# AEROSOL OPTICAL THICKNESS ESTIMATED FROM LANDSAT/ETM+ IMAGE DATA

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## ABSTRACT

We retrieved the aerosol optical thickness $\tau_a$ over land from Landsat-7/ETM+ image data using the correlation between the visible reflectance and middle IR reflectance. This band correlation method for aerosol retrieval was originally proposed for MODIS data analysis by Kaufman et al.(1977)[1]. The results of retrieved aerosol optical thickness $\tau_a$ from Landsat-7/ETM+ data were compared with the simultaneous sky observation data at our study site. We found a good agreement between the retrieved and observed values. We presented the distribution maps of the aerosol optical thickness over land, retrieved from Landsat-7/ETM+ image data. Then, the surface reflectance map was also presented. The aerosol optical thickness over sea was retrieved assuming no reflected contribution from sea in the near IR band[2]. In addition, we discussed some limitations when we apply the band correlation method.

## 1. INTRODUCTION

In the atmospheric correction of the remotely sensed earth image data we need the information on the aerosol optical parameters, such as the optical thickness, Ångström exponent, and the size distribution type. The aerosol optical thickness is the most important parameter among them in the correction. Since simultaneous measurements of the aerosol optical thickness are not always possible, a method for estimating it from the satellite-measured data itself is highly desirable. In this study we applied the band correlation method to Landsat-7/ETM+ data we retrieved the aerosol optical thickness distribution from Landsat-7/ETM+ with an aid of the correlation between the visible reflectance and middle IR reflectance.

## 2. REFLECTANCE CORRELATION

Kaufman et al.(1977)[1] found that there existed empirical correlations for a few land cover classes between the visible reflectance and middle IR reflectance as follows:

$$r_{B1} = 0.25 \times r_{B7} \quad \text{(vegetation)} \qquad (1),$$

$$r_{B1} = 0.42 \times r_{B7} \quad \text{(urban)} \qquad (2),$$

$$r_{B3} = 0.50 \times r_{B7} \quad \text{(vegetation)} \qquad (3),$$

$$r_{B3} = 0.69 \times r_{B7} \quad \text{(urban)} \qquad (4),$$

where $r_{B7}$, $r_{B1}$ and $r_{B3}$ are the reflectances in the band 7, band 1 and band 3. The above correlations hold in the case of dark targets(vegetation) in the band 7 ($0.0 < r_{B7} < 0.1$). It is possible to compute the reflectances in Band 1 and 3 using eqns.(1)-(4). Then, we can retrieve distributions of aerosol optical thickness in these bands for given reflectance distributions by using LUT(Look Up Tables) in which the theoretical radiances at the top of the atmosphere(TOA) are tabulated as a function of the surface reflectance and the aerosol optical thickness for given bands and angles of the incident and reflection.

## 3. RETRIEVAL RESULTS

The images in Bands 1 and 7 by Landsat-7/ETM+(Path-Row:109-35, Acquisition Date: April 15, 2001) are shown in Fig.1-(a) and -(b), respectively. We have the blurred image due to aerosol effects in Fig.1-(a), whereas the clear image with little aerosol effects in Fig.1-(b). Our analysis steps are as follows:

1) We computed the reflectance distribution in Band 7 by removing the attenuation effects of water vapor and other gases, based on Modtran data base.

2) We classified the ETM+ image into 5 categories using a maximum likihood method and the resulting classification map is shown in Fig.2. Those of 5 categories are "Sea", "Snow & Cloud", "Vegetation", "Urban", and "Others".

3) We computed the reflectances in Band 1 and Band 3 for those pixels of "Vegetation" and "Urban" classes from the reflectance distribution in Band 7 with an aid of the band correlations. For those pixels belong to "Sea", "Snow & Cloud", and "Others".the reflectance value remains as undetermined.

4) We computed the mean radiances in Band 1 and 3 at TOP averaged over 33 x 33 pixels (area size of 1km x 1km) from the ETM+ image data. Similarly, we computed the mean reflectances in these bands averaged over the same area of 1km x 1km from the reflectance data computed in 3). We retrieved the aerosol optical thickness values over land for the area of 1km x 1km in Band 1 and 3 using pre-computed LUT of the theoretical radiance at TOP as a function of the reflectance for a given angular condition. The distribution maps of aerosol optical thickness in Band 1 and 3 are shown in Fig.3-(a) and -(b), respectively. The aerosol optical thickness values in both bands over the sea were estimated from those in Band 4, assuming a typical Ångström exponent $\alpha$=1.5. We can retrieve the aerosol optical thickness over the sea in Band 4 from the image data of ETM+ Band 4, assuming no reflectance contribution in the near infrared band. We can see a smooth transition between the sea and land as shown in Fig.3. Furthermore, the distribution of Ångström exponent was computed, based on the results in Fig.3 and the resulting map is shown in Fig.4.

5) Finally, the retrieval of the flectances in the visible and near infrared bands were made by removing the aerosol effects using the retrieved aerosol optical parameters and the results of the atmospheric correction for Kanazawa area is shown in Fig.5.

## 4. DISCUSSIOS

We validated the retrieved aerosol thickness and Ångström exponent values at our validation site by the simultaneous sky observation data. The comparison of the aerosol optical thickness and Ångström exponent with the sky observation data are shown in Fig.6-(a) and -(b), respectively. We found a very good agreement in aerosol optical parameters between the retrieval and observed values.

There are limitations when we use the band correlation method to retrieve the aerosol optical parameters. It is not possible to compute the reflectance of certain land cover types, like snow, in the visible from the band correlation method. Nevertheless, we found that the band correlation method is very useful in the atmospheric correction when any other information on the aerosol parameters are available.

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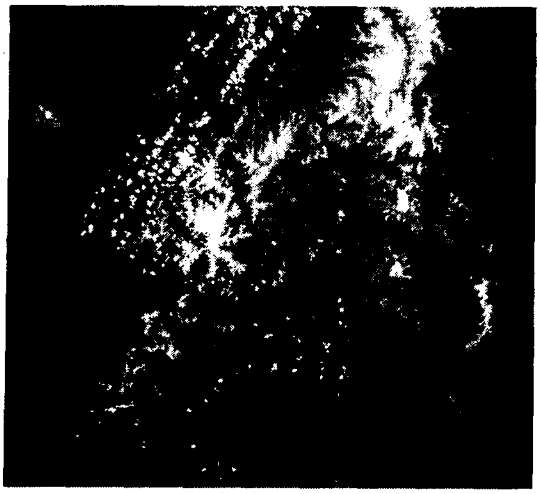
## REFERENCES

1. Kaufman et al., 1997. The MODIS 2.1mm Channel-Correction with Visible Reflectance for Use in Remote Sensing of Aerosol, IEEE Trans. GRS, vol.35, no.5, pp.1286-1298.



(a) Band1 (0.483 $\mu$m)

(b) Band7 (2.1 $\mu$m)

Fig.1. The original images of ETM+.

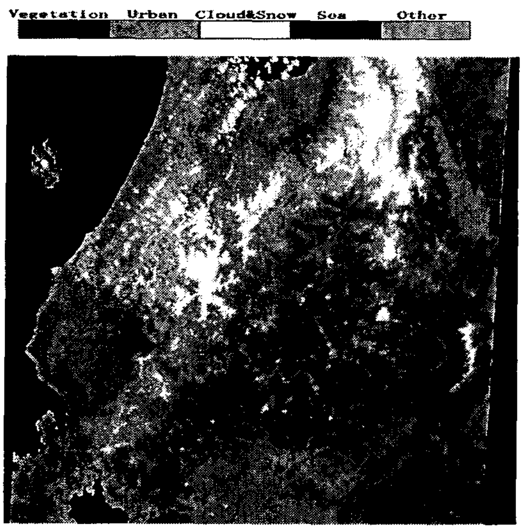
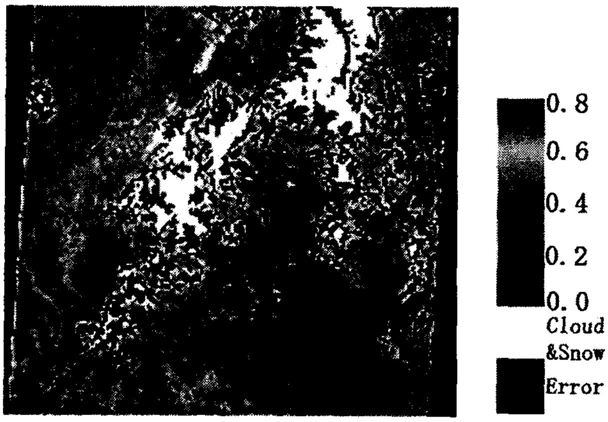



Fig.2. 5 class classification.




(a) Aerosol Optical Thickness Map in Band 1.

(b) Aerosol Optical Thickness in Band 3.

Fig.3. Retrieved aerosol optical thickness maps.

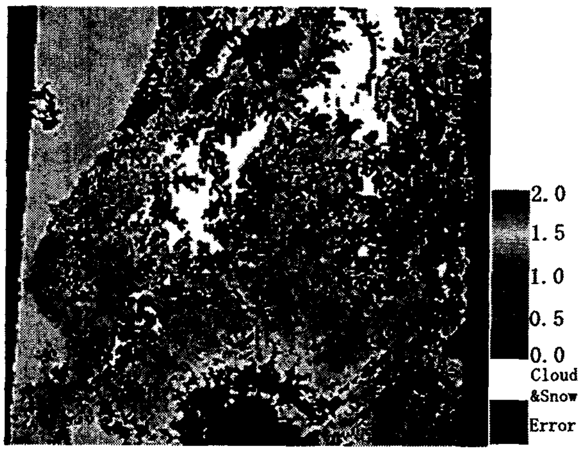
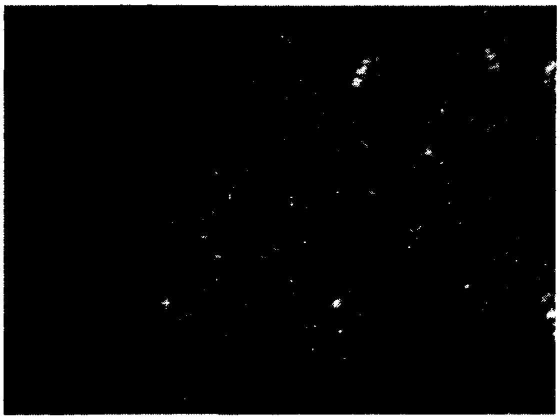


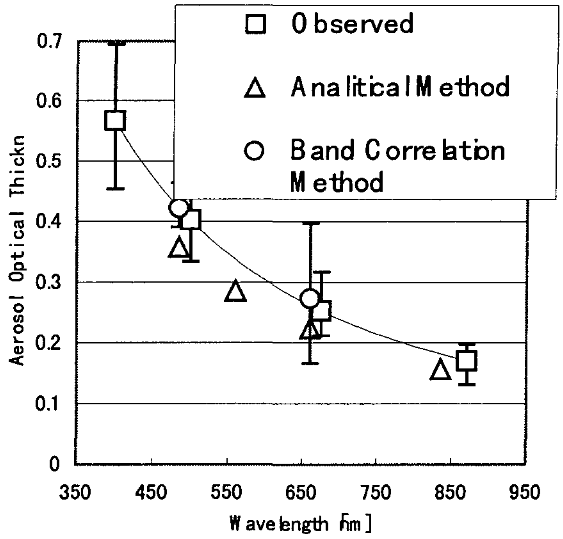

Fig.4. Retrieved Angstrom exponent Map.



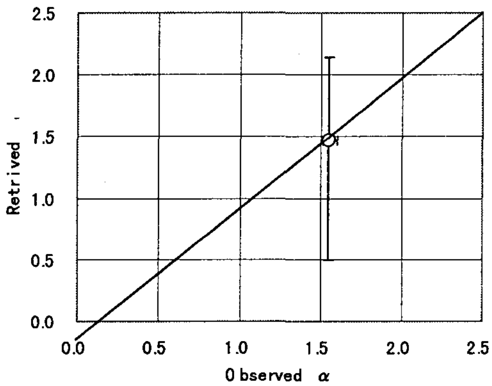
(a) Ogriginal Color Composit.by assigning (R,G,B) to (Band 3, Band2, Band1).

(b) Color Composit of Reflectance after Atmospheric Correction by assigning (R,G,B) to (Band 3, Band2, Band1).

Fig.5. Atmospheric correction results.




(a) Aerosol Optical Thickness.




(b) Ångström nent

Fig.6. Comparison of retrieved aerosol parameters with Observation at the validation site.