

Hyperspectral Data Processing For Mineral Mapping Using AVIRIS 1995 Data in Alto Paraíso de Goiás, Central Brazil

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Abstract. Hyperspectral remote sensing data were acquired in some areas of Brazil in 1995, using NASA's Advanced Visible and Near-Infrared Imaging Spectrometer (AVIRIS). This paper examines the performance of image processing techniques specifically developed for hyperspectral data in the context of mineral mapping applications. The area chosen, located in Goiás State, Central Brazil, near the locality of Alto Paraíso de Goiás, had relatively sparse vegetation at the time of imagery acquisition (dry season). The regional geology comprises a variety of fluvial and marine Precambrian metasediments. Image processing was carried out in two steps: (i) data conversion from radiance units to reflectance using a MODTRAN-based radiative transfer method and; (ii) application of the Tricorder mapping algorithm, specifically designed for identifying superficial materials based on similarities between image pixels and spectra from a spectral library. The results show that hyperspectral remote sensing can add significantly to the amount information that can be extracted from multispectral sensors, such as the Landsat TM, and is a valuable tool for mapping and exploration in sub-tropical regions.

Keywords: Remote Sensing, Hyperspectral Processing, AVIRIS

1 Introduction and Objectives

Hyperspectral remote sensing data were acquired for the first time in South America in 1995, over some areas of Brazil, using NASA's Advanced Visible and Near-Infrared Imaging Spectrometer (AVIRIS). The survey was part of SCAR-B (Smoke, Cloud and Radiation-Brazil), a joint scientific mission between NASA, the Brazilian Space Agency (AEB) and the Brazilian National Space Research Institute (INPE). The unique data set collected over Brazil represents the first hyperspectral data ever acquired over a tropical region.

The primary objectives of the mission were aimed at forest burning and atmospheric/environmental issues. The majority of the data, consisting of some 100 AVIRIS

flight lines, were acquired over forested areas in Northern Brazil (states of Goiás, Mato Grosso, Mato Grosso do Sul, Rondonia, and Tocantins) at the peak of the burning season. Clouds and/or smoke dominate the imagery, preventing the use of most of these data for land/surface applications. However, a few scenes, acquired mostly for calibration purposes, do not contain cloud and smoke. One of these smoke-free scenes is focused on this paper.

The objective of the study is to examine the potential of AVIRIS data for identifying geologic materials in a tropical region, considering the constraints imposed by weathering, soil and vegetation coverage, and also for mapping vegetation types. The area chosen does not contain genuine mineral exploration targets (e.g., hydrothermal alteration minerals associated with precious metal deposits), since SCAR-B data requests were restricted to the mission's specific objectives (smoke and cloud detection). The images were therefore used for assessing the ability of AVIRIS data to map different mineral assemblages that occur in soils and rocks, association with the lithologic units of a poorly geologically known region in Brazil.

2 Physiography and Geology of Alto Paraíso de Goiás

The region of Alto Paraíso de Goiás is located in Goiás State, between 47°30'–47°40' W and 14°00'–14°15' S. The area had relatively sparse vegetation at the time of imagery acquisition (August 1995), coinciding with the peak of the dry season. The dominant vegetation type is the “cerrado” (savanna-type vegetation, typical of Central Brazil). The presence of dry vegetation (grass, shrubs and short trees) at this time of the year contributes to lower considerably the amount of electromagnetic energy reflected from underlying bedrock and soils, thus resulting in a great amount of mixed pixels.

Alto Paraíso is located in the outer portion of the Brasília Folded Belt, a major tectonic unit formed lately during the Brasiliano/Pan African orogeny (~600 Ma). The region contains a variety of metasediments that were folded and sheared under ductile deformation. These factors pose problems for geologic mapping in such a large and still unknown area, for which available maps are restricted to a 1:500,000 scale.

The lithostratigraphic units that occur in this region belong to the Araí Group (Mesoproterozoic) and to the Paranoá Group (Meso to Neoproterozoic). The Araí Group is represented in this region by the Arraias Formation, a thick sequence of coarse quartzites with intercalations of metasilites and phyllites. These rocks form a physiographic unit in the northern/north-eastern portion of study area, called Chapada dos Veadeiros, which is a Brazilian National Park. The Paranoá Group comprises a sequence of meta-pelites, metasilites and quartzites that occurs in the southern portion of the area.

3 Hyperspectral Data Processing

The strategy for image processing comprised the following steps: (i) data conversion from radiance units to reflectance; (ii) application of different classification techniques for mineral mapping that compare image spectra on a individual (pixel) basis to a spectral reference library.

AVIRIS data were provided by the Jet Propulsion Laboratory in radiance units, after being spectrally, radiometrically and geometrically calibrated using laboratory and in-flight procedures described by Chrien *et al.* (1996) and Green *et al.* (1996).

To spectrally compare these data to reference materials, conversion of the data from radiance to reflectance is required. There are different methods to perform this conversion, some that require ancillary ground reflectance data, acquired simultaneously to the flight, and others that allow the process to be done without ground data, allowing to derive “apparent” reflectance from radiance data. Since no simultaneous ground spectral measurements were made during the SCAR-B mission, a method based on the later reasoning was employed here. This method, although less accurate, provides sufficiently good precision for mineral mapping (Crósta *et al.*, 1996b, Boardman and Huntington, 1996).

Details of the procedure used to convert radiance to apparent reflectance data are described in Green *et al.* (1993). The technique relies on a radiative transfer model (MODTRAN), combined with laboratory and in-flight calibration data acquired at the beginning of the 1995 AVIRIS data acquisition season (Green, 1995).

An advanced classification technique was selected used for mineral and vegetation mapping, known as Tricorder. This technique was developed at USGS's Spectroscopy Laboratory and is not yet available in commercial packages. Its performance is remarkably better than other hyperspectral classification techniques, such as Spectral Angle Mapper (Crósta and Souza F^o, 1997).

Tricorder is a complex algorithm for analyzing imaging spectroscopy data sets, being able to identify different materials, such as minerals, water, snow, vegetation, pollution, human-made objects and others (Clark *et al.*, 1990; Clark and Swayze, 1995). This technique analyses simultaneously for multiple endmembers (selected from a digital spectral library or from field/laboratory spectra), using multiple diagnostic spectral features for each endmember .

The first step of the procedure involves the removal of the continuum from both the reference endmembers spectra and the image data (pixel by pixel). Both continuum-removed spectra are then compared using a least square fit algorithm and a linear correlation coefficient to determine the best fit. The diagnostic absorption features of all reference spectra in the library are individually fitted to each pixel spectrum from the image. The fitting does an individual fit of each spectral feature in the spectral library to the pixel spectrum undergoing analysis. The individual fits and band depths are weighted by the area between each absorption feature and its

continuum. The fit is the correlation coefficient to the least square routine. Multiple fits are compared and the best fit is selected. The implementation used in this work has also several constraints are also built into the algorithm, to better separate between spectrally similar materials (Clark and Swayze, 1995).

Tricorder was applied to the Alto Paraíso imagery, to map individual minerals in soils and weathered outcrops and also to assess the extent of vegetation interference in mineral mapping. Tricorder was also used for generating a vegetation map of the area. The AVIRIS scene consists of 1024 lines by 614 pixels and 224 bands, thus forming the hyperspectral data cube. Tricorder analyzes the data cube in 3 groups of bands: the 1 μm group (AVIRIS bands in the 0.400 to 1.000 μm range, which contain diagnostic spectral features for ferric and ferrous iron minerals); the 2 μm group (AVIRIS bands in the 2.000 to 2.500 μm range, which contain diagnostic spectral features for hydroxyl-bearing and carbonate minerals) and; the vegetation group (AVIRIS bands in the visible, near-infrared and short-wave infrared range, which contain diagnostic spectral features for vegetation).

All reference spectra used in both algorithms were extracted from the USGS Digital Spectral Library (Clark *et al.*, 1993), including the vegetation spectra. A total of 64 minerals and 8 vegetation spectra were used for the classification

4 Results

The results of the Tricorder classification are presented in **figures 1, 2 and 3**. For better visualization, the results of the classification are shown as color themes draped over a B&W AVIRIS band.

Figure 1 shows the 1 μm mineral group, identifying minerals such as hematite, goethite, ferrihydrite, jarosite (?) and a mixture of Fe^{2+} minerals and hematite in a few locations throughout the scene, but mostly concentrated along the road that crosses the southern portion of the scene in the east-west direction.

Figure 2 shows the 2 μm mineral group, in which less pixels were classified as minerals, mostly concentrated in only two round-shaped areas by the same road (lower center of the scene). The minerals identified were halloysite, poorly crystalline kaolinite, Na-montmorillonite and mixtures of pyrophyllite+kaolinite and calcite+Ca-montmorillonite (?).

Figure 3 shows the vegetation group, in which most of the pixels on the scene have been classified as one of the following: mixture of green+dry vegetation, green vegetation, dry vegetation and burn vegetation (2 types).

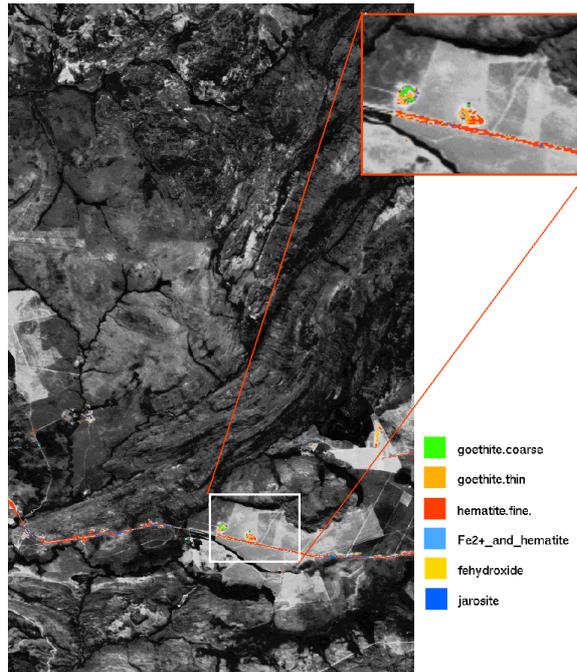


Figure 1 – Tricorder classification results for the 1µm mineral group

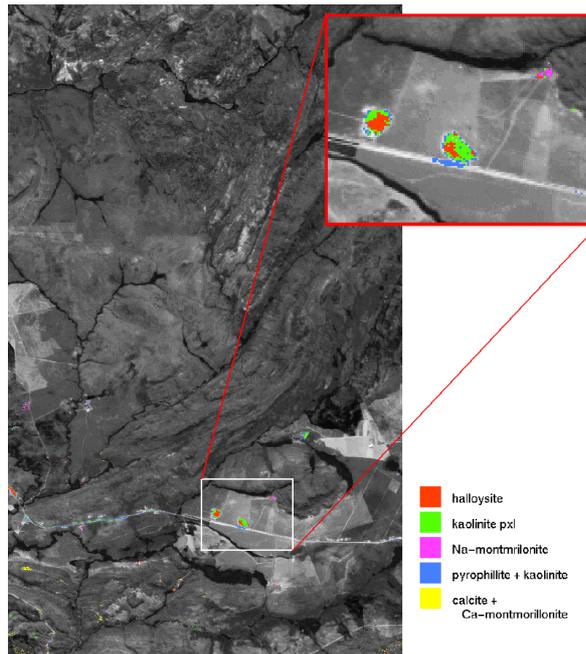


Figure 2 – Tricorder classification results for the 2µm mineral group

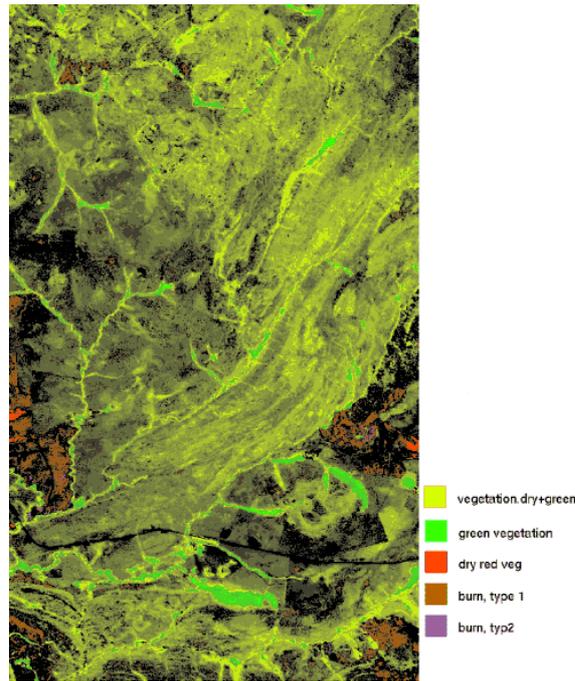


Figure 3 – Tricorder classification results for the vegetation group.

5 Discussion

The results presented here illustrate the potential use of hyperspectral imagery for geologic/mineral mapping in areas where the superficial exposure of geologic materials is limited. Vegetation poses the main constraint on such applications. Small patches of grass of sub-pixel dimensions are capable of masking the absorption features related to genuine mineralogical variations.

Despite these limitations, we demonstrated that it is possible to map areas of occurrence of important minerals, such as hematite, goethite, montmorillonite, halloysite and kaolinite. In the Alto Paraíso de Goiás scene, these mineral assemblages are related to **(i)** primary rock-forming minerals in the study area, in this case clay-rich metasediments (meta-pelites/siltites) of the Paranoá Group in the southern part of the study area, and finer-grained (clay-rich) intercalations in the Arraias Formation/Araí Group in the northern portion, and; **(ii)** to weathering processes of the bedrock, common in lateritic environments, in which the production of clay-minerals such as montmorillonite is common. Areas of occurrence of these minerals, although small (only a few pixels in some cases) were depicted and identified in the AVIRIS data cube by the Tricorder algorithm. A more detailed spectral analysis of these materials are

being currently carried out, in order to compare the spectra from field samples collected at some of the locations classified as above mentioned minerals with those obtained in laboratory. A high-resolution laboratory reflectance spectrometer is being used for this purpose.

The Tricorder algorithm has also mapped the vegetation of the scene in a remarkable way. Most of the pixels on the scene have been classified as a mixture of dry and green vegetation, since the imagery was acquired at the peak of the dry season in this region (August). Tricorder found patches of really green vegetation along the drainage channels, which is also correct. The habit of burning the grass to renew the pastures for grazing, common in this region, produced patches of burn vegetation, which were easily identified by the algorithm, based on their unique spectral response.

5 Acknowledgements

The authors would like to thank R. O. Green (Caltech-NASA/JPL), for guidance on the use of the atmospheric calibration program, and Dr. Roger Clark (USGS Spectroscopy Lab), for the use of Tricorder. This work was funded by Fundação de Amparo à Pesquisa no Estado de São Paulo (FAPESP), through grant 96/8282-8. The authors also acknowledge the support of Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) through research grants 320.229/84 and 301.227/94. Image processing was carried out at the Geo-Referenced Information Processing Laboratory (LAPIG), Geosciences Institute, State University of Campinas, Brazil and at the Spectroscopy Laboratory, at the United States Geological Survey, Denver, Colorado, USA.

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