

Remote Sensing of shallow sea floor for digital earth environment

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Abstract. Understanding the sea floor biodiversity requires spatial information that can be acquired from remote sensing satellite data. Species volume, spatial patterns and species coverage are some of the information that can be derived. Current approaches for mapping sea bottom type have evolved from field observation, visual interpretation from aerial photography, mapping from remote sensing satellite data along with field survey and hydrographic chart. Remote sensing offers most versatile technique to map sea bottom type up to a certain scale. This paper reviews the technical characteristics of signal and light interference within marine features, space and remote sensing satellite. In addition, related image processing techniques that are applicable to remote sensing satellite data for sea bottom type digital mapping is also presented. The sea bottom type can be differentiated by classification method using appropriate spectral bands of satellite data. In order to verify the existence of particular sea bottom type, field observations need to be carried out with proper technique and equipment.

1. Introduction

Coastal waters are essential for environmental systems since they are active areas for the processing of nutrients and carbon and therefore play an important role of carbon cycle. According to [1], human activities within a watershed can be expressed within coastal waters by changes in water quality and overall system response because the majority of the human population live within 60 km of a coast, coastal waters are critical areas for recreation, commerce and national defense. Studies in coastal waters are important to obtain a better perspective of earth system processes for climate alteration research and ecological factors for management decisions. Remote sensing of sea bottom types are complex because of the modifications of the signal as it moves through the water column and interacts with the sea bottom substrate [2].

A lot of research activities had been made to preserve these sea bottom types [3]. Continuous monitoring will help to preserve sea bottom features from becoming extinct. In fact, Malaysia also has a group of researchers who specialize in this field [4-5]. The first checklist of the marine benthic algae in Malaysia was published by [6]. Presently 375 taxa of seaweed [5] and 14 seagrass species [4] have been recorded. Meanwhile, 323 coral reefs species have been identified during status information on the coral reefs of the east coast of Peninsular Malaysia [7]. As regards of sea bottom types mapping, a number of studies can be found in the literature combining in situ observations and remote sensing techniques. Remote sensing provides the most flexible and accurate techniques for sea bottom assessments at differential scale, while ground techniques are not suitable to complete the mission by a certain time [8]. The conventional sensors that are widely used in sea bottom features mapping are medium and high resolution images that are capable of detecting these features.

Besides satellite data, fieldwork also needs to be done to recognize the characteristic of substratum types which shows in the image as well as benthic plant species and other cover types. However, field validation is frequently performed a few days to weeks earlier or later than collection of the satellite

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data [8]. This main purpose of this paper was to review the technical characteristics of signal and light interference within marine features, space and remote sensing satellite data. Furthermore, relevant and up-to-date remote sensing techniques were reviewed to produce precise sea bottom type map. To determine the accuracy of the results obtained, field validation was conducted using appropriate techniques and equipment.

2. The basic concept for understanding signal and light interference within marine features, space and remote sensing satellite

Light is a major factor for marine plants to stay alive to get enough oxygen for photosynthesis process. According to [9], light underwater is diminished by two processes namely absorption and scattering. Absorption and scattering processes combine to reduce the intensity of the radiance distribution, while the scattering processes also change the directional character of the radiance distribution [10]. As light continue downwelling propagation, the optical interference also continue until at some depth the intensity of the light becomes zero. In addition, another process also occur when light propagate in the water body which is attenuation process [10]. This attenuation process is also known as an additive consequence of the absorption and scattering processes that occur among the light and other materials that are present in the water. Figure 1 shows the interaction of all processes within the water column determining light attenuation.

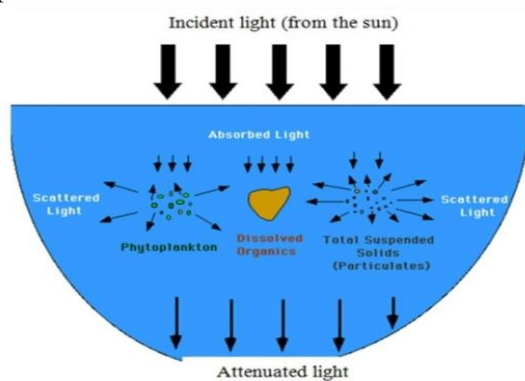


Figure 1. Absorption, scattering and attenuation of light in water.

Fundamentally, the capability of ocean remote sensing is dictated by the nature of the information regarding the sea that it is possible to communicate by electromagnetic radiation (EMR) [11]. The use of visible to near infrared waveband had been primarily used in terrestrial applications with their high reflectance signal and importance on spatial information. Visible wavelength is the only part of the electromagnetic range that can penetrate into the water column, up to 30 meter depth in clear waters. It allows the receiving of particles and dissolved material concentrations and permits the optical properties inside the surface layer of ocean and the mapping and monitoring of subsurface, for example, bathymetry and sea bottom features [12]. In contrast, near infrared spectrum cannot tell much about the details of the ocean. This waveband had been studied in detail for its rich information content concerning vegetation. The sea already absorbs almost every part of the solar near infrared radiation incident upon it before it can be reflected back. Thus the sea looks very dark in an image formed in this waveband, and its greatest value is to distinguish between water and land, defining the coastline clearly [11].

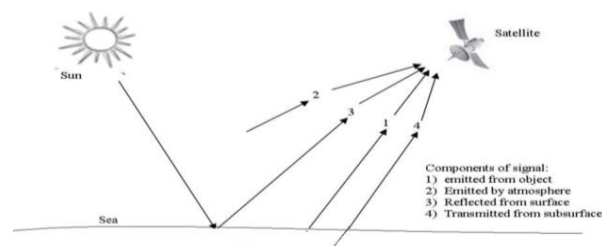


Figure 2. Signal components of electromagnetic radiation between sea and satellite sensor.

In the absence of cloud it does not mean that there is no atmosphere distortion that will corrupt the measured remote sensing signal from the sea. Figure 2 summarises the components of signal between rays of electromagnetic energy and the atmosphere. Ray 1 is the energy coming from water that had been emitted. Ray 2 is energy emitted by the constituents of the atmosphere. Ray 3 represents the useful signal which had been reflected from surface. Radiation leaving the sea surface reaches the sensor, containing detail information about the sea. Ray 4 indeed represents useful signal from water column.

3. Mapping shallow sea bottom types using remote sensing technique

In this section, we review applications of image processing methods applied to remote sensing satellite data as a tool for mapping sea bottom types exist. [13] mapped seagrass beds in Funakoshi bay which is located in Honshu Island, Japan using IKONOS satellite image and sea truth data. The field observations were obtained using side scan sonar on a standard boat speed, with a 100 m wide signal which utter ultra-sound waves with reflectance patterns that enables to differentiate sea bottom types. Sea truth and satellite image were overlaid in two ways: (1) with consideration of water depth and (2) without consideration of water depth. The IKONOS satellite image with supervised classification without consideration of water depths indicates a relatively realistic correspondence with side scan sonar map in shallow areas but this correspondence weakened in waters deeper than 10 m.

To map deep water areas, [3] used unsupervised classification in East Asia, Micronesia and Melanesia regions. The satellite data that were used are ALOS AVNIR-2, Landsat ETM+ and Landsat TM imageries which include coastlines and coral reefs areas. ISODATA method was chosen to avoid large variations in classification accuracy. The classification process was carried out twice in order to enable detailed classification of the coral reefs areas i.e. (1) classification of shallow sea areas and deep sea areas and (2) classification within the shallow sea areas. For classification of deep sea areas, ratio images of (Green-Red)/(Green+Red) was performed and were binarized visually. Meanwhile, classification within the shallow sea areas was carried out by interpreting the brightness value information from the satellite data in each cluster and the distribution location within the coral reefs. Quantitative and qualitative comparisons were conducted to verify the accuracy of result obtained. The extraction accuracy of coral reefs was 71.3%.

For time-series study, long term images are required to monitor the distributions of sea bottom types. [14] mapped seagrass cover and its distribution at Moreton Bay, Australia from a full Landsat archive, from 1972-2010 using MSS, TM and ETM+ data. This study was conducted to study a complete long-term image archives at the study area. The method of object based approach using Definiens eCognition 8.0 was used to classify the sea bottom types. The validation processed was conducted for the images of date between 2002 to 2010 due to data availability. The results showed fine and broad scale changes of seagrass. The overall accuracy of seagrass map for 2002 – 2010 ranges from 55% to 82% with an average of 63% accuracy.

[15] mapped coastal marine areas using IKONOS imagery over Funakoshi Bay (Jerlov water type II), Japan and Mahares in the Gulf of Gabes (Jerlov water type II and III), Tunisia. The methods used in this study were depth invariant index and bottom reflectance index techniques. The depth invariant index technique was only capable for very clear waters (Jerlov water types I and II). To overcome this problem, [15] produced a bottom reflectance index since it is not only able to improve the accuracy for Jerlov water types I and II but is also suitable for less clear waters (Jerlov water type II and III). Both methods were applied separately and finally it was classified via supervised classification. An exponential graph of radiance versus depth for sand and seagrass for green and blue bands using field data was performed in order to obtain attenuation coefficient values. Attenuation coefficients are nearly similar to Mahares, however in Funakoshi they are dissimilar. It was showed that Lyzenga's model does not fit well in the Funakoshi Bay well, even with higher water transparency level. The accuracy for Funakoshi Bay using depth invariant index was 61.7% while the accuracy using bottom reflectance index was 83.3%. For the study area in Mahares, the accuracy using depth invariant index was 54% and the accuracy increased to 90% using bottom reflectance index.

[16] mapped seagrass cover and identified its changes in the Eastern Banks, Moreton Bay, Australia. Quickbird data of year 2004 and 2007 was used using linear and ratio empirical methods to map seagrass cover. The field data was obtained in 2004 and 2007 using photography method that

was taken by diver. Each photo was evaluated to determine their bottom cover type and seagrass species. The results showed that the linear method effectively and accurately mapped seagrass cover with accuracies ranging from 57% to 95%.

From all of the above studies, it can be summarized that remote sensing techniques are followed by field observations in order to validate the effectiveness and accuracies of method used. However, some studies did not mention the technique of field observation that were used.

4. Field validation

Traditionally, field observations had been used. It needs accurate observations by a person to determine the species populations to accumulate precise data on population parameters (i.e. species composition, population density, patchiness and precise borders). [17] used underwater videography to estimate the area of seagrass beds. This study presents a cost-effective method of defining the subtidal seagrass region and calculates the basal area of seagrass cover. The combination of underwater videography, differential global positioning system (DGPS), geographic information system (GIS) and line transect methods were used in order to create thematic maps and quantify basal area of subtidal seagrass cover at several sites in Washington State. A series of straight line transects were measured to collect the data to be processed in the laboratory. These data were imported to a GIS system to create thematic maps.

[18] used photographic techniques to illustrate marine habitat in Ryder Bay Antarctica. Photographic surveys were taken at depth of 8 and 20 m by divers using SCUBA equipment with Nikon camera. To analyse the images, Adobe Photoshop 5.5 were used. It can be concluded that photographic methods offer a realistic, non-destructive technique to survey a rigid subsurface marine assemblages.

As technology advanced, a new system called acoustic technique had been developed. It was used by [19], who mapped three bottom types using different acoustic systems or classification methodologies at the Te Matuku Marine Reserve, New Zealand. The instruments used are single-beam echosounder, side scan sonar and multibeam echosounder. To measure with high accuracy among three different instruments, a map-to-map comparison was conducted using pixel-to-pixel similarity in the same area. Mapping from multibeam echosounder and side scan sonar showed almost similar results and produced the highest accuracy. Generally, during monsoon seasons, field work that is related to marine applications could not be carried out due to safety reasons. These problems can be overcome by remote sensing techniques that provide satellite scene of the particular study area. However, field validation is still required to assess the accuracy of the results obtained. Table 1 summarizes the techniques and instruments that have been used by some researchers.

Table 1. Summary of techniques and equipment.

Author	Technique	Equipment
Norris et al. (1997)	Videography	<ul style="list-style-type: none"> • Differential global positioning system (DGPS) • Underwater videography
Bowden (2004)	Photography	<ul style="list-style-type: none"> • SCUBA equipment • Underwater camera
Schimmel et al. (2010)	Acoustic	<ul style="list-style-type: none"> • Single-beam echosounder • Side scan sonar • Multibeam echosounder

5. Conclusions

This paper reviews the technical characteristics of signal and light interference within marine features, space and remote sensing satellite data. The study of signal and light interference is important due to the possibility and suitability of applying remote sensing satellite data to marine applications. Several methods and techniques to remote sensing satellite data showed useful information of interest such as species coverage and changes. Field validation is important in order to validate the results obtained. Acoustic technique can be best technique in order to verify the result as it can cover large areas in short time. Accordingly, remote sensing satellite data can be best processed and analysed to get maximum information about the species volume, spatial patterns and species coverage, including those to be discovered.

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