# ATMOSPHERIC CORRECTION METHOD FOR AVIRIS DATA IN TROPICAL REGIONS

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## 1 Introduction

The remote sensing has been defined as a group of activities that has for objective to characterize the properties of the objects through the detection, registration, and analysis of the radiant flow emitted, or reflected by them. The essence of this activity is based in the identification of objectives and in the discrimination among them, in that the radiation received by the sensor becomes the base of the whole the process. However, the mechanism of acquisition of this radiation is not ideal, since between the sensor and the surface there exists an extremely dynamic medium: the atmosphere. This atmosphere interacts with the electromagnetic radiation, provoking significant alterations in the coming radiant flow from the target.

The main factors causing these alterations, as loss of focus in the image and deformation of the superficial brightness is the molecular scattering, the scattering for aerosols, and the absorption by the atmospheric gases. These alterations are actually a persistent and uncomfortable problem in the analysis of data for remote sensing. A lot of time this analysis will depend on the spectral characteristics of the sensor and of the atmospheric conditions at the date and hour of data acquisition (Freire, 1996).

With the advent of hyperspectral sensors, capable of acquiring dozens of simultaneous images of a same area, and of producing a reflectance spectrum practically continuous for each "pixel" of the scene, a larger emphasis was given in the minimization of atmospheric influences. The methods of atmospheric correction can be divided in physical, that are the most complete and based on the radiative transfer theory; and the alternative ones, that are simplified and generally suppose the interference of the atmosphere as an additive term (Freire, 1996).

In this work the method developed by Green et alia was used (1993) for the atmospheric correction of hyperspectral images, obtained from AVIRIS sensor ("Airborne Visible/Infrared Imaging Spectrometer"). The general objective was motivate by the importance of the atmospheric correction in the image analysis, using as target a green vegetation (riparian forest) as reference for this discussion.

The method of radiative transfer used in the present study is based on the model MODTRAN, which facilitates the determination of the water vapor, the molecular scattering and the gases. Although in an much less expressive way, the same is still capable to evaluate the aerosols and, consequently the scattering produced by these (Crósta, 1997).

AVIRIS sensor is an airborne hyperspectral sensor that belongs to JPL ("Jet Propulsion Laboratory") and it was used in Brazil between the months of August and September of 1995, during the mission SCAR-B (" Smoke/Sulfate, Clouds, and Radiation-Brazil ").

## 2 Materials and Methods

### 2.1 – AVIRIS Sensor

AVIRIS is the second generation of imaging spectrometers developed by JPL for use in remote sensing. It has as purpose the use in several scientific areas, such as Botany, Geology, Hidrology, Oceanography, and Atmospheric Sciences. Its design and construction were initiate in 1984 and completed in June 1987. After its calibration in laboratory, its maiden flight was on June 25, 1987.

This sensor was designed to take advantage typically in the diagnosis of the narrow absorption features, that occurs in the materials of the terrestrial surface. It is capable to propitiate images in 224 contiguous spectral bands with 10 nm width within the range of 400 nm and 2450 nm (Wallace and Enmark, 1987).

AVIRIS still possesses, a instantaneous field of view of 1 mrad and the sweeping angle of 30°. This implies in an imaging swath of 10,5 Km composed of "pixels", that encompass a resolution of 20 meter in the soil obtained at an altitude of 20 Km. The system image is obtained from sweeping mirrors, that define a line of 614 "pixels" of width, perpendicular to the flight direction, and for the direction of the aircraft, that defines the extension of the image.

This sensor was used during the mission of SCAR-B, whose objective sought the study of particles suspended in the air (aerosols). In this mission two main observation platforms were used: the ER-2, that is an aircraft with the capacity of flying in the low stratosphere, and the Convair C-131A, with capacity of flying in the troposhere (Kirchoff, 1995). More information on the equipments flown on the SCAR-B mission can be found in SCAR-B report (1996).

**2.2 – Study Area**

During the mission accomplished by SCAR-B, it were obtained images by the AVIRIS sensor, on the following areas: North of Brasília (DF), Cuiabá (MT), Swampland at Mato Grosso (MS), Porto Nacional (GO), Alta Floresta (MT), Vilhena and Ji-Paraná (RO).

The images selected for this work were the one of Cuiabá of August 25, 1995 (Figure 1). The reason for the choice of this image, was due to the fact that it possesses extreme non standard atmospheric conditions, so, in this way, it was not only to be useful on the verification of the importance of the atmospheric correction, as well as in the evaluation of the employed method efficiency.

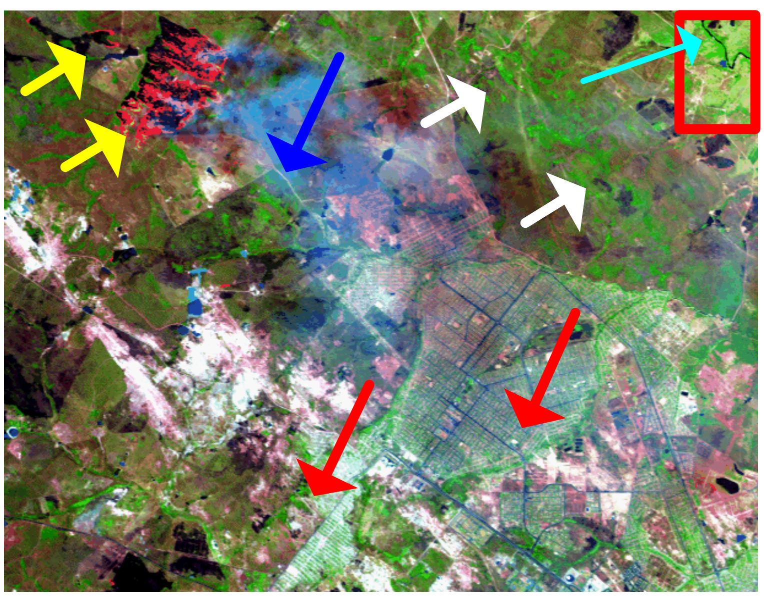

Fig.1 - AVIRIS image of the Cuiabá area obtained in 25/08/95, band 137 (1,6512µm-(R)), band 50 (0,8263µm-(G)), and band 29 (0,6574µm-(B)), in reflectance values not corrected for atmospheric effects of the riparean forest target in prominence (red square). Some important points were indicated by arrows.

In the Figure 1, it can be observed that:
1 - this area presented strong forest fires (yellow arrows) and smoke (blue arrow);
2 - the urban area (red arrows), corresponds to the Northeast area of Cuiabá;
3 - the river, indicated by the cyan arrow, is the Coxipó river. Its riparian forest was used as sample vegetation in the accomplished comparisons;
4 - the area possesses an extensive area composed of savannas (white arrows).

**2.3 - Method of Atmospheric Correction**

The method developed by Green et alia (1993) it is of the radiative transfer type. It was developed for atmospheric correction of hyperspectral images, obtained from the AVIRIS sensor. This method is based on the MODTRAN 3 model, on the calibration of AVIRIS sensor for the obtained radiance in laboratory, and on calibration in flight data. The referring calibration data to the year of 1995, were obtained in Ivanpah Playa's area, California (Crósta, 1997).

The objective of this method is to calculate the reflectance at the terrain surface, from the data of total radiance measured by AVIRIS. For this method, the reflectance value is calculated as a function of the total radiance, of the solar irradiance on the atmosphere top, on the reflectance of the atmosphere and on the atmospheric transmittance in the two ways (from the sensor to the surface and from the surface to the sensor), on the path traveled by the electromagnetic energy. More information about the method can be obtained by Green et alia (1993).

**2.4 - Methodology**

The methodology was composed of two main steps. The first step was the elaboration of an algorithm capable of converting the original image (obtained by JPL in radiance) for apparent reflectance (non corrected for the atmospheric effects). The program developed for this conversion was based on to following equation:

$$r_l = \frac{p.L_l}{E_l.\cos q_S} \qquad (1)$$

where,

$L_l$ = it is the radiance value detector by sensor;

$E_l$ = it is the solar irradiance corresponding to each band at the top of the atmosphere;

$q_S$ = it is the zenith angle.

Once defined the program, and corrected the units, the non corrected image in apparent reflectance was generated. This was to reference base to the comparisons among the data obtained by the program elaborated by Green et alia (1993) and the algorithm developed in the present study.

In the second step, it was made a comparative analysis of the AVIRIS reflectance data, corrected and non corrected for the atmospheric absorption effects and scattering, using a target composed by green vegetation (riparian forest) as reference. Values of NDVI (Normalized Difference Vegetation Index) were obtained considering both situations.

The elaboration of these calculations was accomplished by three different methods:

1. it was used the Bands 28 (red- 0.6477 µm) and 42 (near infrared- 0.7495 µm) of AVIRIS, used by the atmospheric correction method in obtaining of the NDVI image;
2. it was used a program developed by Green and Shimada (1997) for the simulation of reflectance values of the TM sensor data from AVIRIS data. The simulated bands 3 and band 4 of TM (LANDSAT), were used for the respective calculations;
3. NDVI was calculated, being varied the bands (42 to 83) relative to the near infrared and keeping constant the band 28 (red) of the AVIRIS sensor. The obtained result supplies the variation of NDVI values for the corrected and non corrected samples for the atmospheric effects and the differences in percentage among these.

**3 Results and Discussions**

The difference among the spectra obtained from the corrected and non corrected images for the atmospheric effects, considering as target the riparian forest, can be analyzed through the Figures 2.

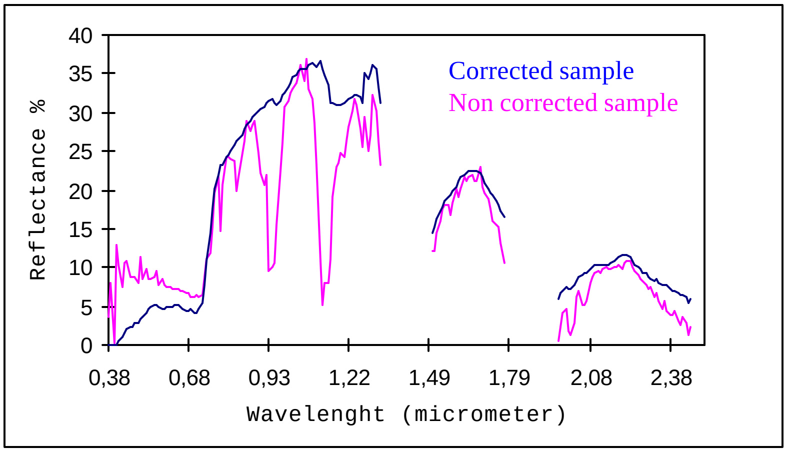


Fig.2 - Difference between the AVIRIS reflectance spectra, from corrected and non corrected for the atmospheric effects, of a same sample of a riparian forest target. The location of that target is shown in Fig.1.

As it can be verified, great differences happen in the visible region of the spectrum, caused mainly by the atmospheric scattering and in a lesser proportion by absorption. As an example it can be mentioned the ozone absorption band. In the range between 0.7 and 2.5 µm, where the influence of the reflected energy is smaller, the largest difference happens due to the absorption of gases, for example, the absorption caused by water vapor (0.72 µm, 0.82 µm, 0.94 µm, 1.14 µm), carbonic gas (1,4 µm, 1,6 µm and 2,0 µm), and oxygen (0,76 µm).

It can be verified although, that the correction accomplished by the method in the visible region was for the smaller values of reflectance, where the influence of the scattering effect, that is around 50% of the arriving signal at the sensor (Deschamps et alia, 1981), is removed by the method. With relation to the near infrared region, where the differences happen practically in relation to the atmospheric absorption, it is also noticed the coherence in the correction, because it is shown that the absorption bands were eliminated during the correction.

The Table 1 exhibits the NDVI values of the corrected and non corrected sample for the atmospheric effects, using a riparian forest target with 26 x 26 "pixels", as well as, the difference in percentage among these obtained values. The calculations were made considering the band of the red at 0.6477µm and the infrared at 0.7495 µm.

**TABLE 1 – REFLECTANCE VALUES (%) OF BAND 28 AND 42 FROM AVIRIS AND DIFFERENCE IN PERCENTAGE FROM VALUES OF NDVI OBTAINED**

| | BAND 42 (I.R-0.7495µm) | BAND 28 (RED-0.6477µm) | NDVI | DIFFERENCE NDVI CORR/NCOR |
|---|---|---|---|---|
| NON CORRECTED | 21.66463 | 6.99602 | 0.518 | 23.72% |
| CORRECTED | 21.93846 | 4.92692 | 0.633 | |

Obs: visibility of 30 Km.

As it can be verified, a difference of 23% exists between the values of NDVI, that is to say, the value of NDVI (riparian forest) of the corrected sample is 23% larger than the value of NDVI of the non corrected sample. This difference can be larger or smaller in function of the atmospheric conditions of the scene at the time of acquisition. In this way, the cleaner the image, lesser will be the difference, and the "dirtier" (humidity, aerosols) the image, greater can be this difference (Green, 1997).

In order to confirm the obtained results, the same procedure was accomplished using a program for simulation developed by Green and Shimada (1997), in which data obtained from AVIRIS were simulated for the TM bands. The results can be observed in the Table 2.

**TABLE 2 – REFLECTANCE VALUES (%) RESULTING FROM SIMULATION OF TM3 AND TM4 BANDS, FROM AVIRIS DATA, AND THE PERCENTAGE DIFFERENCE OF NDVI OBTAINED VALUES**

| | BAND 4 | BAND 3 | NDVI | DIFERENCE NDVI CORR/NCOR |
|---|---|---|---|---|
| NON CORRECTED | 25.893 | 7.283 | 0.561 | 21.7% |
| CORRECTED | 28.570 | 5.391 | 0.683 | |

The accomplished NDVI calculations, commented in the second step, in which the infrared bands (42 to 83) have been varied, and in which it was kept constant the band 28 (red) of the AVIRIS sensor, can be verified in the Table 3.

**TABLE 3 – VALUES OF NDVI AND ITS DIFFERENCES IN PERCENTAGE BETWEEN CORRECTED AND NON CORRECTED SPECTRA FOR ATMOSPHERIC EFFECTS OF THE RIPARIAN FOREST TARGET**

| BAND(I.R) | BAND | NDVI CORR | NDVI NCORR | PERCENTAGE |
|---|---|---|---|---|
| 42 | 0.7495 | 0.6332 | 0.5118 | 23.72 |
| 43 | 0.7591 | 0.6498 | 0.3558 | 82.62 |
| 44 | 0.7687 | 0.6504 | 0.4952 | 31.34 |
| 45 | 0.7783 | 0.6610 | 0.5516 | 19.83 |
| 46 | 0.7879 | 0.6663 | 0.5536 | 20.35 |
| 47 | 0.7975 | 0.6711 | 0.5473 | 22.62 |
| 48 | 0.8070 | 0.6782 | 0.5461 | 24.19 |
| 49 | 0.8166 | 0.6841 | 0.4775 | 43.25 |
| 50 | 0.8263 | 0.6884 | 0.5124 | 34.34 |
| 51 | 0.8359 | 0.6933 | 0.5601 | 23.78 |
| 52 | 0.8454 | 0.6996 | 0.5816 | 20.29 |
| 53 | 0.8551 | 0.7036 | 0.6111 | 15.14 |
| 54 | 0.8647 | 0.7084 | 0.5946 | 19.14 |
| 55 | 0.8742 | 0.7134 | 0.6054 | 17.83 |
| 56 | 0.8838 | 0.7156 | 0.6103 | 17.24 |
| 57 | 0.8935 | 0.7201 | 0.5585 | 28.94 |
| 58 | 0.9031 | 0.7221 | 0.5188 | 39.19 |
| 59 | 0.9127 | 0.7237 | 0.4915 | 47.24 |
| 60 | 0.9223 | 0.7267 | 0.5172 | 40.52 |
| 61 | 0.9319 | 0.7287 | 0.1500 | 385.91 |
| 62 | 0.9415 | 0.7316 | 0.1774 | 312.51 |
| 63 | 0.9511 | 0.7272 | 0.2087 | 248.38 |
| 64 | 0.9607 | 0.7256 | 0.3760 | 92.99 |
| 65 | 0.9703 | 0.7293 | 0.5232 | 39.40 |
| 66 | 0.9799 | 0.7343 | 0.5765 | 27.37 |
| 67 | 0.9895 | 0.7374 | 0.6279 | 17.44 |
| 68 | 0.9991 | 0.7423 | 0.6369 | 16.54 |
| 69 | 1.0087 | 0.7461 | 0.6464 | 15.41 |
| 70 | 1.0183 | 0.7507 | 0.6510 | 15.32 |
| 71 | 1.0280 | 0.7525 | 0.6560 | 14.71 |
| 72 | 1.0376 | 0.7548 | 0.6647 | 13.56 |
| 73 | 1.0472 | 0.7568 | 0.6765 | 11.88 |
| 74 | 1.0568 | 0.7573 | 0.6598 | 14.78 |
| 75 | 1.0664 | 0.7573 | 0.6819 | 11.06 |
| 76 | 1.0760 | 0.7598 | 0.6508 | 16.75 |
| 77 | 1.0856 | 0.7608 | 0.6383 | 19.20 |
| 78 | 1.0952 | 0.7599 | 0.6080 | 24.98 |
| 79 | 1.1048 | 0.7591 | 0.5384 | 41.00 |
| 80 | 1.1144 | 0.7636 | 0.2098 | 263.89 |
| 81 | 1.1240 | 0.7575 | -0.1509 | 602.17 |
| 82 | 1.1336 | 0.7527 | 0.0620 | 1114.54 |
| 83 | 1.1432 | 0.7432 | 0.0704 | 955.82 |

Although it is known that the referring bands to the absorption gases are not usually included for the possible calculations of NDVI, the same bands were used just to verify the possible consequences of its inclusion in the calculations, considering the absence of a due atmospheric correction. It can be verified although, that the variations were very abrupt, for this situation, and could vary from 11% to 1114% for the difference between the NDVI_CORR (corrected) and NDVI_NCOR (non corrected).

The negative values observed in the Table 3, occur when the infrared values of the band are smaller than the reflectance values in the red.

## 4 Conclusion

The results show the importance and the need of an atmospheric correction, above all, in the use of hyperspectral data, having as example the use of vegetation index images. The results also show, that care should be taken in the selection of the correction method, as well as for its correct use, since a bad correction can produce larger errors than the non correction of an image.

The method used presented satisfactory results, correcting in precise way the water vapor.

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