

MAPPING OF LITHOLOGICAL UNITS OF ÇANKIRI BASIN, CENTRAL ANATOLIA, TURKEY WITH PROBA CHRIS HYPERSPECTRAL DATA

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ABSTRACT:

Remote sensing provides a valuable basis for regional geological mapping. This study aims for the mapping of lithological units in Eldivan-Çankırı part of Çankırı Basin using hyperspectral remote sensing. A Proba (Project for On-Board Autonomy) CHRIS (Compact High Resolution Imaging Spectrometer) Level 1A hyperspectral satellite image of the study area is provided by European Space Agency (ESA) as a Category-1 LBR (Low bit rate) project for the mapping purposes. A field spectroscopy study at a time close to the overpass of the Proba CHRIS satellite has been carried out. Besides, hand specimens have been collected at some sites for laboratory spectroscopy study. Quantitative and qualitative information on reflectance properties of geological materials of Çankırı Basin are extracted from image, field and laboratory spectroscopy study.

INTRODUCTION

Hyperspectral images can stimulate unique geologic insights in mapping. This paper covers the utilization of Proba (Project for On-Board Autonomy) CHRIS (Compact High Resolution Imaging Spectrometer) hyperspectral image for the discrimination of geological features and mapping purposes. In this study, the European Space Agency (ESA) provided the hyperspectral satellite image, Proba CHRIS Level 1A, of Eldivan-Çankırı part of Çankırı Basin as a Category-1 LBR (Low bit rate) project. A field spectroscopy study at a time close to the overpass of the Proba CHRIS satellite has been planned and carried out. During the field study hand specimens have been collected at the site for the laboratory spectroscopy study. The satellite data, field and laboratory spectroscopy data are integrated for the processing of the hyperspectral data.

The study area, Çankırı Basin is located in Central Anatolia. It is one of the largest Tertiary basins in Turkey. It is a unique area to study lithological units resulting from subduction and collision processes. It is an easy accessible site. The basin is sparsely vegetated.

The geology and tectonic relations of Çankırı basin have been studied and mapped in previous studies by Dellaloğlu et al., (1992) and by Tüysüz et al., (1992, 1993, 1995). The most recent study in Çankırı basin is a geological remote sensing study by Kaymakçı (2000). He has mapped the lithological units in the basin using Landsat TM images.

PROBA CHRIS

The Proba satellite is launched on October 2001. The satellite has two earth observing instruments HRC (High Resolution Camera) and CHRIS. Since 2004, Proba is operated by ESA Redu Ground Station in Belgium. Its CHRIS instrument, is

funded by the British National Space Centre (BNSC), has been built by SIRA Space, UK.

The earth observing instrument CHRIS has a swath width of 14 km. CHRIS has 5 different acquisition modes. The mode 1 image data has 62 spectral bands and a 34 m spatial resolution at nadir at 556 km. It is within the spectral range of 405 nm - 1009 nm and has 7.5 nm as nominal bandwidth. The mode 2, 3, 4 image data have 18 spectral bands and mode 5 has 37 bands with 17 m spatial resolution at nadir. At each mode 5 images of the same area are taken with various acquisition angles: -55, -36, 0, +36 and +55.

FIELD SPECTROSCOPY STUDY

The most essential part of this study has been the planning of the field study. This had to be done during the ESA Category -1 project proposal. First, the Proba CHRIS image acquisition date has been planned as to be suitable for the field spectroscopy study and the weather conditions of Central Anatolia. Second, the area has been chosen to be easily accessible, lithological diverse and not cover an urban area.

It is important for field spectroscopy to measure an area of ground within the image at the time that the satellite passes overhead, or at least at a time close to the overpass. The acquisition date of the image requested is fixed to be as cloud free as possible and suitable for field spectroscopy study. In Central Anatolia this is usually Mid-Summer. So, the field study is planned at 21-27 July 2006 and the overpass of the satellite any day within. The exact day of the satellite overpass has been declared two days before the acquisition to be on the 25.07.2006 by ESA.

During the field study a field spectrometer, ASD FieldSpec HandHeld Pro is used to characterize the reflectance of the site.

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The ASD field spectrometer is measuring in the range of 325 - 1075 nm. This range is covering the spectral range of Proba CHRIS hyperspectral image data. The field spectrometer measurements are collected randomly over the study area (Fig. 1). Before going to the field, the measurement sites are defined from a Terra ASTER image (27.04.2001) and ancillary data including different surface covers and accessible sites. As many as possible sites have been chosen. At the field study 106 sites are measured. Samples of the geological materials covering the surface of the site are collected at 30 sites to be measured with a laboratory spectrometer. Throughout the field study, at some days there have been no stable weather conditions. This has to some extent affected the field study. Due to this, before each spectral measurement the spectrometer has been calibrated and hand specimens collected.

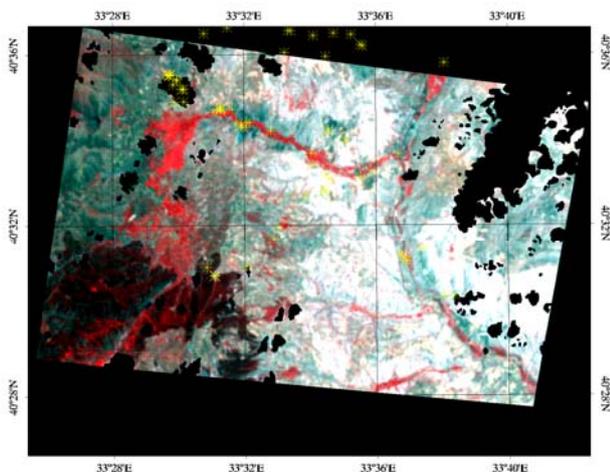


Figure 1. Proba CHRIS image of the study area with field measurement sites (yellow asterisks)

Not all the field measurement sites had laboratory samples. The laboratory measurements of the hand specimens are done to verify spectral details and provide information for removing artifacts from the field and image data. After receiving the image data it has been observed that some of the image is cloud covered and cloud shadowed. These no data areas have even included some field measurement sites.

METHODOLOGY

The Proba CHRIS image mode 1 with the acquisition angle -55 has been covering the study area. In the image data the missing pixels have been filled and stripes have been removed using the HDFclean program (Cutter, M., A., 2006). The clouds and cloud shadows have been masked.

The Proba CHRIS image data is atmospherically corrected to remove the effects of scattering and absorption of the atmosphere and to convert from radiance values received at the sensor to reflectance values of the imaged surface materials. Three different atmospheric correction methods are used (Bertels, et al., 2006 and Van der Meer, et al., 2001):

1) Scene derived correction: IARR

The internal average relative reflectance normalizes the image to a scene average spectrum. This shifts all spectral radiances to the same relative brightness. The resulting spectral values represent reflectance relative to the average spectrum.

2) Ground-calibrating method: Empirical Line Calibration

The technique is used to force image data to match selected field reflectance spectra. It requires field or laboratory reflectance spectra of at least two uniform ground targets. For each spectral band a linear regression is calculated between the reference spectra and the image spectra.

3) Radiative transfer model: 6S

The 6S (Second Simulation of the Satellite Signal in the Solar Spectrum) model is used to predict the atmospheric radiative properties and to model the radiance at the sensor (Vermote, et al., 1997).

After calculating reflectance values of the Proba CHRIS image the backscatter response curves are derived for different surface materials to integrate the image, field and laboratory spectral data. These data are used to create a spectral library of the study area for the end member selection.

Following these, the dimensionality, the inherent redundancy and noise in Proba CHRIS data is reduced by the principal components transform, minimum noise fraction. Then the reference spectra and the image spectra are compared and a spectrum match, spectral angle mapper, is applied. The spectral angle mapper is a spectral classification that matches pixels to the reference spectra. The algorithm determines the spectral similarity between two spectra by calculating the angle between the spectra. Following the classification process the lithological map of the Çankırı-Eldivan area is produced and verified with the ancillary data.

RESULTS AND DISCUSSION

At first, the atmospherically corrected Proba CHRIS hyperspectral image data is compared with field and laboratory spectra. Three different methods have been used for the calibration of the hyperspectral image data: IARR, empirical line calibration and 6S. The results of the internal average relative reflectance correction have not matched the field and laboratory spectra. There are a few green agricultural areas and a small forest area in the study area. The vegetation and the small dam lakes caused strong absorption and affected the result.

The empirical line calibration requires at least two reference targets: white and dark. In the image area there are good white targets but none dark target with field spectroscopy data is supplied for the empirical line calibration. This caused a minor mismatch with the field and laboratory spectra.

The best atmospheric correction has been the 6S radiative transfer model. 6S is quite effective but needs a lot of input parameters to execute the program. Some of these parameters need additional field measurements. Nevertheless, the program has let choose between default parameters.

Wavelengths range (nm)	Xa	Xb	Xc	Total irradiance
405.0-486.9	0.0031	0.2242	0.19069	1372.602
486.9-586.9	0.0028	0.1078	0.13097	1439.093
586.9-697.8	0.003	0.0581	0.09385	1263.639
697.8-749.0	0.0036	0.041	0.07557	1044.318
749.0-1008.8	0.0052	0.0265	0.05653	712.782

Table 1. Coefficients for atmospheric correction simulated using 6S code

The surface reflectance is obtained by using the coefficients in Table 1. with the following formula (Gonzales, et al., 2006):

$$Y = X_a \times (\text{measured radiance}) - X_b$$

$$Acr = \frac{Y}{(1 + X_c \times Y)}$$

where X_a, X_b, X_c = coefficients simulated by 6S
 Acr = atmospherically corrected reflectance

After atmospherically correcting the image data, the spectral backscatter response curves are derived for the different surface materials measured at the field sites to use as reference spectra in the further processing of the Proba CHRIS image.

Next, the minimum noise fraction (MNF) transform is applied to the image data. This reduced the dimensionality of the dataset while retaining a small number of noise-free components. Consequently, the computational requirements for subsequent processing have been reduced. The first 16 transformed bands showed high variance in the MNF Eigenvalue plot. The data is reduced from 62 spectral bands to 16 transformed bands.

The reference spectra are processed to provide an average spectrum for minimizing the noise in the data. This data is used for the end member selection. In order to match the reference spectra with the image spectra derived from the reference sites spectral angle mapper is used. The spectral angle mapper determines the spectral similarity between the two spectra by calculating the angle between the spectra and treating them as vectors in n-D space. It is relative insensitive to illumination and albedo effects when applied to calibrated reflectance data. This technique compared the angle between the end member spectrum vector and each pixel vector in the 16-D space of the transformed data. The smaller angles are representing closer match to the reference spectrum. The not matching pixels are not classified.

After the classification process a land cover map of the Çankırı-Eldivan area is produced. This interpreted map of the study area is used to verify the lithological units. Finally, a geological map is produced. In the verification part, the laboratory spectra of the samples collected in the field and the geological map of the study area are used.

CONCLUSION

Remote sensing is a very useful tool for regional geological mapping. This study covered the utilization of Proba CHRIS hyperspectral image for lithological mapping of Eldivan-Çankırı part of Çankırı Basin. Additionally, the pros and cons using hyperspectral data instead of multispectral data are examined.

The Proba CHRIS has 62 spectral bands with narrow bandwidth which increases its discrimination ability. But it has some disadvantages over a multispectral image data. The processing time takes more time and effort.

Unfortunately, Proba Chris has no SWIR (shortwave infrared) bands. The SWIR bands are useful for lithological discrimination and are widely used in geological applications.

Other than this inherent constrains, the area is imaged in the 5 acquisition angles at each acquisition. The coverage of these different angles varies. The best fitting areal coverage has been the -55 acquisition angled image data. But the spatial resolution has increased than the nadir acquisition that caused trouble in identifying features during geometric correction and spectral end member selection.

A hyperspectral remote sensing study is nothing without a field spectroscopy study. Although great effort has been given for the planning of field study there have been some setbacks at the field and processing of image data due to the unstable weather conditions. So, it is important to collect as many measurements as possible from diverse sites of the study area not to end up with no data.

The Proba CHRIS showed excellent results in land cover mapping but not as good result in lithological mapping. Nevertheless, it has been a valuable experience both the field spectroscopy study and the processing of Proba CHRIS image data.

REFERENCES

- Bertels L., et al., 2006. *HyperTeach. Training in Imaging Spectroscopy - Theory*. VITO, pp. 56-69.
- Cutter, M., A., 2006. HDFclean V2 software. <http://earth.esa.int/object/index.cfm?fobjectid=4409> (accessed 22 Apr. 2008).
- Dellaloğlu, A.A., Tüysüz, O., Kaya, O.H. and B., Harput, 1992. *Kalecik (Ankara) - Eldivan - Yapraklı (Çankırı) - İskilip (Çorum) ve Devrez Çayı arasındaki alanın jeolojisi ve petrol olanakları*. TPAO Rap. No. 3194, Turkey.
- Gonzales, L., et. al., 2006. Msixs software. http://www-loa.univ-lille1.fr/Msixs/msixs_gb.html (accessed 22 Apr. 2008).
- Kaymakçı, N., 2000. *Tectono-stratigraphical evolution of the Çankırı Basin (Central Anatolia, Turkey)*. Ph.D.Thesis, Utrecht University, Netherlands. *Geologica Ultraiectina*, no. 190, 248 pp.
- Tüysüz, O. and A.A., Dellaloğlu, 1992. *Çankırı Havzasının Tektonik birlikleri ve jeolojik evrimi*. Türkiye 9. Petrol Kongresi Kitabı, Turkey.
- Tüysüz, O., 1993. *Karadenizden Orta Anadolu'ya bir jeotravers*. Türkiye Petrol Jeologları Bülteni, 5(1), pp. 1-33.
- Tüysüz, O., Dellaloğlu, A. A. and Terzioğlu, N., 1995. *A magmatic belt within the Neo-Tethyan suture zone and its role in the tectonic evolution of northern Turkey*. *Tectonophysics* 243, pp. 173-91.
- Van der Meer, F., and S., De Jong, 2001. *Imaging Spectrometry: Basic Principles and Prospective Applications*. Kluwer Academic Publishers, Dordrecht, Netherlands, pp. 44-63.

Vermote E., Tanré D., Deuzé J. L., Herman M., and Morcrette J. J., 1997. *Second Simulation of the Satellite Signal in the Solar Spectrum (6S)*. 6S User Guide, pp 1-54.

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