Estimating the Attenuation Coefficient for the River Nile Using High Spatial Satellite Images Reflectance’s

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ملخص البحث

بالرغم من ان هناك عدة عوامل تدخل في حسابات اعماق البحار والانهار والمحيطات عن طريق قيم الانعكاس الطيفي لوحدة التمثيل المكانيه للصوره الفضائيه تبقى قيمة معامل الاضعاف الضوئي من اهم تلك العوامل ويرجع ذلك الى ان كل العوامل الاخرى لها قيمه واحده ثابته في منطقة الدراسه بعكس قيمة الاضعاف الضوئي ولذلك كان اهتمامنا بحساب تلك القيمه لنهر النيل وهو محور دراستنا ولان قيمة الاضعاف الضوئي تختلف باختلاف عكارة المياه ونسبة تركز الطحالب بها .ونظرا لعدم تجانس مياه نهر النيل فقد اعتمدنا فى حساب قيمة الاضعاف الضوئي على خصائص طبيعة مياه نهر النيل والتي تحقق لنا التنوع الطبيعي لقيم معامل الاضعاف الضوئي فمن الطبيعي ان يكون قيمة معامل الاضعاف الضوئي في المناطق الضحله يختلف منه عن قيمة الاضعاف الضوئي للمناطق العميقه وكلاهما يخنلف عن المناطق الصافيه والتي تقل بها نسبة الطحالب وتنخفض بها نسبة العكاره وقد استخدمنا في دراستنا مرئية فضائيه من المستشعر (geo-eye) والذي يحقق قيمة تمثيل مكانيه 1.65 m وتغطي المرئية مسافه تقدر بحوالي 15 كم من نهر النيل واستخدمنا كذلك النماذج الرياضيه المناسبه لحساب الاعماق بالاعتماد على معامل قيمة الاضعاف الضوئي لكل من الضوء الازرق والاخضر لكل منطقه كما استخدمنا اجهزه قياس الأعماق لرصد اعماق النهر لمقارنتها بالاعماق المحسوبه.

فى هذا البحث تم استخدام قيم الانعكاس الطيفى المحسوبة من تقنية الاستشعار عن بعد والاعماق المرصودة بالايكو ساوندر لحساب معامل الاضعاف الضوئى لنهر النيل و ذلك باستخدام النموذج الرياضى الخاص بمعامل الاضعاف الضوئى.

Abstract

Although there are lots of parameters affect on computing the depths of the sea, rivers and oceans by the reflectance value from the satellite image. The attenuation coefficient is still the most important parameter, because all other parameters have same value in the study area in opposite to the attenuation coefficient. This value was computed for the river Nile, which is our focus of this study. The attenuation coefficient changes by changing the amount of water impurities and the concentration of the algae in it. Due to heterogeneity of water of the river Nile, so while calculating the attenuation coefficient, we depend on the natural properties of the river Nile which check the natural diversity for the values of the attenuation coefficient. It is usual that the attenuation coefficient in the shallow water changes from that in deep water and both change from pure water, where the algae is found in very small

amount and decreases in it the amount of impurities. We used in our study satellite image from (geo-eye) with resolution 1.65m. The image covers 15 Km from the river Nile, also we used the mathematical model for computing the depths by depending on the attenuation coefficient value for both the blue and the green band for each study area. Also we used the echo sounder for measuring the depths and comparing them with the computed depths. In this research, we used the remote sensing technique reflectance's values for geo-eye satellite sensor for estimating the attenuation coefficient of the river Nile, by using the water attenuation mathematical model through the observed field depths by echo sounder instrument as reference. The estimated depths were obtained with a relatively low difference versus the traditional depths.

Introduction

The aim of the study was to derive multispectral attenuation coefficient directly from remote sensing reflectance. Then calculating the depths from these derived attenuation coefficient, using the Geo-eye satellite data. The diffuse attenuation coefficient Kd(λ) is an important water property related to light penetration and availability in aquatic systems. The diffuse attenuation coefficient is also an indicator of water clarity and water quality. Accurate estimation of the diffuse attenuation coefficient is critical to estimate accurate depths. The goal of this research was to examine the light penetration of river Nile, based on situ measurements. Kd(λ) depends on both the composition of the medium and directional structure of the ambient light field, hence it is classified as an apparent optical property of the water. Nevertheless, experience has shown that *Kd*(λ) values are largely determined by the inherent optical properties of the aquatic medium and are not altered significantly by changes in the incident radiation field such as a change in solar elevation. *Kd*(λ) is strongly correlated with optically active substances in water (suspended sediment, and chlorophyll concentration), thus it provides a relationship between biology and optics. Researches on remote sensing of attenuation coefficient *Kd*(λ) focused on modeling diffuse attenuation coefficient from relationship between the blue-green normalized water-leaving radiance ratio and these two bands are used to estimate the diffuse attenuation ratio $k(\lambda_g)/k(\lambda_b)$ for the river Nile over two different types of water at shallow water and in deep water. Therefore this study went on to estimate spectral attenuation coefficient based on the inverse relationship between *Kd*(λ) and Reflectance ρ_3 using geo-eye data, and the depths observed by echo sounder. This is may be the first time that the remote sensing bathymetric technique using reflectance values to estimate the depths of the river Nile in Egypt.

Previous work

The diffuse attenuation coefficient of water around Roatan Island, Honduras for the blue, green and red portion of the spectrum showed *Kd*(λ) value of 0.138, 0.158, and 0.503 m− 1 respectively. Error analysis revealed a significantly high uncertainty in the red region (600–700 nm) and, as expected, low estimation uncertainty in blue and green. By using IKONOS satellite sensor, it can penetrate up to 8 m in the blue band, 6 m in green, and 2 m in the red region.

The developed algorithm for attenuation coefficient of *Kd*(490) for the west and east coast of India was applied to IRS-P4 OCM satellite data. The OCM data were processed to estimate normalized water leaving radiance in 443nm and 555 nm band, a good correlation between measured and modeled values were obtained with a correlation coefficient r^2= 0.80 with RMS 0.011m.

Research on water attenuation coefficient was carried on by the use of HR2000 fiber optic spectrometer which, discovers that the attenuation coefficient at different depths has good spectral features. There are two peaks near the 700nm and 800nm. As the depths increase, the peak near 800nm diminishes. At first the attenuation coefficient reduces progressively, and then it tends to have uniformity variations. The *Kd*(490) at 555nm has the highest correlation with the remote sensing reflectance, which contributes to the inversion of *Kd*(490) by using the band combination of ρ_s (555) and ρ_s (490). Besides that, the diffuse attenuation coefficient of each band has a very good linear relationship, the diffuse attenuation coefficient of any band can be calculated through a known one, which can greatly increase the accuracy when use the principle component analysis in color inversion.

Study area

The study region is located in Qenna, which is nearly 600 Km south from Cairo. This region is ranged from 32°33'34.27" to 32°36'51.42" E longitude and from 25°21'12.01" to 25°14'22.32" N latitude. The study area is a part from the river Nile, which crosses Egypt from south to north. In this area the width of the river Nile is large and this increases the efficiency of the study. Also it is at the beginning of the river Nile in Egypt, so the water is free from the sediments or factory wastes. It has different depths and these depths range between 1m at banks and 20 m at middle.

Data

Multi-spectral image of (geo-eye) with resolution 1.65m for multispectral bands and 0.46m for panchromatic band was used for this study. The image has Columns: 16460 pixels, Rows: 29568 pixels. It was taken at 08:40 local time of July 10, 2009 as shown in fig (1). Image data was used for deriving diffuse attenuation coefficient $Kd(\lambda)$. An atmospheric correction scheme was used for retrieving water leaving radiances in blue and green channels of 412, 443, 490 and 550 nm. The depth data during this project was collected using single-beam echo sounder (Batty 500 MF) to measure water depth, and GPS to determine the position. The depth and position data were recorded and processed on a laptop computer using HYPACK hydrographic survey software as shown in table(1), some of these validation data are used in the calculations and the other are used for validation. The traditional data is shown in figure (2).

Figure (1): Geo-eye Satellite Image of the study area.

Figure (2): Geo-eye Satellite Image & Traditional data

Table (1): Traditional technique Observations by using GPS and Echo Sounder.

Position by GPS		Traditional Depth by echo-sounder(m)
Easting(m)	Northing(m)	
455374.14	2801145.05	-15.76
455372.71	2801146.19	-15.64
455368.91	2801149.22	-14.27
455377.46	2801142.41	-14.02
455365.59	2801151.86	-13.81
455378.41	2801141.65	-13.35
455362.26	2801154.51	-13.14
455499.39	2800791.78	-12.95
455493.47	2800796.51	-12.95

Methodology

The aim of this research is to confirm the possibility of computing the diffuse attenuation ratio $k(\lambda_g)/k(\lambda_b)$ of the river Nile in different regions, on different bathymetric depths, as a function in reflectance value of the green and the blue band of the used image. In the research, GPS points were used to rectify the image. The mathematical model used in this application is a function in the reflectance value and not a function in the pixel value. This method started with converting the image from DN_s(Digital Numbers) to radiances (L) from equation (1).

$$L = G * DN + B \quad (1)$$

Where,

DN: Digital Number value recorded.

G: slope of response function (channel gain), get it from metadata file.

L: measured spectral radiance (over the spectral bandwidth of the channel).

B: intercept of response function (channel offset) get it from metadata file.

then these radiances were corrected from the effective errors such as, sun glint and atmospheric errors (L_λ).

River Nile reflectance's values were computed from corrected radiance values as follow (Martin Taylor 2005):

$$\rho_s = \frac{\pi .\ L\lambda .\ d^2}{Esun\lambda\ .\ \cos\theta s} \quad (2)$$

where,

ρ_s = Unitless planetary reflectance,

L_λ = Corrected Radiance for spectral band λ at the sensor's aperture ($W/m^2/\mu m/sr$).

d = Earth-Sun distance in astronomical units equal (0.98321) at study area.

$ESUN_\lambda$ = Mean solar exoatmospheric irradiances its equal (830) ($W/m^2/\mu m$) at study area.

θ_S = Solar zenith angle, it was 17.36476 degree.

By using water attenuation model, the depth is obtained as follow:

The diffuse attenuation ratio $k(\lambda_g)/k(\lambda_b)$ has been estimated with different Regions Of Interest (ROI), on different bathymetric lines at shallow and deep waters. The water attenuation is also assumed to be homogenous. The water attenuation model is given by(Audrey Minghelli-Roman, Laurent Polidori, Sandrine Mathieu-Blanc, Lionel Loubersac, and François Cauneau 2007)

$$Z = a \left\{ \left\{ \ln[\rho s(\lambda b) - \rho w(\lambda b)] + \frac{k(\lambda g)}{k(\lambda b))} \ln[\rho s(\lambda g) - \rho w(\lambda g)] \right\} + b \right. \quad \mathbf{(3)}$$

$$\frac{k(\lambda g)}{k(\lambda b))} = [(Z - b) - \ln[\rho s(\lambda b) - \rho w(\lambda b)]] / [a \ln[\rho s(\lambda g) - \rho w(\lambda g)] \quad \mathbf{(4)}$$

where ps (λb) is the reflectance in blue band, ps(λg) is the reflectance in green band.

Our study area has more than six thousand known depth points to be considered as reference points by two different methods. First one depends on selected data for shallow area. The second one depends on selected data for deep area. In case of shallow area, reference points with known depths were chosen as shown in figure (3). Almost this area is close to the Nile banks, which is full of obstacles such as chlorophyll algae, mud and algae. The depths and the reflectance values were used to compute the attenuation coefficient. As mentioned before, the computing of diffuse attenuation ratio $k(\lambda_g)/k(\lambda_b)$ for the river Nile was done for wavelengths 412,443, 490 and 550 nm. The coefficients (a , b) are to best fit the formula from. The value of (a, b, $k(\lambda_g)/k(\lambda_b)$) are computed by using the values of the echo sounder depths through equation (4). Another depths were used to validate the obtained attenuation coefficient in shallow water as shown in table (2). This table confirmed on the accuracy of ($k(\lambda_g)/k(\lambda_b)$) in computing the depths. It was found that the depths obtained by ($k(\lambda_g)/k(\lambda_b)$) were near to the values computed by echo sounder for the shallow water. The standard deviation for the reference depths was 0.70, for the computed depths was 1.60m and the attenuation coefficient was 1.17974. In case of deep area reference points were chosen with very large depths as shown in figure (4). These points represent the navigational route of the river Nile, this area is clear. The obtained attenuation coefficient is used to compute another depths with unknown value, then we found these depth were identical to those measured by echo sounders as shown in table (3), and this table confirmed on the accuracy of ($k(\lambda_g)/k(\lambda_b)$)) in computing the depths. it was found that the values computed by ($k(\lambda_g)/k(\lambda_b)$)) were close to the values computed by echo sounder for deep area. The standard deviation for the reference depth was 0.18m, for the estimated depth was 0.33m and the attenuation coefficient was -1.16001.

Figure (3): reference points in shallow area.

Figure (4): reference points in deep area

Table (2): estimated depths versus actual depths of shallow water.

DGP Position		Observed depth(m)	Estimated Depth(m)	Difference(m)
Easting(m)	Northing(m)			
455328.83	2802632.16	1.04	1.16	-0.12
455040.50	2802991.85	1.04	1.28	-0.24
455004.76	2803169.05	1.13	1.69	-0.56
455003.68	2803172.41	1.16	1.61	-0.45
455010.10	2803186.63	1.16	0.96	0.20
455042.17	2802989.78	1.19	0.69	0.50
455329.92	2802630.81	1.22	1.84	-0.62
455004.54	2803178.66	1.22	1.04	0.18
455055.52	2802973.20	1.28	1.04	0.24
455043.28	2802988.40	1.28	0.88	0.40
455005.43	2803180.58	1.28	1.08	0.20
455054.40	2802974.59	1.34	0.84	0.50
455052.74	2802976.65	1.34	1.04	0.30
455007.84	2803184.15	1.37	1.00	0.37
455329.55	2802631.26	1.4	1.64	0.24
455056.07	2802972.51	1.4	1.04	0.36
455007.06	2803165.80	1.4	1.12	0.28
455042.73	2802989.09	1.43	0.69	0.74
455329.19	2802631.71	1.46	1.64	-0.18
455039.39	2802993.23	1.46	0.77	0.69
455012.16	2803162.07	1.46	1.16	0.30
455003.65	2803173.46	1.49	1.65	-0.16
455174.92	2802021.37	1.52	0.73	0.79
455058.86	2802969.06	1.55	1.16	0.39
455004.25	2803177.63	1.55	1.37	0.18
455174.72	2802025.13	1.62	0.88	0.74
455053.85	2802975.27	1.62	1.04	0.58
455057.74	2802970.44	1.68	0.69	0.99
455056.63	2802971.82	1.68	1.36	0.32

Table (3): estimated depths versus actual depths of deep water

DGPS Position Easting(m)	Northing(m)	Estimated Depth(M)	Observed Depth(m)	Difference(m)
455371.76	2801146.95	14.49	15.24	0.75
455371.29	2801147.32	14.49	14.97	0.48
455370.81	2801147.70	14.49	14.81	0.32
455368.91	2801149.22	11.47	14.27	2.80
455376.99	2801142.78	16.05	14.23	1.82
455377.46	2801142.41	16.05	14.02	2.03
455366.06	2801151.48	11.47	13.90	2.43
455365.59	2801151.86	11.47	13.81	2.34
455365.11	2801152.24	11.47	13.78	2.31
455377.94	2801142.03	16.05	13.72	2.33
455378.41	2801141.65	11.47	13.35	2.88
455496.43	2800794.14	10.42	13.20	2.78
455494.58	2800795.62	13.17	13.20	0.03
455494.21	2800795.92	13.17	13.17	0.00
455494.95	2800795.33	13.17	13.14	0.03
455496.06	2800794.44	10.42	13.11	2.69
455495.32	2800795.03	13.17	13.08	0.09
455493.84	2800796.21	13.17	13.08	0.09
455495.69	2800794.73	10.42	13.05	2.63
455361.78	2801154.89	12.64	13.05	0.41
455361.31	2801155.27	12.64	12.98	0.34
455499.39	2800791.78	13.17	12.95	0.22
455498.65	2800792.37	13.17	12.95	0.22
455496.80	2800793.85	13.17	12.95	0.22
455493.47	2800796.51	13.17	12.95	0.22
455499.02	2800792.07	13.17	12.92	0.25
455497.91	2800792.96	13.17	12.89	0.28
455497.17	2800793.55	13.17	12.89	0.28
455497.54	2800793.26	13.17	12.86	0.31
455378.88	2801141.27	11.47	12.86	1.39
455360.83	2801155.65	12.64	12.80	0.16
455450.90	2800830.48	11.47	12.77	1.30

Conclusions and Recommendations

We want to refer to mention that not echo sounder points were used as reference points for computing the depths by remote sensing technique, due to the presence of barriers in the aquatic media which hinder the access of the sent wave by echo sounder or hinder its rebound. Therefore, we didn't depend on a single value, but set of values were taken and calculate for them the standard deviation and choose the best of them. So it was logically to increase the proportion of false values calculated from the remote sensing technique, due to the increased effects and obstacles, but the research proved that we can depend on that method at least in specifying the navigational path of the River Nile.

With reference to equation (2), we succeeded in reaching the specific not approximated values of the required parameters or values deduced from tables or calculated from special web sites to compute the values of (sun radiation, the distance between the earth and the sun in the day of computing) for reaching the corrected values of the reflectance.

This research shows that Multi-spectral image of (geo-eye) can be used for estimating the diffuse attenuation ratio $k(\lambda_g)/k(\lambda_b)$ for the river Nile, and the table confirmed on the accuracy of $(k(\lambda_g)/k(\lambda_b))$ in computing the depths, except in shallow areas which is very close to the banks of the river as a result of the presence of impurities or algae and for turbid waters. This method gives more accurate results on a large area with clear and homogeneous water and in deep area. It requires at minimum two known depths to train the model. The degree of success was proven largely depending on the comparability of images in terms of spatial and spectral resolutions. The (geo-eye) used in this study are compatible in spectral resolution for computing the bathymetric depths.

Further work is also needed for seasonal and long term monitoring of diffuse attenuation in the river Nile.

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