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ATMOSPHERIC CORRECTION ANALYSIS ON LANDSAT DATA OVER THE AMAZON REGION

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14. Abstract/Notes

The Amazon Region natural resources are studied in two ways and compared. Initially, a LANDSAT scene and its attributes are selected, and a maximum likelihood algorithm classification is made. The next step is the atmospheric correction of the scene, takin into account Amazonic peculiarities (checked with ground truth) of the same area, and the subsequent classification. Finally a comparison, wich shows that the classification improves with the atmospherically corrected images, is made.

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ABSTRACT

The Amazon Region natural resources are studied in two ways and compared. Initially, a LANDSAT scene and its attributes are selected, and a maximum likelihood algorithm classification is made. The next step is the atmospheric correction of the scene, taking into account Amazonic peculiarities (checked with ground truth) of the same area, and the subsequent classification. Finally a comparison, wich shows that the classification improves with the atmospherically corrected images, is made.

I - INTRODUCTION

In order to better use orbital remote sensing techniques for natural resources studies, it is desirable to minimize the nontarget-related attributes influence, as that of atmospheric absorption and scattering.

Therefore, the main objective of this paper is to analyse the atmospheric influence on LANDSAT imagery for the Amazon region data.

The selected area was centered around the city of Manaus (Capital of Amazonas State, Brazil), containing the Manaus International Airport (Eduardo Gomes Airport), from which radiosonde data are available.

The results will be used at INPE (Institute for Space Research, Brazil) and other Brazilian institutions that utilize remotely sensed LANDSAT data for Amazon Region studies.

II - STUDY AREA

The selected study area is the scene sub-image 248.62 (WRS). The land area is approximately 900 km², located between 59° 50' W - 60° 00' W and 03° 00' S - 03° 10' S. Within the selected area the city of MANAUS, its INTERNATIONAL AIRPORT, jungle plantations, and rivers with different types of water, which makes it a good choice, are located. The proximity of MANAUS enable one of the authors to collect data on site for use as ground truth.

The LANDSAT material used were CCT's in four channels, for September 28th, 1981, and the machine processing performed on INPE's IMAGE-100 System, assembled by GENERAL ELECTRIC CO.

III - METHODOLOGY

A procedure developed at INPE for atmospheric correction[1] was used. Its steps are as follows: (i) the atmospheric transmittance is determined by a modified LOWTRAN 4[2] computer program (originally developed by the Air Force Geophysical Laboratory, AFGL, USA). This program was modified for interactive remote video terminal use, with optional graphical output[3]. The atmospheric model, inferred from radiosonde data, was acquired at Eduardo Gomes Airport (Manaus, AM, Brazil), at the same date and approximately at the same time of the satellite pass; (ii) using the transmittance, the solar zenith angle, and the estimated values for the average ground albedo and aerosol optical depth, the LANDSAT image is corrected pixel by pixel by the I-100 System.

In order to analyse quantitatively the atmospheric correction effect, it was necessary to obtain true grey level range for the selected classes identified in the scene.

The procedure, with and without atmospheric correction, for obtaining the spectral classes was the following: (i) noise removal, (ii) radiometric correction to minimize stripping, (iii) main area selection at 1:100,000 scale, (iv) training areas selection (obtained by field trip ground truth); (v) spectral parameters acquisition through the MAXVER[4] (maximum likelihood) algorithm.

Other quantitative parameters were measured in order to compare the data with and without atmospheric correction. Initially, the JM distance (Jeffreys Matusita Distance) was computed to determine the separability among the spectral classes for one or a combination of channels. The JM distance[5] is given by the formula:

$$JM = 2\,(1 - e^{-\alpha}), \tag{1}$$

where

$$\alpha = \frac{1}{8}\,(U_1 - U_2)^T\,\varepsilon^{-1}\,(U_1 - U_2) + \frac{1}{2}\ln\left[\frac{\det \varepsilon}{\sqrt{\det \varepsilon_1 \det \varepsilon_2}}\right] \tag{2}$$

and

U_i = averages of class i matrix 0, i = 1,2;

$(\ )^T$ = transposed matrix;

$(\ )^{-1}$ = inverse matrix

$\varepsilon = \frac{1}{2}[\varepsilon_1 + \varepsilon_2]$;

ε_i = covariance matrix class i, i = 1,2;

$\det \varepsilon = \varepsilon_i$ determinant, i = 1,2.

The applicability of these measurements for class separation, mainly for vegetation covered areas, was shown by Aoki and Santos[6].

Another useful parameter is the ratio between the average grey levels with and without atmospheric correction, for each class, for each MSS channel. This ratio is expressed by:

$$RA(i,\beta) = \frac{C'(i,\beta)}{C(i,\beta)}, \tag{3}$$

being $C'(i,\beta) > C(i,\beta)$,

where $C'(i,\beta)$ = average gray level for class i, channel β, with atmospheric correction.

$C(i,\beta)$ = average gray level for class i, channel β, without atmospheric correction.

Next, the product PA, composed of the contrast index between two classes multiplied by the average value of these classes is studied:

$$PA(i,j,\beta) = \frac{C(i,\beta)}{C(j,\beta)} \times \frac{C(i,\beta) + C(j,\beta)}{2} \tag{4}$$

for i > j,

being $C(i,\beta)/C(j,\beta)$ the contrast index, and $(C(i,\beta) + C(j,\beta))/2$ the average, where $C(i,\beta)$ = average gray level value for class i (or j), without atmospheric correction; and β is LANDSAT MSS channel.

The product PA' is similarly obtained for atmospheric corrected values.

Following, the ratio RB (i,j,β) between PA' and PA for PA' > PA is:

$$RB(i,j,\beta) = PA'(i,j,\beta)/PA(i,j,\beta). \tag{5}$$

Finally, the standard deviation for each class, for each MSS channel, with and without atmospheric correction, taking into account the size of the training area, is analysed.

IV - RESULTS

From radiosonde data, assuming a visibility of 20 km, the atmospheric transmission was computed through the use of a LOWTRAN 4[2]:

$T_4 = 0.6905$,

$T_5 = 0.7467$,

$T_6 = 0.7343$,

$T_7 = 0.7646$.

The zenith angle (50^0), aerosol optical depth assumed (0.12), and estimated albedo (0.20) are the other input parameters for the atmospheric correction program[1]. A composition of channels 4,5 and 7, atmospherically corrected is shown in Figure 1.

It is noted on the picture that the Negro River water and the Solimões River (Amazonas River) water are strikingly different. The city of Manaus is in the middle of the picture. This picture is a sub-image of orbit 248.62 (WRS), with a 1:100.000 scale on the I-100 video.

Figure 1 - Area under study with atmospheric correction.

In the selected scene, six classes were considered: (1) dark water, (2) muddy water, (3) jungle (tropical rain forest), (4) secondary forest, (5) urban areas (city of Manaus and environs), and (6) agricultural areas. The classes spectral parameters with and without atmospheric correction, obtained by the MAXVER algorithm, are presented on Table 1.

The values of RA for each class and channel are presented on Table 2.

Table 3 presents RB for each pair of classes, while Table 4 presents the standard deviation as computed by MAXVER.

V - DISCUSSIONS AND CONCLUSIONS

From Table 1, it is observed that, depending on the target, the correction in general increased the average grey levels. For example for class 1, channel 7, the difference was 118%, while for class 4, channel 4, the difference was only 25%. The value of the correction is highly dependent on the target.

It is observed from Table 2 that class 1 was more affected by the correction, followed by class 2, while on the other classes the effect was not so prominent.

Table 3 shows that the RB value did not change very much for pairs of classes on the visible and near infrared (channels 4,5,6), while for the infrared channel 7 it varied from 1.00 to 1.66.

The standard deviation increase with the atmospheric correction; thus, it is supposed that a class has a larger set after correction, which should improve the classification. It should be noted that class 3 (jungle) presented a much larger standard deviation than the other classes, while class 4 (secondary forest) presented a small standard deviation. This result is still under study.

In addition to these quantitative results, it was observed that after an atmospheric correction is performed there is a noticeable increase in the image visual quality, with sharper natural ground target contours. Finally, the above results are preliminary, and many more tests and field trips are needed to achieve a better understanding of the atmospheric effect on LANDSAT imagery over the Amazon Region.

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Table 1 - Spectral parameters obtained by MAXVER

MSS CHANNEL / CLASS	W/O CORR.				W/ CORR.				# SAMPLES/ CLASS	# PIXELS/ CLASS
	4	5	6	7	4	5	6	7		
1	17.40	18.00	10.36	5.07	22.02	22.40	15.24	11.08	10	360
2	36.19	48.57	26.64	9.23	44.23	57.84	36.72	17.10	10	360
3	63.61	93.54	95.49	76.70	76.23	110.32	127.19	111.66	10	360
4	20.03	21.01	63.68	74.55	25.13	25.96	85.40	108.51	10	360
5	31.82	44.69	70.46	75.21	38.98	53.34	95.19	109.36	4	96
6	23.54	25.01	83.33	96.03	29.23	30.33	111.22	138.86	4	144

Table 2 - RA

MSS CHANNEL / CLASS	4	5	6	7
1	1.26	1.24	1.47	2.18
2	1.22	1.19	1.38	1.85
3	1.20	1.18	1.33	1.46
4	1.25	1.24	1.34	1.46
5	1.22	1.19	1.35	1.45
6	1.24	1.21	1.33	1.45

Table 3 - RB

MSS CHANNEL / PAIR OF CLASSES	4	5	6	7
1 - 2	1.26	1.16	1.32	1.66
1 - 3	1.15	1.13	1.22	1.00
1 - 4	1.26	1.23	1.24	1.00
1 - 5	1.20	1.16	1.26	1.00
1 - 6	1.23	1.19	1.23	1.02
2 - 3	1.18	1.17	1.30	1.18
2 - 4	1.20	1.16	1.32	1.18
2 - 5	1.22	1.18	1.33	1.18
2 - 6	1.21	1.18	1.30	1.16
3 - 4	1.15	1.14	1.32	1.46
3 - 5	1.19	1.17	1.32	1.46
3 - 6	1.17	1.15	1.34	1.44
4 - 5	1.21	1.16	1.35	1.45
4 - 6	1.24	1.20	1.33	1.44
5 - 6	1.21	1.18	1.33	1.44

Table 4 - Standard deviation

MSS CHANNEL / CLASS	W/O CORR.				W/ CORR.			
	4	5	6	7	4	5	6	7
1	1.80	2.04	2.57	2.26	2.21	2.46	3.46	3.14
2	2.05	2.17	2.31	1.95	2.36	2.52	3.17	2.87
3	20.38	38.28	35.02	22.59	23.93	44.61	46.02	31.74
4	1.75	1.87	4.84	5.42	2.02	2.07	6.43	7.58
5	2.83	4.30	3.96	4.21	3.46	5.00	9.10	5.96
6	2.71	2.89	5.10	5.62	3.20	3.40	6.77	7.89