ_s is the solar zenith angle and E_0 is the solar equivalent radiancy. d is the distance from solar to earth[16].

$$d = \frac{1}{1 - 0.01674\cos[0.9856(JD - 4)]} \tag{3}$$

Where JD is the Julian Day when the satellite is passing.

MOTRAN 4.0 is used to compute L_p and τ_v in order to get reflectance of hazy & clear regions in this paper.

3) Classification of hazy & clear regions. This classification result has not specific significance in here, and non-supervision is used to classify. Study indicates [8] that 20-50 clusters produce similar results, probably because there are not enough bands available for clustering analysis. ISODATA method is used to get 50 clusters in both hazy & clear regions of same surface ground object.

4) Matching mean reflectance of same cluster in both hazy & clear regions. If the reflectance is identical in one scene, hazy regions will be removed using mean reflectance of clear regions substitute those of hazy regions. Mean reflectance matching is performed in the all four bands of SPOT5 separately.

5) Spatial smoothing of the retrieval aerosol optical depth. Aerosol optical depth is needed to be retrieved for absolute atmospheric correction. Firstly, mean radiance of hazy & clear regions will be computed based on same clusters. Secondly, scale of visibility will be estimated according to imagery condition. Finally, aerosol optical depth can be retrieved by means of MOTRAN 4.0 and be smoothed using low pass filter. The filter window size is 3×3 in this paper.

6) Reflectance retrieval by considering adjacency effects. Atmospheric correction of multi-spectral imagery of SPOT5 can be done using MOTRAN 4.0 based on the spatial distribution of aerosol optical depth. The imagery articulation will be damaged after clusters, especially for high spatial resolution remote sensing imagery, so it is necessary to remove adjacent effect. Convolution method is used in this paper.

Fig. 2 is the general flow chart.

B. Atmospheric correction of SPOT5 panchromatic imagery

The atmospheric correction result of panchromatic imagery will affect directly the image fusion effect, so it is not proper to enhance processing simply avoiding to lose high and low frequency information, for example, liner stretch, contrast and brightness control and so on. In the same time, these relative methods can not be satisfied with requirement of quantitative remote sensing.

Panchromatic imagery can be obtained when multi-spectral imagery of SPOT5 is being shot, but has also the same area. So these two imageries have the same atmospheric condition. So the following atmospheric method can be used to panchromatic imagery of POT5 by means of the above aerosol optical depth.

Firstly, aerosol optical depth imagery is resampled into the same spatial resolution of panchromatic imagery. Secondly, atmospheric correction can be done using MOTRAN 4.0 based on the resampled aerosol optical depth imagery. Finally the adjacency effect is removed.

III. AN CORRECTION EXAMPLE

A SPOT5 scene is selected as the study area, located in Yichang city, Hubei province in China, and path/row is 275/288, 6th, Nov, 2007. The scale of visibility is assumed to 40km according this study area position and imagery condition. The coefficient of radiance correction is in table.1

Fig. 3 is visual effect contrast in local imagery before and after correction, and original image is false color composition among XS3, XS2, XS1. Because original imagery is polluted heavily by aerosol, those information of local surface ground objects lose wholly. In addition to, spectral information distortion is heavily and hue is worse. But after correction, hazy regions are removed wholly, and the hue is improved obviously.

Fig. 4 is visual effect contrast in local imagery before and after correction. Because of heavily aerosol, the DN of original panchromatic imagery is high and abnormal, and the articulation and contrast are both worse. We can obtain just little spatial texture information, and this will reduce the result of the following work such as image fusion, small dim target recognition. After correction, the texture characteristic of panchromatic imagery is enhanced obviously. That is to say, in all, the two results are both pleased.

IV. CONCLUSIONS AND DISCUSSIONS

An improved mean reflectance matching in both hazy & clear regions method can not only remove the hazy regions in SPOT5 multi-spectral imagery, but can obtain surface reflectance imagery. The aerosol optical depth imagery is used to correct panchromatic imagery by means of MOTRAN 4.0 and get the better result. The both surface reflectance imageries of SPOT5 can provide the basic data for the quantitative remote sensing.

It may prove the accuracy of clusters that visible bands of SPOT5 after removing haze are introduced the clusters in both

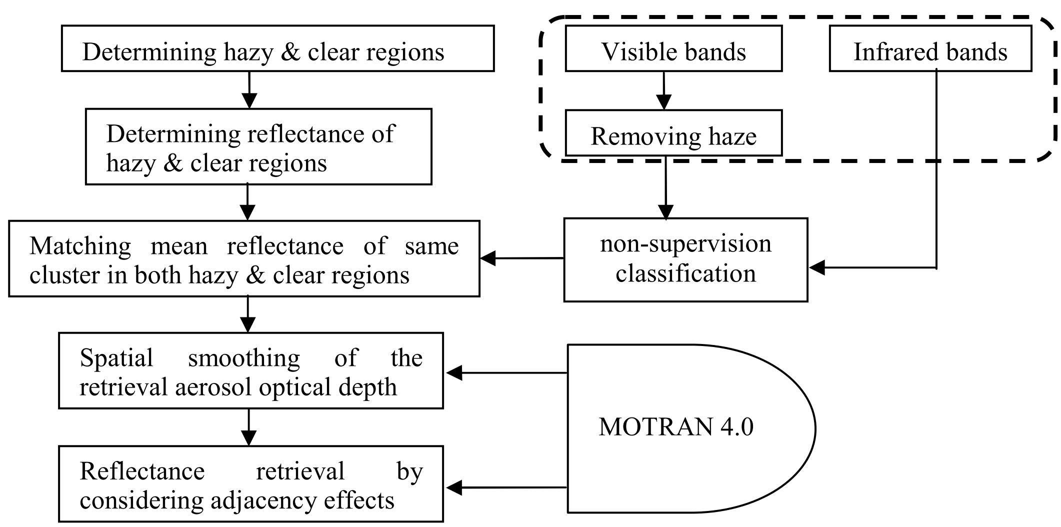

Figure.2. The general flow chart of atmospheric correction of multi-spectral imagery of SPOT5.

TABLE.I. THE COEFFICIENT OF RADIANCE CORRECTION OF SELECTED SPOT5

Band	**XS1**	**XS2**	**XS3**	**SWIR**
Gain	2.903215	3.866820	4.132190	18.071528
Bias	0.000000	0.000000	0.000000	0.000000
Solar equivalent radiancy	1858	1575	1047	234
Solar zenith angle	138.658401			

Figure 3. The effect contrast before and after correction of multi-spectral imagery(left one is original, then right one is correction imagery)

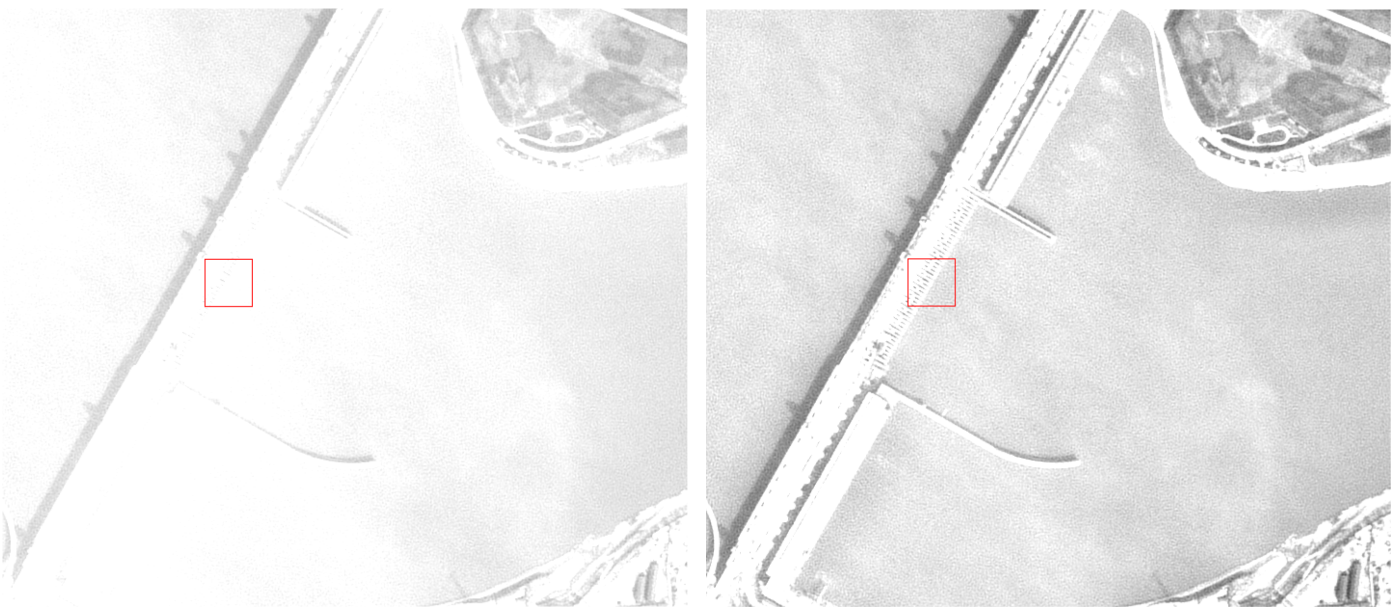

Figure 4. The effect contrast before and after correction of panchromatic imagery (left one is original, then right one is correction imagery)

hazy & clear regions. This makes up for the disadvantages of mean reflectance matching in both hazy & clear regions method in terms of high spatial resolution satellite remote sensing imagery such as SPOT5 and so on. Thus, the method is also suitable for other high spatial resolution satellite imagery in this paper.

Hazy regions are selected to remove haze in imagery in process, and then there appears the obvious transient trace in corrected imagery in transient regions. The smoothing process of transient trace is the future work.

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