SPECTRAL MEASUREMENTS FOR CORRECTING LANDSAT DATA FOR ATMOSPHERIC EFFECTS

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ABSTRACT

A combined ground truth measurements, with an Exotech Model 100 A radiometer, and digital values Landsat 4 MSS, from the same area and at the same time, were evaluated to correct the atmospheric effect. The parameters had been the beam transmittance and path radiance, in the four optical bands, determined from corresponding measurements of sun radiance as a function of sun elevation sky radiance, and azimuth angle. This experimetal method was compared with empirical methods and there was a high correlation, between the radiances sensed by the Landsat 4 MSS and the ground truth measurements, corrected by means of the atmospheric effects.

1. INTRODUCTION

The influence of atmospheric effects, over the electromagnetic radiation, registered by the Landsat 4 satellite sensors could be important and change with the local conditions at the time of satellite scanner, as well as the wavelenght of the radiation.

The problem can be explained mathematically but it is very difficult to consider all the possible effects (scattering, absorption, transmittance, path radiance, etc) In this opportunity an experimental method was taken into account to allow the measurement of these parameters.

The correction of the atmospheric effect had great importance in multitemporal analysis, classifications and band ratios studies. This avoided mistakes in the interpretation of the results.

The radiance L_s (mW/cm^2 sr) measured by the vertically downlooking Landsat 4 MSS could be expressed by:

$$L_s = \frac{\rho}{\pi}\left(H_{sun}\cos Z + H_{sky}\right)\tau + L_p$$

where τ is the atmospheric transmittance for one air mass and L_p (mW/cm^2 sr) the path radiance. The global irradiance Lr was expressed by

$$L_r = \frac{\rho}{\pi}\left(H_{sun}\cos Z + H_{sky}\right)$$

Where H_{sun} (mW/cm^2) is the direct sun irradiance
H_{sky} (mW/cm^2) is the diffuse sky irradiance
Z is the zenith distance of the sun

An experimental approach was used for determination of τ, H_{sky} and L_p, using and Exotech model 100 A radiometer (Maracci).

2. MEASUREMENTS

Many testing areas, near Buenos Aires City were analysed, by going to the place and locating said area over the satellite image. An homogeneous area, with suitable dimensions for the Landsat image, to register the measurements on ground at the least time possible respect to satellite overpass was looked for. An area of 50 ha distinguished from urban areas of the environment and divided in five visually differentiated subareas in accordance with density and type of grass present was chosen.

The measurements lasted six months and a half. Only three of all the possible measurements were accepted due to adverse weather conditions. Those accepted were taken on days free of clouds.

The Exotech 100 A was previously calibrated (Herren, 1984), using a grey body as an extensive homogeneous source.

Between 45 and 50 measurements were registered on the ground at intervals of 1 to 5 minutes during a two

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hour period. The measurements started an hour before satellite scanning and lasted one hour after it. The surface of each subarea determined the number of measurements made on them.

During each ground measurement, the local time, the visual ground conditions and atmospheric situation was registered. All the measurements were taken into account with the radiometer, mounted on a tripode, at 1m high. The resolution was of 30 cm from each side.

3. ATMOSPHERIC PARAMETERS

In order to estimate the transmittance and the path radiance L_p, it was necessary to measure the sun radiation at different hours of the day and the sky radiance at the Landsat pass (Maracci). It must be noted that the sun zenith angles were known at each measurement. (Almanaque Náutico y Aeronáutico, 1984) Table 1. It was determined that all the area was measured without sun zenith angle variation. Polygons were chosen for each subarea of the test site, and the grey levels Ck and the standard dispersion Δ Ck were measured. These digital data were transformed to physical radiance values

$$\langle L_s \rangle_k \pm \Delta \langle L_s \rangle_k$$

(Robinove, 1982). An arithmetic average of radiometric measurements on each subarea k, registered at the same time Landsat 4 MSS overpass, was done.

$$\langle L_r \rangle_k = \left\langle \frac{H\rho}{\pi} \right\rangle_k$$

The two data systems, that is to say $\langle L_s \rangle_k$ and $\langle L_r \rangle_k$ were compared by calculating their mean reflectance factors and standard deviations. The deviation of the reflectance factors (satellite minus ground based values) were, in general, smaller that the experimental errors. (Staenz, 1981).

4. EMPIRICAL METHODS

In a first order correction, a constant value is subtracted from the ERTS frame for each band. This constant is different for each of the four bands and for each frame.

Three different methods have been used but each of them is based on the fact that band 7 is essentially free of haze effects (Chavez, 1975), and this event has been proved by measuring the path radiance in the ground truth method.

The first method determines that there are, at least, a few pixels which have 0% refelctance band 7, so the histograms for bands 4, 5 and 6 are offset to right and there is a number of pixels at some grey level "X". Grey level "X" is assumed to be the amount of haze in each particular band.

In the second method the grey level of each pixel in band 7 is plotted against the grey level in each of the other bands. A least squares technique is used to fit a straight line through each of the three plots. The line intercepts the band I axis at some value "X". This offset is the amount of haze in the band.

The third method developed is an extension of Chavez' Regression Technique (Switzer 1981) and it uses the correlation among all four bands of data simultaneously instead of in pairs. It doesn't require the presence of areas of low reflectance; instead it is used in areas of homogeneous reflectance, as test areas, for estimation of the band atmospheric path radiances. Kimsa and Brizuela (1985) introduced a variation to assure homogeneity of the chosen sites, by gathering only those pixels of the frame that fulfill the relations such as:

$$0.7 < \frac{X6}{X5} < 1.1$$

and

$$0.9 < \frac{X7}{X6} < 1.1$$

5. CONCLUSIONS

Atmospheric transmittance for one air mass is determined by plotting the measured values H_{sun} as function of cos Z, doing a least square fit of them (Maracci), instead of using Roger's method (Roger 1973) where τ is determined directly from two H_{sun} values. A close approximation in this last case was observed because the relation between H_{sun} and cos Z is not lineal as it is supposed in Roger's method. The path radiance Lp has a great influence on bands 4 and 5 where Ragleigh scattering is the highest.

The atmospheric effect distort vegetation spectral features due to path radiance increase in the visible and lower effect in the near infrarred.

When comparing the temporal grass variation on the radiometric measurements in band 7, the radiance increased with spring time and grass density and transmittance increased too.

The Landsat data are processed and corrected at the same time by means of empirical methods such as covariance matrix method (Switzer 1981), and minimun grey histogram value (Chavez 1975), and compared with the radiometric ground truth measurements. Table II. A high conclusion was obtained that is to say a high correlation between the two empirical methods and the experimental one.

Both empirical methods are useful for correcting atmospheric effects, but the covariance matrix method does not require auxiliary data.

The low disagreements found between both methods can be owed to zenithal angular variation that is not taken into account when doing radiometric measurements, calibration errors can be owed to Landsat multispectral scanner, (Robinove, 1982) as well as Exotech model 100 A radiometer.

It must be taken into account that the here used atmospheric effect methods do not include all the effects present in the electromagnetic radiation interaction with the atmospheric mean.

Any way the conclusion to which we arrived means a solution to the distorted spectral Landsat digital data by the atmospheric influence. This paper shows that using these empirical simple methods (Chavez 1975; Switzer, 1981) there is a good agreement at first order between Landsat digital data and the radiometric measurements, that is to say it is not necessary to realize complicated ground truth measurements.

The digital data, thus corrected, are radiometrically more reliable than the original grey tones and the corrected images have high quality.

6. REFERENCES

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DATE	BAND 4		BAND 5		BAND 6		BAND 7	
	T	Lp	T	Lp	T	Lp	T	Lp
2/8/84	0.69 ± 0.01	250	0.70 ± 0.01	234	0.71 ± 0.01	136	0.68 ± 0.01	119
18/8/84	0.65 ± 0.099	236	0.69 ± 0.03	201	0.75 ± 0.04	89	0.85 ± 0.04	71
5/10/84	0.83 ± 0.04	260	0.85 ± 0.04	223	0.86 ± 0.03	121	0.89 ± 0.02	102

: Beam Transmittance

Lp : Path Radiance (uW/cm^2 sr)

TABLE I: Atmospheric Parameters

Methods	n	r	a	b	Significance Level
Without Correction	52	0.88	0.59	207	1%
Minimum Histogram Value	52	0.90	0.68	54	1%
Modified Covariance Matrix	52	0.91	0.69	20	1%

n: Number of observations

r: Correlation coefficient

a: Regression slope line

b: Intercept of the line

Table II: Regression analysis between ground truth and satellite data.