BATHYMETRY MAPPING FROM SATELLITE IMAGES FOR LY SON ISLAND, QUANG NGAI PROVINCE

Le Nhu Nga, Nguyen Thi Kim Nga

Institute of Mechanics

ABSTRACT. Up to present, in Vietnam, the traditional methods used to map marine bathymetry are still very popular. These techniques have advantages of giving a high accuracy but still show big disadvantages of taking too much time for the data acquisition and processing and of being very expensive for the field works. Compensated to these cons the remote sensing technique seems to be an ideal solution since the images covers almost places on the earth with very high frequency (hours) of acquisition and served with a reasonable price even some of them can be downloaded from the internet for free of charge.

In this paper, LANDSAT-7 (ETM+) optical-multispectral image, a space-born sensor, of Ly Son Island area, Quang Ngai Province where the water is relatively clear was used, some state-of-the-art methods of bathymetry mapping from optical-multispectral satellite images were reviewed and tested, the data from marine chart was used for the model calibration and quality assessment, and the discussion on the potential of these data sources for mapping coastal areas of Vietnam was also conducted.

1. Introduction

The bathymetry is a branch of the oceanography that deals with the measurement of the depths of the sea and studies its configuration and evolution over time. It is an important data for activities on marine and coastal areas such as engineering, navigation, researches, management and for hydro-dynamical applications as input data.

In Vietnam, the echo-sounding technique with sonar equipment mounted on a ship or boat has been being applied mostly for the bathymetry mapping (Dang, 1998). In the world, the remote sensing technique has been being used for decades (IfM HH. 2005; Green et al., 2000) from different sensors such as optical, RADAR and LIDAR. RADAR was used for global and regional scale while optical and LIDAR were used for smaller area scale and for more detail and accuracy requirements. To coastal areas, for a high accuracy data requirement, the Air-born Laser Bathymetry (ALB), LIDAR, is the most favorite one. But this is a very costly data source. So, optical satellite images such as SPOT, LANDSAT, Ikonos, QuickBird become very interested to researchers now a day to find a low-cost mapping tool. These are the reasons this paper focused on applying optical satellite images to estimate the water depth and to look at the potential of this technique as a good mapping tool for coastal areas of Vietnam.

The LANDSAT-7 (ETM+) image and the marine chart of the Ly Son Island was selected for the study because (i) the water of the area is relatively clear, (ii) the image was available to be downloaded from the internet, and (iii) the marine chart was available with a reasonable price compared with unaffordable field work for the study.

2. Study area

Ly Son Island, Quang Ngai Province is located at the central of Vietnam and far enough, about thirty kilometers, from the coastline to prevent much turbidity influenced by sedimentation from the rivers and from the onshore waves. The area has relatively clear water and stable and homogenous bottom property.

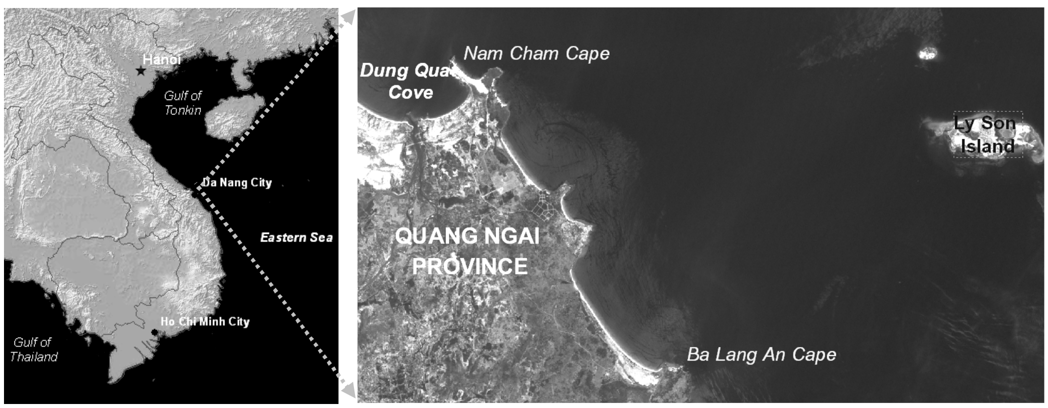

Figure 1. The study area of Ly Son Island and its location in Vietnam

3. Bathymetry mapping concept

This paper accepts the fundamental principle behind using remote sensing to map bathymetry is that different wavelengths of light will penetrate water to varying degrees. Intensity of the sun light I_d will be attenuated by interaction with the water column when passing through water length p as following:

$$I_d = I_0 e^{-pk}, \tag{1}$$

where $I_0 -$ intensity of the incident light and $k -$ attenuation coefficient (Green et al., 2000).

The longer wave length of light has a higher attenuation coefficient than shorter ones. Therefore, the blue light can penetrate much deeper in the water than the red. For clear water, the blue light can penetrate 30m deep, but red and near-infrared can penetrate 5m and 0.5m only, respectively (Green et al., 2000). Fig. 3 illustrates this idea. Therefore, on the same band, the higher DN (digital number, value of each pixel of the image) value a pixel has the deeper water column is.

The intensity of light can be quickly attenuated by interaction with suspended materials such as sediments, phytoplankton and dissolved organic compounds. The depth of attenuation of the blue light can be sub-meters only in turbidity water areas (Green et al., 2000).

Currently, there are several methods studied to map bathymetry from the optical-multispectral satellite images. To this study area, three most popular methods: Benny and Dawson, 1983; Jupp, 1988; and Lyzenga, 1978 (Green et al., 2000) were used to test.

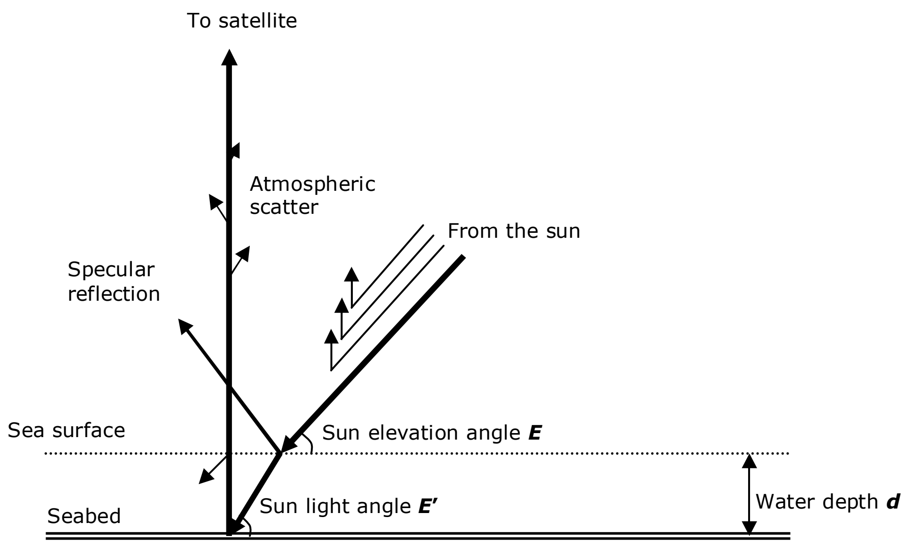

Figure 2. Path of light from the sun to satellite (Benny, A.H, and Dawson, G.J., 1983)

Benny and Dawson (1983), and Jupp (1988) methods assumed that (i) light attenuation is an exponential function of depth (equation 1); (ii) water quality (attenuation coefficient) does not vary within an image; (iii) the color of the substrate/seabed (reflective properties) is constant. Lyzenga (1978) method, like two above methods, accepted the first two assumptions but did not the third one (Green et al., 2000).

The second and third assumptions are weakness of these methods because a satellite image normally covers a very large area and the water and sea-bed properties vary, in some cases, very much.

4. Data sources and data processing

4.1. Satellite image

The LANDSAT-7 (ETM+) image (path 124, row 49) covering the area of Quang Nam and Quang Ngai provinces was captured on 9^h56 AM (Vietnam's local time, GMT+7), July 13 2001. The image was downloaded for free of charge on the website of the Earth Science Data Interface (http://glcfapp.umiacs.umd.edu/). The image consists of six bands (1-blue, 2-green, 3-red, 4-near infrared, 5-infrared, and 6- thermal infrared) and has a 30m of spatial resolution. The quality of the image is quite good with less noisy and less cloudy.

The study area was clipped out from the image with a dimension of 387 columns and 239 rows (11.61×7.17km respectively). Then, the clipped image was enhanced for visual interpretation and corrected geometry by using the marine chart.

The band 1, 2, 3 were used for the bathymetry estimation while band 4 used for coastline extraction because the light could only penetrate few centimeters only on this band.

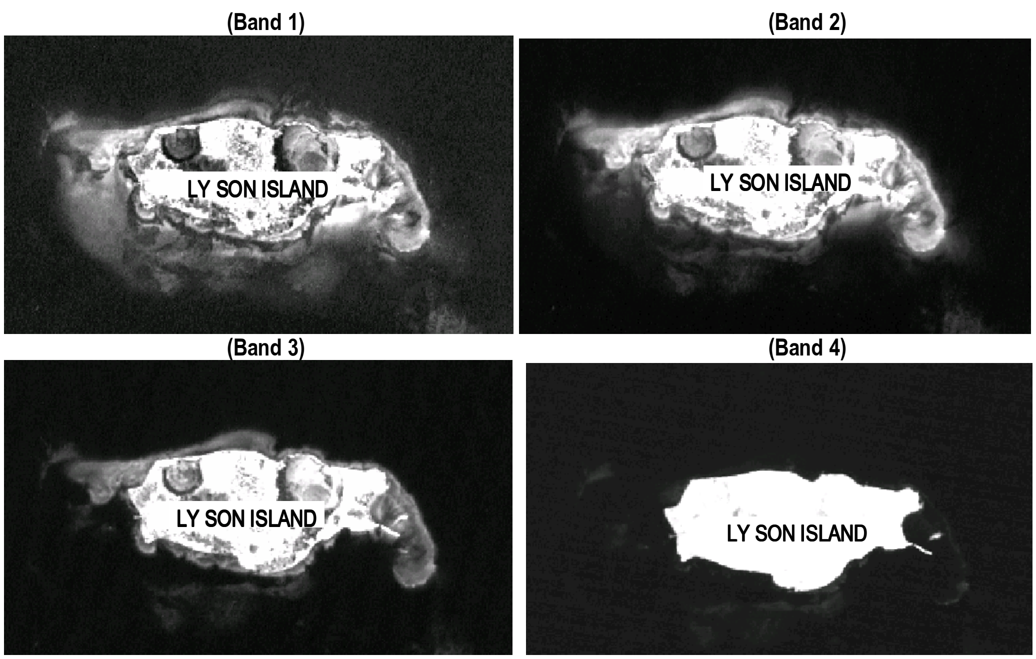

Figure 3. Band 1-4 of the study area

4.2. Marine chart

The marine chart of the area at scale 1:100.000, published in 1980 by the Vietnam's Navy, was collected. A latter and larger scale one should have been used if it was available.

The chart was scanned, geo-referenced and then used as reference data for the image geometric correction and for the depth data extraction for the model calibration and verification. 56 depth points were measured from the chart. Among them 30 were used for calibration and 26 for verification.

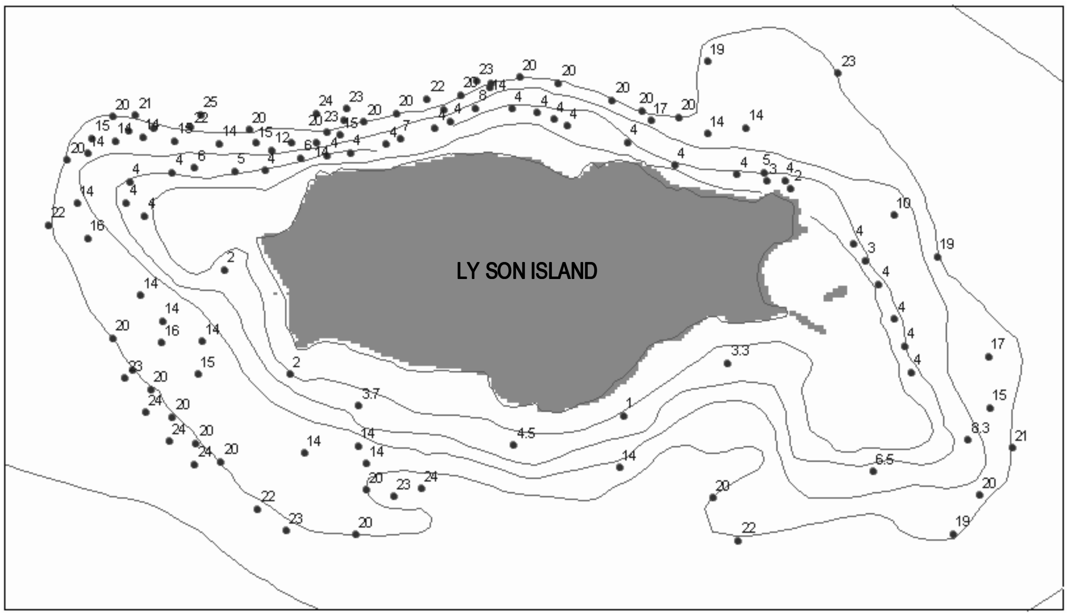

Figure 4. Digitized bathymetry of the marine chart.
The coastlines from the chart and from the satellite are relatively well-fitted

4.3. Tidal data

The tidal magnitude of the area at the time image captured on 9^{h}56 AM (local time), July 13, 2001 was referred to Dung Quat Cove station. Because the Dung Quat Cove station was a subordinate station only, so its tide was calculated based on Da Nang station, the closest reference station (Marine Hydrometeorological Centre, 2000).

The tidal data was used to synchronize the depth of water from the chart with those from the image.

5. Result and accuracy assessment

In this paper, only bathymetry map calculated by using the Jupp's method which gave the best result.

The accuracy assessment was done by using 26 check points extracted from the marine chart and separated with the 30 reference points. The highest and lowest accuracies are of 0.13m and 4.14m (see Table 2 for more detail). The correlation coefficient is of 0.76 (see Fig. 6 for more detail).

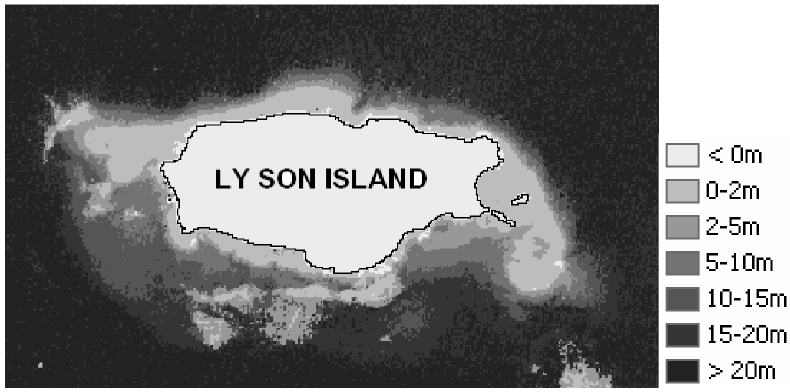

Figure 5. Map of calculated bathymetry of the study area

Table 2. List of 26 bathymetry points used to assess the accuracy of the model

No	X (UTM)	Y (UTM)	Check data (m)	Estimated data (m)	Error (m)
1	299789	1703444	19.00	18.87	0.13
2	299974	1699184	18.00	18.18	0.18
3	297703	1703012	2.40	2.20	0.20
4	299377	1702633	6.20	6.41	0.21
5	294997	1701465	2.00	1.57	0.43
6	299098	1700018	2.10	1.63	0.47
7	300901	1699835	4.70	5.19	0.49
8	299967	1700526	3.30	2.43	0.87
9	293729	1701718	16.00	17.01	1.01
10	301709	1700926	8.80	7.53	1.27
11	294717	1702427	6.40	5.10	1.30
12	301350	1701626	6.20	7.79	1.59
13	296850	1702743	8.60	6.97	1.63
14	296612	1700250	3.70	2.05	1.65
15	295853	1702411	2.40	0.37	2.03
16	300018	1702464	8.30	6.15	2.15
17	297868	1699587	4.50	2.12	2.38
18	298469	1702830	4.80	2.16	2.64
19	295498	1700610	5.30	2.66	2.64
20	296645	1699367	21.00	18.36	2.64
21	293698	1702651	15.00	17.72	2.72
22	294180	1700397	18.00	15.23	2.77
23	294273	1701214	13.00	10.05	2.95
24	295489	1699332	19.00	15.88	3.12
25	302337	1699746	8.30	11.48	3.18
26	297032	1703133	23.00	18.86	4.14

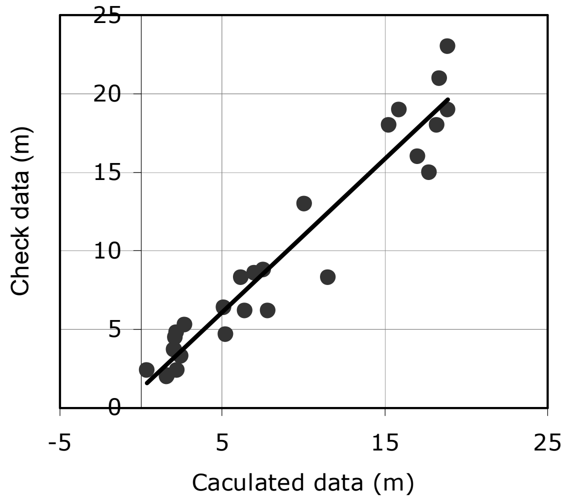

Figure 6. Correlation between the check data and the calculated data

The correlation coefficient would be expected 0.8 or above for a good reference data (Green et al., 2000). In this study, the reference data (the depths extracted from an out-dated marine chart and the tidal data referred to other station) are not so accurate; therefore, the result is acceptable.

6. Discussion and Conclusion

The result above doesn't show accurate enough (some decimeters) for a published marine chart; but to a rude map with less accuracy requirement purposes and in situations that other techniques could not be done, especially for a low-cost solution the optical-multispectral image is a suitable source.

Vietnam has a very long coastline, unfortunately, the Northern and Southern parts are affected much by turbidity waters from the rivers therefore the technique is not suitable; but in the middle part where the water is clear and seabed is relatively homogeneous and covered mostly by sand, the technique can be applied; the technique also is very suitable for islands such as Hoang Sa (Paracel) and Truong Sa (Spartley) archipelagos where other techniques are very difficult and too expensive to be applied.

Like some other studies which recommended using the Jupp's method, for this study, the Jupp's method also gave the best result but it is more complicated and requires more time to calculate and more field work data to calibrate. So, for a single band image, the Benny and Dawson method should be used because it is a simple one; and the Lyzenga's method could be used to improve the accuracy if the bottom properties are known.

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