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14. Abstract/Notes

The presence of the terrestrial atmosphere is a constant problem in satellite image classification. This paper describes a procedure to test quantitatively the performance of an atmospheric correction algorithm. This specific algorithm was developed at INPE, based on O'Neil's model. The procedure consists of correcting two images of the desired scene, for different days, changing the aerosol optical depth and comparing at selected areas, the contrast and the correlation between the images. For a better correction, the contrast improves, as well as the correlation. Based on the previous information, it is possible to select the proper aerosol optical depth. Care should be taken, however, since an exaggerated contrast improvement by itself or a good correlation alone are not sufficient. Using both criteria, a better judgement can be made. Scenes that have undergone considerable temporal changes, as those at different stages of a given crop, should be avoided. Some modifications were made in LOWTRAN program to calculate quickly the atmospheric transmittance and to allow an interaction with the user. Graphic output of input and output data was also introduced.

15. Remarks

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AN INTERACTIVE MODEL FOR ATMOSPHERIC CORRECTION IN SATELLITE IMAGES

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ABSTRACT

The presence of the terrestrial atmosphere is a constant problem in satellite image classification. This paper describes a procedure to test quantitatively the performance of an atmospheric correction algorithm. This specific algorithm was developed at INPE, based on O'Neil's model. It is difficult to obtain a reasonable atmospheric model for Brazilian conditions, due to lack of aerosol data. The procedure consists of correcting two images of the desired scene, for different days, changing the aerosol optical depth, and comparing at selected areas, the contrast and the correlation between the images. For a better correction, the contrast improves, as well as the correlation. Based on the previous information, it is possible to select the proper aerosol optical depth. Care should be taken, however, since an exaggerated contrast improvement by itself or a good correlation alone are not sufficient. Using both criteria, a better judgement can be made. Scenes that have undergone considerable temporal changes, as those at different stages of a given crop, should be avoided. In order to make the interactive model practical, it was necessary to calculate quickly and interactively the atmospheric transmittance. This was done by means of a modified LOWTRAN program. The modifications were introduced in order to make LOWTRAN more user-friendly, by allowing direct user interaction via video terminals, including graphic of the input model and the output profiles.

1. INTRODUCTION

A problem in satellite image classification is the presence of the terrestrial atmosphere: it tends to blur the original scene, making the satellite sensor acquire a different spectral signature depending on the atmospheric conditions.

One of the ways to tackle the problem is to simulate the atmosphere, and compensate for the image the effect that would be produced by this synthetic atmosphere. The problems involved in modelling the atmosphere are enormous (Turner and Spencer, 1972), due to lack of data and to the simplifying assumptions one is forced to make. Fortunately, even a simple model may produce good results, as the algorithm implemented at INPE (Dias et al., 1981) has shown.

Another problem then arises: how to test the correction quality? A direct approach is to check a posteriori, using ground truth. However, this is a slow and expensive procedure. This work suggests an unsupervised procedure to evaluate approximately the quality of an atmospheric correction if the aerosol optical depth is not known.

2. DESCRIPTION OF THE PROCEDURE

The atmospheric correction algorithm used at INPE is rather simple. It uses a LOWTRAN-4 program (Selby et al., 1978) to compute the atmospheric transmittance and O'Neil's tables to determine the path radiance (O'Neil et al., 1978). It was developed for LANDSAT use.

The LOWTRAN-4 program was modifed to allow plotting of the input atmospheric model, and the total absorption output profiles, molecular absorption, and aerosol absorption versus wavelength. Figure 1 is an example of the inputs, and Figure 2, of the outputs. Besides that, the program has been made interactive. Figures 3 and 4 present "menus" for the choice of models, the possible changes into the parameter cards, or the program termination, respectively. All the input parameters are entered in an interactive way. A B-6800 computer with video terminals has been used as input and video, and a Calcomp plotter, or line printer, as output medium.

For the correction itself an Image-100 coupled to a PDP-11/45 is used. The input data are: a) the LANDSAT channel; b) aerosol optical depth; c) ground albedo; d) solar zenith angle; e) transmittance (from LOWTRAN); f) full image (T) or only inside a cursor (C); g) another training area (T) or repeat for another channel (C).

The LOWTRAN program input data is fairly well known, especially if radiosonde data is used for an atmospheric model (which is generally the case). The standard models are not well suited for Brazilian conditions.

There is quite a number of parameters to estimate, as can easily be seen. The proposed procedure keeps the measured or estimated parameters constant, except for the aerosol optical depth, that is an important unknown, especially for Brazilian condition due to lack of reliable data. The correction is made by changing the aerosol optical depth from 0.12 to 0.48 at 0.12 intervals for the desired image, I1, and another image, I2, of the same scene taken at a different time.

Initially, a correlation operation (correlation coefficient) is obtained between I1 and I2 for selected areas that do not have changed in time. The best correlation should indicate a minimum of atmospheric effect. Unfortunately, this is not a strong indication of a "correct" correction, for false interpretations are possible. The size of the area to be correlated is important. If it is too large (a whole image, for instance), part of it can compensate for another part. If it is too small, the result can be meaningless, especially if a good geometric correction was not done, as in our case. A reasonable value is 32 x 32 or 64 x 64 pixels, or areas that are not supposed to change with time.

In order to confirm the better correction, the contrast of selected points is examined. Generally, the better the contrast the better the correction. If the atmosphere were to be removed, the contrast would improve. For contrast the following expression is assumed

$$C = (Ia - Ir) \; / \; (Ir + Lp/T), \tag{1}$$

where Ia is the target pixel brightness and Ir, its neighbour's brightness such that $|Ia - Ir|$ is maximum, Lp is the path radiance and T the atmospheric transmittance.

3. PRELIMINARY RESULTS

Extensive tests of this proposed algorithms were not done yet. However, for a preliminary study, two images of Vale do Paraíba, Brazil, on July 11th, 1973 and January 31st, 1978 of LANDSAT-1, channel 4 were used.

The atmospheric correction was made for aerosol optical depths of 0.12, 0.24, 0.48 for November 7th, 1973 and of 0.12, 0.24 for January 31st, 1978. The correlation results (only to 0.12 and 0.24) are presented on Table 1. The albedo was estimated at 0.2.

Point ≠ 1 corresponds to a 64 x 64 pixel window on a highway near the city of Taubaté, SP, Brazil; point ≠ 2, also 64 x 64, corresponds to the city of Cruzeiro, SP, Brazil; point ≠ 3, 64 x 64 pixel, is a hilly region known as Serra do Mar, covered by a tropical forest; point ≠ 4 is the whole 512 x 512 subimage. If the averages (64 x 64) are taken, the best correlated pairs are the images 0.12 giving 0.288, followed by 0.12 (January 31st), and 0.24 (July 11th) giving 0.281. The worst correlated pairs are the 0.24 images with 0.265. The other pair's correlation was 0.273.

The contrast is presented on Table 2, for selected pixels inside the windows above, plus a pixel on an improved aircraft runaway at Inpe's airport at Cachoeira Paulista (point ≠ 5). Since the images are not geometrically corrected, it is possible that the pixels' number do not correspond, but visually they correspond to the same landmarks.

4. CONCLUSIONS

At this point, a large series of tests with a large number of images has to be done, under different conditions. This work is under way, and not reported yet in this paper. However, based on the preliminary tests, a few conclusions can be drawn in support of the ideas here presented. For this, first test images taken on different seasons and four and a half years apart were chosen.

From Table 1, point ≠ 3 (Serra do Mar) was the worst correlated, as expected, since the vegetation should have changed from Winter (73) to Summer (78). Point ≠ 2 (city of Cruzeiro) was the best correlated, since the intrinsic reflection of a stable urban area should not change much with time. Point ≠ 4 (512 x 512 pixel) was better correlated, because of the larger number of points. The best candidates for aerosol optical depths are January 31st with 0.12 and July 11th with 0.12 or 0.24.

Based on Table 2, it is seen that point ≠ 3 did not change much its contrast on July 11th (Winter); but did on January 31st (Summer), again as expected. On the other hand, point ≠ 5 had a large variation in 1973, since the runaway was under construction with a considerable amount of particles in the air. In 1978, it was already built and no large variation of contrast occurred for different aerosol optical depths. Taking the averages, the candidates for aerosol optical depth are 0.24 for July 11th, 1973, and 0.12 for January 31st, 1978. This conclusion is in accordance with Table 1, if it is noted that the aerosols are not uniformly spread but with different concentrations over different areas. If point ≠ 3 is not included, the best average correlation is 0.12 (January 31st) and 0.24 (July 11th), The exclusion of point ≠ 3 can be justified on the basis that it changed with time.

Finally it should be remarked that, if selected windows and points are carefully chosen, this method has a potential to indirectly estimate the aerosol optical depth and determine its proper value for a better atmospheric correction, thus checking its quality.

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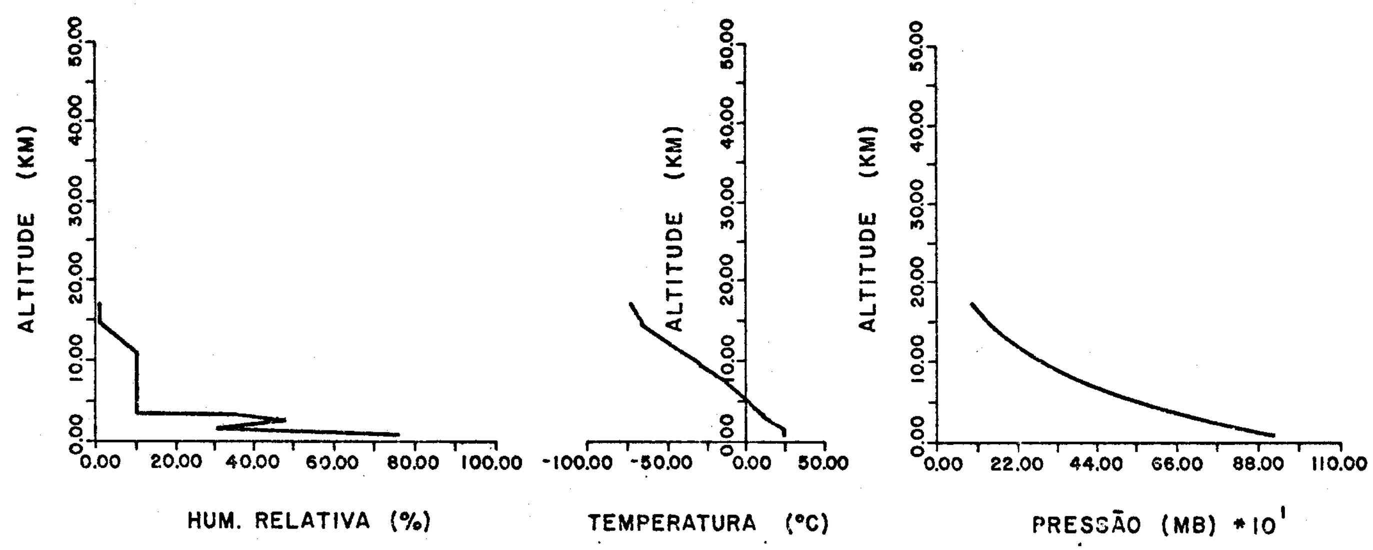

Figure 1 - Input.

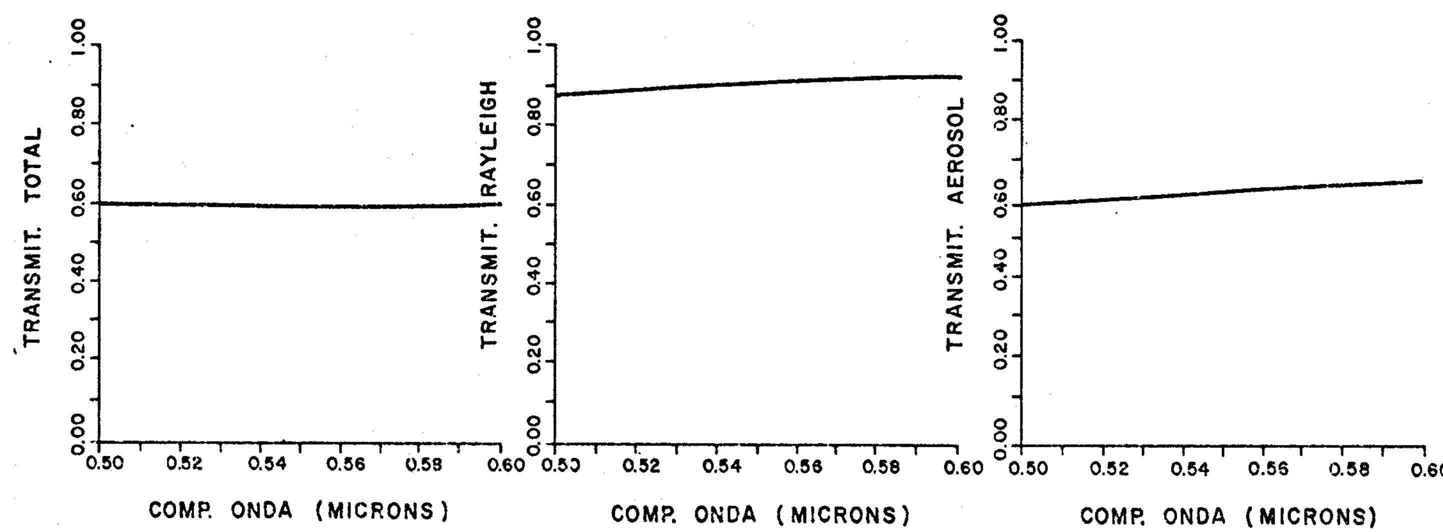

Figure 2 -- Output.

TABLE I. CORRELATION COEFFICIENTS

		July 11th, 1973							
		Point ≠ 1		Point ≠ 2		Point ≠ 3		Point ≠ 4	
		0.12	0.24	0.12	0.24	0.12	0.24	0.12	0.24
Jan. 31st, 1978	0.12	0.269	0.269	0.365	0.366	0.231	0.208	0.408	0.392
	0.24	0.246	0.245	0.343	0.344	0.230	0.208	0.409	0.384

TABLE II. CONTRAST

July 11th, 1973	Original	0.12	0.24	0.48
Point ≠ 1	9.52E-2	8.32E-2	9.42E-2	6.66E-2
Point ≠ 2	1.88E 0	3.20E 0	2.81E 0	2.69E 0
Point ≠ 3	1.00E 0	1.10E 0	1.19E 0	1.26E 0
Point ≠ 5	1.45E 0	1.17E-1	2.39E 0	1.61E 0
AVERAGE	1.106E 0	1.388E 0	1.621E 0	1.406E 0

January 31st, 1978	Original	0.12	0.24
Point ≠ 1	5.55E-1	5.29E-1	5.12E-1
Point ≠ 2	1.91E-1	2.05E-1	1.45E-1
Point ≠ 3	2.66E-1	3.10E-1	2.72E-1
Point ≠ 5	4.47E-1	4.35E-1	4.23E-1
AVERAGE	3.650E-1	3.697E-1	3.382E-1