DEVELOPMENT OF AN ALGORITHM OF ABSOLUTE ATMOSPHERIC CORRECTION FOR MULTITEMPORAL SATELLITE IMAGES. APPLICATION TO THE REGION OF ORAN (WEST OF ALGERIA).

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ABSTRACT

This paper presents an algorithm for modelling of the different parameters which influence the reflectance at the satellite's level in order to estimate the reel reflectance of the objects at the ground surface. However, the model described would compensate the atmospheric effects, the irradiance and the observation conditions, and characterise the objects by their unique and reel values. Thus, the model developed makes directly two images comparable by the compute of the reel reflectance value of the objects from image's digital number. In this study, the algorithm has been tested and validated by using two images of Landsat TM (1984,1993) of the Oran's region (West of Algeria). The results on this paper show that, in the illuminated area as sea water, sand, vegetal covert, the difference between the two date's reflectance is nearly null. This, shows that these areas have been totally corrected by the algorithm. Except in the mountain's areas where the problem of shadow still exists and it has not been resolved. On the other hand, in the areas where the changes occurred (New road of Misserghine and the trails effected into the forest of M'sila), the reflectance is highly different between the two dates.

MOTS CLES : Modèle de correction atmosphérique, Reflectance, Eclairement, LANDSAT.

RESUME

Ce papier présente un algorithme pour la modélisation des différents paramètres qui influencent le reflectance au niveau du satellite afin d'estimer la reflectance réelle des objets à la surface du sol. Cependant, le modèle développé tend à compenser les effets atmosphériques, l'éclairement et les conditions d'observation, et caractériserait les objets par leur unique et réelle valeur. Ainsi, le modèle développé rend directement deux images comparables par le calcul de la valeur réelle de la reflectance des objets à partir du compte numérique de l'image. Dans cette étude, l'algorithme a été testé et validé en utilisant deux images de Landsat TM (1984,1993) de la région d'Oran (Ouest d'Algérie). Les résultats présentés sur ce papier montrent que, dans les zones éclairées comme l'eau de mer, sable, couvert végétal, le différence entre des reflectances des deux dates est presque nul. Cela, montre que ces zones ont été totalement rectifiées par l'algorithme. Excepté dans des zones de montagne où le problème d'ombre existe encore et il n'a pas été résolu. Par contre, dans les zones où les changements survenaient (Nouvelle route de Misserghine et les pistes opérés dans la forêt de M'sila), la reflectance est hautement différente entre les deux dates.

1 INTRODUCTION

The reflectance constitutes the characteristic value of an object which is the ratio of the reflected and incident energy and depends on the wavelength, object state and observation conditions (solar incident angle, view observation angle, and relative azimuth between the radiation and observation directions).

At the satellite, the measured values are, for each spectral band, the mean spectral radiance outside the atmosphere. So, from the image, we can calculate the radiance in the above of the atmosphere, and then, we deduced the reflectance by algorithms. However, this reflectance is not the same at the ground level because of the presence of the atmosphere. This atmosphere, spatially varied, makes differences in the path effected by the solar radiation. So, the sensor measures are very delicate to interpret due to the interaction of the radiation proprieties with the atmosphere through the double path sun earth and earth sensor.

So, the objective of this study is modelling the different parameters influencing the reflectance at the satellite in order to estimate the reel reflectance of the surface's object. This modelling, constituting on atmospheric correction, must in theory characterise an object by its unique value at the ground surface. In this research, the Landsat TM of the two years 1984 and 1993 are used to testify the atmospheric correction model and the spectral reflectance of four (04) data sets are compared between the two dates and the reel value of the reflectance given by laboratories reflectance measures.

2 METHODOLOGY

The model developed estimates the factor of absolute reflectance of the surface which is assumed lambertian and homogeneous. In the following sections, we describe the different mathematics expressions and equations which are used in the model.

First of all, the total irradiance at the ground level is described by the summation of the direct (Edr) and diffuse irradiance (Edf) and is given by :

$$Et = Edr + Edf \tag{1}$$

The direct illumination on a horizontal surface at the ground is described by :

$$Edr = Es.\mu s.Tdr(\vartheta s) \tag{2}$$

where μs is the cosines of the solar zenith angle, Es the solar constant irradiance outside the atmosphere and $Tdr(\vartheta s)$ is the direct transmission factor.

And respectively, the diffuse is given by:

$$Edf = Es.\mu s.Tdf(\vartheta s) \tag{3}$$

which $Tdf(\vartheta s)$ is the diffuse transmission factor.

Then, the total irradiance at the ground level become :

$$Et=Es.\mu s.T(\vartheta s) \tag{4}$$

where $T(\vartheta s)$ is the total transmission factor which represents the summation of the two transmission factors (direct and diffuse).

On the other hand, the atmospheric scattering is due to the interaction of photons with the molecules of the Rayleigh scattering and the aerosols of the Mie scattering. However, a percent of photons are transmitted into the direction of radiation at the ground, and this, defines the direct transmission factor:

$$tdr(\vartheta s) = Exp(-\tau/\mu s) \tag{5}$$

where τ is the optical thickness of the atmosphere. Also, the ground receive a diffuse irradiance which corresponds to the photons scattered by the atmosphere towards the ground. So, the percent of these photons defines the diffuse transmission factor noted $tdf(\vartheta s)$, and the total transmission factor is defined by :

$$T(\vartheta s) = tdr(\vartheta s) + tdf(\vartheta s) \tag{6}$$

The atmospheric upward direct transmission factor at view angle ϑv of observation is noted by :

$$tdr(\vartheta v) = Exp(-\tau/\mu v) \tag{7}$$

with μv is the cosines of the zenith observation angle and respectively, the total transmission factor at view angle ϑv is :

$$T(\vartheta v) = tdr(\vartheta v) + tdf(\vartheta v) \quad (8)$$

Thus, the total transmission factors $T(\vartheta s)$ and $T(\vartheta v)$, at view angle ϑs of radiation and respectively at view angle ϑv of observation, are given by the following analytic expressions :

$$T(\vartheta s) = \frac{1}{1 + \beta\tau / \mu s} \quad (9)$$

$$T(\vartheta v) = \frac{1}{1 + \beta\tau / \mu v} \quad (10)$$

where $b\tau$ is the retrodiffusion coefficient which corresponds to the percent of diffuse photons. It is noted by :

$$b\tau = br.\tau r + bp.\tau p \quad (11)$$

In the standard model of continental aerosol, br and bp equal respectively to 0.5 and 0.16. So, the absolute reflectance value of the target is estimated by:

$$\rho = \pi.Lsat - Latm/Et.tdr(\vartheta v) \quad (12)$$

and the spectral observed at the satellite for each digital number DN is given by :

$$Lsat = \frac{(L\max - L\min)}{255} + L\min \quad (13)$$

where Lmin, Lmax represent the spectral radiance for 0 and 255 DN, and Latm is the atmospheric diffuse radiance towards the sensor. It is given (J. Perbos, 1982) by the following analytic expression:

$$Latm = Es.\ \tau P(\xi) / 4.\pi.\mu v \quad (14)$$

which $\tau P(\xi)$ is the diffusion phase function. It represents the diffuse relative probability of photons defining the angle ξ with the incidence direction. This angle ξ is between the direction of observation and radiation and it is estimated (M. C. Rouquet, 1986) by :

$$\cos(\xi) = -\mu s.\mu v - sqrt(1-\mu s2).sqrt(1-\mu v2).\cos(\varphi) \quad (15)$$

and $$\tau P(\xi) = \tau r.Pr(\xi) + \tau pPp(\xi) \quad (16)$$

which φ is the summation of the two azimuth angles of radiation and observation.

with $$Pr(\xi) = 0.7552 + 0.7345.\cos(\xi) \quad (17)$$

where $Pp(\xi)$ is variable with the aerosol's type and it is estimated by interpolation between values calculated for four (04) wavelength (0.45µm,0.55µm,0.65µm and 0.85µm) and fifty (50) values of $\cos(\xi)$.

Also, the atmospheric optical thickness τ which is defined as the summation of Rayleigh and Mie optical thickness, is given by :

$$\tau = \tau r + \tau p \quad (18)$$

where τr and τp represent respectively the Rayleigh (index r) and Mie (index p) optical thickness.
Thus, the atmospheric expressions of these optical thickness are estimated (J. Perbos, 1982) and given by :

$$\tau r = (84.35.\lambda^{-4} -1.225.\lambda^{-5} + 1.4.\lambda^{-6}).10^{-4} \quad (19)$$

and

$$\tau p = 0.632.\lambda^{-1} - 0.0194.\lambda^{-2}).Exp(-V/15) \quad (20)$$

with V and λ are respectively the visibility in Km and the wavelength in µm.

2.1 Satellite Data Used

The study site is a 36 km by 27 km area located at the west of Oran in the Northwest of Algeria. The area contains a diversity of cover types including agricultural sites, sand, sea water, lake salty and the forest in the mountain terrain. The area is characterised by relief covering the forest and by horizontal surface in the most rest of the area. Two Landsat 5 Thematic Mapper images were used, scene 198/35 from April 07, 1984 and from March 15, 1993. The bands used are TM1(Blue), TM3 (Red) and TM4 (near IR), (Table 1).

Table 1. Data used for the Landsat 5 TM

	1984			1993		
	TM1	TM3	TM4	TM1	TM3	TM4
Lmin	0	0	0	-1.5	-1.2	-1.5
Lmax	153.6	205.5	207.7	152.1	204.3	206.8
Latm	19	5	3	17	5	3
V (Km)	40			23		
ϑs	39°.76			48°.75		
ϑv	8°.24			8°.22		
φs	129.78			134.21		
Es	2056.21			2084.24		

The values of Lmin and Lmax are given by SSC-Satellitebilt in Kiruna in ($w.m^{-2}.sr^{-1}.\mu m^{-1}$), and Esun is estimated from graph (Neckel and laboratory, 1984) in ($w.m^{-2}.\mu m^{-1}$). The values of Latm are calculated from Terravue software. The two images are used just to validate the method and for comparing the values of the absolute reflectance of the features.

3 RESULTS AND DISCUSSION

First, the optical thickness, transmission factors and irradiance are calculated for each canal and date (Table 2). The table 2 shows that the optical thickness estimated in 1984 for the canal TM1 is less little then in the 1993. This, is due to the value of visibility which indicates the presence of aerosols and molecules in the short wavelength.

Table 2. Atmospheric parameters (Irradiance in $W.m^{-2}.\mu m^{-1}$)

	1984			1993		
	TM1	TM3	TM4	TM1	TM3	TM4
τ	0.243	0.109	0.06	0.422	0.242	0.176
$tdf(\vartheta s)$	0.163	0.090	0.064	0.316	0.230	0.184
$tdr(\vartheta s)$	0.729	0.868	0.914	0.527	0.693	0.766
$Edf(\vartheta s)$	257.8	142.9	100.4	433.5	316.1	252.5
$Edr(\vartheta s)$	1151	1372	1445	724.5	951.7	1052

So, the diffuse irradiance in the TM1 of 1984 is less little then in the 1993, but, the direct irradiance is more greater then in the 1993. This, indicates that the image in 1984 is very illuminated then in 1993.

Secondly, in order to valid the method, we have taken four (04) data samples : sea water, sand, wheat and forest in the two images. However, for each image, we have calculated the absolute reflectance value which is extracted for each data samples (Table 3). We remark that the values in the two dates are very similar with a small error. Except in the forest sample where we see a small difference in the TM4 of 1.7%. So, this is due, may be, to the relief effects and also to the presence of trails which are due to the forest cutting done between the years. The difference of 3.4%, between to two dates in the wheat sample in the TM4, is due that the wheat is in maximum of chlorophyll's activities in April than in March.

Table 3. Mean values of the DN and reflectance (1984,1993)

	April 7, 1984		March 15, 1993		
Band	DN	ρ	DN	ρ	Difference (%)
Sea water					
TM1	64.24	0.056	54.07	0.058	0.3
TM3	12.56	0.016	12.42	0.017	0.1
TM4	6.99	0.012	7.77	0.011	0.1
Sand					
TM1	138.38	0.183	98.17	0.169	1.4
TM3	114.14	0.281	83.83	0.271	1.0
TM4	107.76	0.368	84.50	0.369	0.1
Wheat					
TM1	67.79	0.062	56.29	0.064	0.2
TM3	25.37	0.050	20.71	0.046	0.4
TM4	146.77	0.505	105.43	0.467	3.8
Forest					
TM1	69.68	0.062	54.31	0.060	0.2
TM3	27.41	0.047	21.16	0.048	0.1
TM4	50.04	0.198	44.19	0.181	1.7

In general, the values of absolute reflectance of the data samples, which are unchanged into the two dates, are very near and comparable to the reel value of absolute reflectance given by the laboratory measures.

Finally, this method has made the two images in the same referential in which the atmospheric effects are supposed removed. Then, by this treatment, we can do a Multitemporal study in which the changed area may be detected and estimated very easy. So, in our study, after having corrected the two images, we have detected a multiple changes which are made between the two dates and specially, the new road of Misserghine between Oran and Misserghine cities. Also, we have seen the changes made in the forest of M'sila by the presence of diverse trails effected into this forest.

4 CONCLUSION

The results have demonstrated that the proposed correction algorithm is successful in determination of the absolute reflectance values of the objects. But, it is very difficult to calculate the reel reflectance value of all objects and specially whom are influenced by both the slope, aspect, shadow effects and environments. So, in the next work, we will try to develop a method to take into account theses parameters in order to remove theirs effects for calculating and ameliorating the values of objects reflectance situated in the mountain area.

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