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Predicting Water Depth of Lake Using Remote Sensing image

Mohammed I. Abd-Almajied*

Department of Astronomy and Space, Collage of Science, University of Baghdad, Baghdad, Iraq.

Abstract:

One of the most important of satellite image is studying the surface water according of its distribution and depth. In this work, three images have been taken for Baghdad and surrounding for year (1991, 1999 and 2014) and by using of envi program has been used. Different classes have been evaluated for Al-Habania and Al-Razaza River according to its depth and water reflectance. In the present work four types of water depth (very shallow, shallow, moderate, and deep area) have been detected.

Keywords: Water depth, Satellite Image, Remote Sensing

تخمين عمق المياه باستخدام الصور الفضائيه

محمد اسماعيل عبد المجيد*

قسم الفلك والفضاء، كلية العلوم، جامعة بغداد، بغداد، العراق.

الخلاصه:

تكمن اهمية الصور الفضائية في دراسة المياه السطحية لمعرفة خواصها من حيث التوزيع والأعماق. في هذا العمل تم اخذ صورتين لمنطقة بغداد ومحيطها للسنوات (١٩٩١، ١٩٩٩ و ٢٠١٤) وباستخدام برنامج envi. وقد تم الحصول على مناطق مختلفة لسطح المياه لبحيره الحبانيه والرزازه اعتمادا على الاعماق وانعكاسات المياه حيث تم الحصول على اربع مناطق (جدا ضحله، ضحله، متوسطه، وعميقه) في هذا العمل.

Introduction:

Remote sensing offers an effective way to predict water properties and mapping water due to its appearance distribution. This can be done by obtaining the reflectance measurements in two or more wavelengths and can be used to analyze specific characteristics of water. To chief good and successful analyzing, one must understand the structures and reflectance properties. On important application of remote sensing is studying and mapping of water level in lake in the present work.

Water depth can be measured either directly or with remote sensing techniques in different ways. Past, soundings where carried out with tied to a line, but for almost a century, echo sounders have been established. In the last decades, the arrival of multi ray of light echo sounders has growth the

*Email:moh81ismail@yahoo.com

efficiency, accuracy and spatial resolution of coastal and ocean mapping immensely. In spite of that, to date only about 10% of the World ocean is mapped with echo sounders, generally along the coasts and within the uncommon economic zones (EEZ) of coastal states. Before the arrival of multi ray of light echo sounders, water depth mapping was got done with single beam echo sounders. In the 1960s and 1970s echo sounders were used by mounted on merchant ships during their intercontinental journeys, passing many unexplored areas that have never been mapped again. Even when considering both single [1].

Single ray of light and multi ray of light soundings, many areas stay blank on water depth maps. Vogt et al. calculated that about 40 years of continuous mapping working with all available survey vessels would be needed to fully map the World ocean below the 500m isobath (line of constant depth) [1].

2 Theory:

Determining the water depth using remote sensing is depending on the absorption of electromagnetic waves in the water upright depth. Aircraft laser scanning with LiDAR (Light Detection and Ranging) devices to measure water depth has a penetration of about three times the Secchi depth, corresponding to less than 100m in sea water even under ideal circumstances. LiDAR is therefore restricted to shallow coastal areas, where it can be worked very efficiently—and where the use of even modern multi ray of light echo sounders is particularly laborious [1][2].

A satellite altimeter mission special worked for water depth mapping is simpler and cheaper than one intended to observed ocean currents, tides, or climate. It also yields information about Earth's gravity field that is independently useful for resource exploration and for to make up for the errors in inertial navigation systems [3].

A recently satellite altimeter mission, confident to map the deep ocean water depth and gravity field, will achieve a resolution threshold that is critical for both basic science and practical applications, including [4]:

- Defining the effects of water depth and seafloor roughness on ocean circulation and mixing, climate, and biological communities, habitats, and mobility.
- Improving tsunami hazard forecast accuracy by mapping the fine-scale topography that steers
  tsunami wave energy.
- Knowing the geologic processes responsible for ocean floor characteristics unexplained by
  simple plate tectonics, such as abyssal hills, seamounts, microplates, and propagating rifts.
- Mapping the marine gravity field to cause to inertial navigation and allow to see the subseafloor structure of continental margins for both geologic research and offshore resource exploration.
- Giving water depth maps for numerous other practical applications, including planning submarine cable and pipeline routes, causing to tide models, and explaining international boundaries on territorial claims to the seabed under the United Nations Convention on the Law of the Sea.

2.1 Registration:

Image registration is a process of arranging two images acquired by same/different sensors, at different times or from different look at on a straight line. To register images, we need to define geometric transformation that aligns images with regard to the reference image. The most common transformations are rigid, affine, projective, perspective and global [5].
Image registration essentially is made up of following steps [6]:

- Feature detection: Salient and distinguishing objects (closed-boundary regions, edges, contours, line intersections, corners, etc) in both reference and observed images are detected.
- Feature matching: The similarity between the features in the reference and observed image set up.
- Transform model estimation: The type and parameters of the so-called mapping functions, arranging on the straight line the observed image with the reference image, are calculated.
- Image resampling and transformation: The observed image is transformed by purpose of the mapping functions.

2.2 Atmospheric Correction:

A better landsat images, a reduction in between image variability can be obtained through normalization for solar irradiance by converting the spectral radiance to exoatmospheric reflectance. The benefit of using reflectance is the cosine effect of different solar zenith angles due to the time difference between data acquisitions can be removed, and it compensate for different values of the exatmospheric solar irradiance arising from spectral band difference. The joined surface and atmospheric reflectance is computed as follow [7]:

$$P_\lambda = \frac{\pi L_\lambda d^2}{ESUN_\lambda \sin\theta} \qquad (1)$$

Where:

L_λ = Radiance in units of W/(m^2 * sr * μm)

d = Earth-sun distance, in astronomical units.

$ESUN_\lambda$ = Solar irradiance in units of W/(m^2 * μm)

θ = Sun elevation in degrees

2.4 Water Depth:

The spectral absorptivity differ spectrally form band to band. The reflected irradiance decreases faster in the high absorptivity spectral band as the depth column increase than in the low absorptivity band. The equation that describes this theory is [8]:

$$Z = m_1 \frac{\ln(nR_w(\lambda_i))}{\ln(nR_w(\lambda_j))} - m_0 \qquad (2)$$

Where:

$R_w(\lambda_i)$ and $R_w(\lambda_j)$ = the atmospheric corrected pixel value for bands i and j.

m_1 = a tunable constant to scale.

n = a fixed constant, chiefly for ensuring positive value after the log transform and a linear response between the ratio and the depth.

m_0 = an offset value when Z=0.

Study area:

In the present work, three images have been selected for Baghdad and surrounding for period (November 1991, 1999, and 2014) with the following specification (path and raw (169, 37), or latitude and longitude $(33^o 10'55'', 43^o 29'53'')$, with resolution of 30 meter for landsat 4-5 tm, landsat 7 and landsat 8 oli respectively, for band 1, 2, 3, 4, as in the figure-1, figure-2, and figure-3.

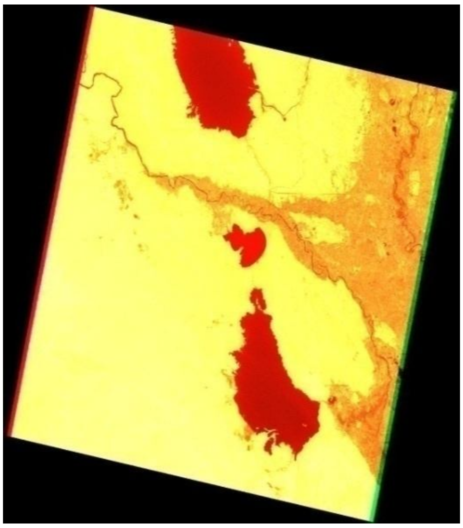

Figure 1- Image of 1991

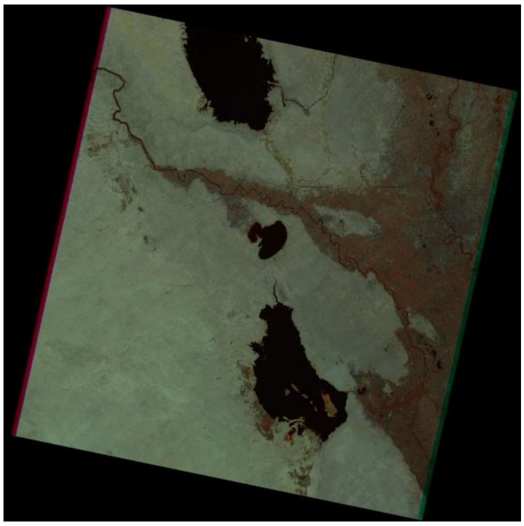

Figure 2- Image of 1999

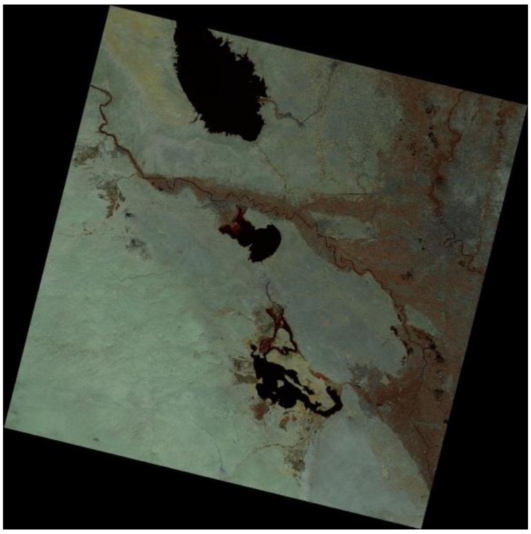

Figure 3- Image of 2014

Steps of the Work:

To use the images and make them more suitable and analyzing several steps should be made. As:

1. Radiometric calibration to calibrate data to reflectance and obtain a clear image by using equation [1].
2. Rotate these images to the same orientation so as to obtain same alignment. A sampling by cubic convolution and an angle (-13) counter clockwise have been done.
3. Subset three images to the same size to get identical of the same scene.
4. Image registrations have been done to make the three images in the same alignment using image to image method.
5. A vector layer has been selected so as to create a binary mask for the selected area which is the Al-Habania lake and Al-Razaza lake with the same area for three images.
6. Atmospheric correction has been made so as to eliminate any artifacts that present in these images as result from atmosphere by using internal average relative reflectance method.
7. Applying the water depth (by calculating the water reflectance and depth with independent of material brightness) and the result of this step is extracting the land and remains water and all water area as seen in figure -4 to figure-9.

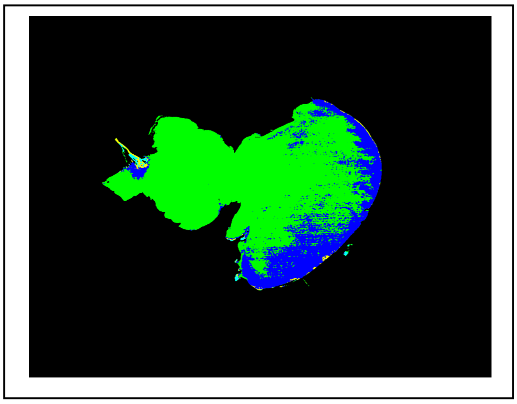

Figure 4- Image of Al-Habania Lake 1991

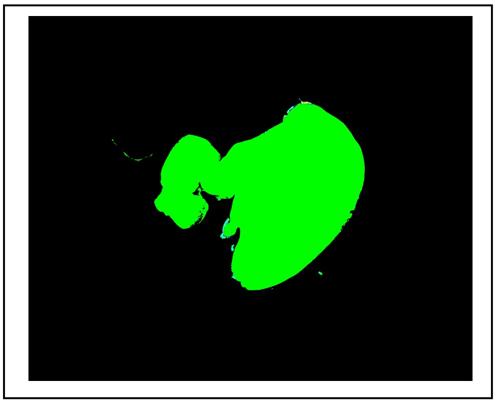

Figure 5- Image of Al-Habania Lake 1999

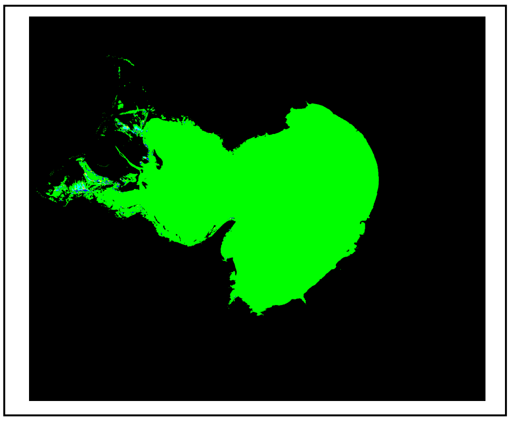

Figure 6- Image of Al-Habania Lake 2014

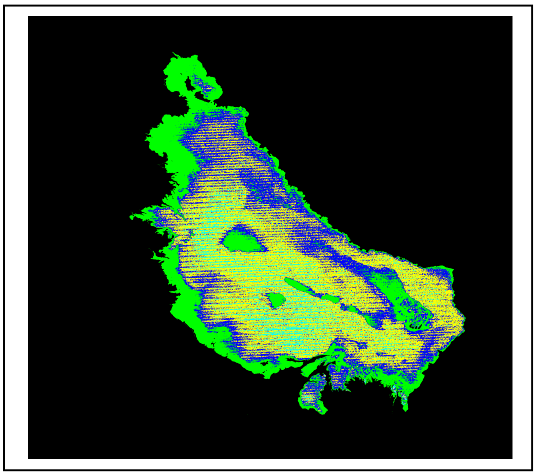

Figure 7- Image of Al- Razaza Lake 1991

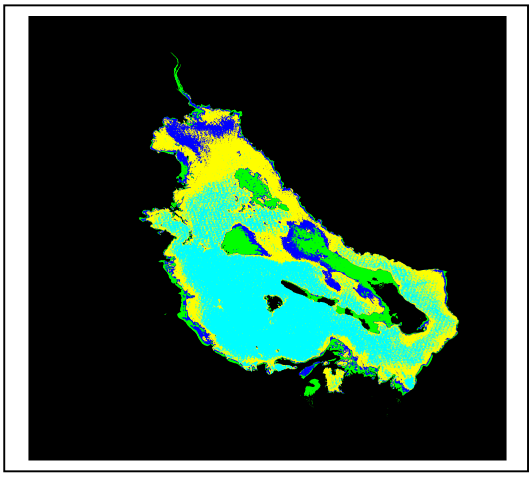

Figure 8- Image of Al- Razaza Lake 1999

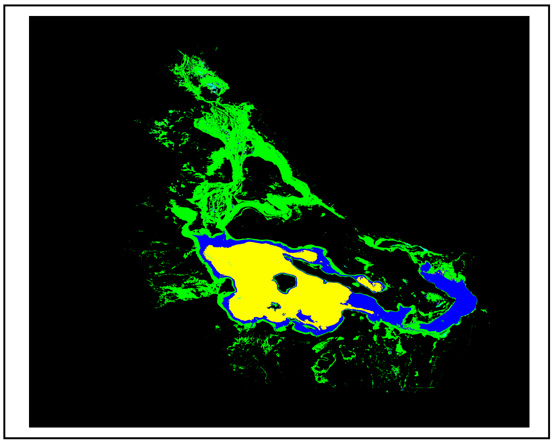

Figure 9- Image of Al- Razaza Lake 2014

8. The final result of area and number of pixel of water depths are divided in several classes according to the depth of water as shown in table (1) and table (2).

Table 1- Statistics of Al-Habania Lake

Depth of Water	Class Color	Statistics of Year 1991		Statistics of Year 1999		Statistics of Year 2014		Estimated Depth [9]
		Area (m^2)	Number of Pixel	Area (m^2)	Number of Pixel	Area (m^2)	Number of Pixel	(m)
Very Shallow		170422200	189358	178265700	198073	246420000	273800	> 3
Shallow		47493900	52771	280800	312	984600	1094	3 - 20
Moderate		1608300	1787	247500	275	486000	540	20 - 50
Deep		993600	1104	512100	569	820800	912	< 50

Table 2- Statistics of Al- Razaza Lake

Depth of Water	Class Color	Statistics of Year 1991		Statistics of Year 1999		Statistics of Year 2014		Estimated Depth [9]
		Area (m^2)	Number of Pixel	Area (m^2)	Number of Pixel	Area (m^2)	Number of Pixel	(m)
Very Shallow		399708000	444120	172237500	191375	399476700	443863	> 3
Shallow		394981200	438868	145876500	162085	141770700	157523	3 - 20
Moderate		598682700	665203	441034200	490038	220259700	244733	20 - 50
Deep		141051600	156724	554757300	616397	3376800	3752	< 50

Results and Discussion:

In the present work several points have been noticed. The water surfaces are divided into several classes according to depth and components and this point is very important to identify the water surface. For the selected cased which shown in the table 1 and table 2 are found that:

1- The area of water is differing over the 23 years.

2- The level of water of Al-Habaina lake is decreasing in the year 1999 because of the decreasing rain level and also the water level of Al-Forat River that convert part of it when it has overflow as see in table 1.

3- In year 2014 the level of Al-Habania lake has partial increased because channel that feed Al-Razaza lake has been closed.

4- The level of Al-Razaza lake has get low dramatically because of the effect of climate and channel that feed it form Al-Habania lake is close and increase eyes of slat in it as shown in table (2).

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