Bathymetric Mapping Techniques for Shallow Marine Waters Using Satellite Image Data at the Oceanographic Research Center (P2O)-LIPI in Jakarta

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Article Info

Received
20 April 2026

Accepted
20 May 2026

Keywords:
Production,
P20-LIPI,
ArcGIS 10.5,
Planet *scope*,
Oseanografi

Abstract

An application is a subclass of computer software that utilizes the computer's capabilities directly to perform a task desired by the user. The purpose of this study was to investigate bathymetric mapping techniques using Planet Scope satellite imagery and methods for processing data collected in the field. The research was conducted from January to February 2019 at the Remote Sensing Laboratory of the Oceanography Research Center, Indonesian Institute of Sciences (P2O-LIPI), East Ancol, North Jakarta. The methods used during this internship included active participation and literature review. To this context, the author processed satellite image data and analyzed the data using a laptop equipped with ArcGIS 10.5, Microsoft Excel, and ENVI 5.3. The results from data processed manually to determine absolute depth exhibited a higher level of accuracy ompared to data processed automatically.

1. Introduction

A software application is a subclass of computer software that directly utilizes a computer's capabilities to perform a task desired by the user. An example of such a software application is *ArcGIS*, one of whose functions is used in bathymetric mapping. Bathymetry can be defined as the measurement and mapping of the seafloor topography. Information on seafloor depth (bathymetry) in a given body of water is crucial for land-use planning in coastal areas (Ardiansyah, 2015). Seafloor depth (bathymetry) also provides various important insights about a marine area. In addition to maritime navigation, seafloor depth is useful for natural resource management, early warning systems, and disaster impact simulations. Seabed depth measurements can be conducted manually using ships, but this process is extremely time-consuming (Alsubaeia, 2012). The growing need for rapid access to bathymetry data has driven the development of manual measurement systems that utilize other technologies, such as satellite-based remote sensing (Ariyanto, 2012).

The Oceanography Research Center of the Indonesian Institute of Sciences (P2O-LIPI) serves as a platform for students to explore rapidly evolving scientific fields. This is evident in P2O-LIPI's core mission: to guide the development of science and technology rooted in Indonesia so that they may be utilized for the welfare of the Indonesian people in particular and humanity in general (Anzari & Surbakti, 2017). In addition, P2O-LIPI also serves as a platform for Marine Science students to learn more about oceanography (Asakura, 2010). Therefore, based on the information presented, the author is very interested in conducting an internship on bathymetric mapping techniques for shallow waters using satellite imagery—specifically Planet Scope satellite imagery—at the Oceanography Research Center of the Indonesian Institute of Sciences (P2O-LIPI) as an application of the theories taught on campus and, it is hoped, as preparation for facing future

global challenges (Ardiansyah, 2015). Furthermore, the goal is to study bathymetric mapping techniques to determine depths in shallow waters, which will be beneficial in providing spatial information for planning, activities, and decision-making related to the marine sector (Hasbi, 2007).

2. Methodology

2.1. Time, Place, and Materials

The research was conducted from January 14 to February 8, 2019. It took place at the Remote Sensing Laboratory of the Oceanography Research Center, Indonesian Institute of Sciences (P2O-LIPI), in East Ancol, North Jakarta.

2.2. Method

The methods used in this study were active participation and a literature review. In this study, the author processed satellite imagery and analyzed the data using a laptop equipped with *ArcGIS* 10.5, *Microsoft Excel*, and *ENVI* 5.3.

2.3. Procedures

Download Satellite Images

Planet Scope imagery data can be downloaded from planet.com. In this study, the secondary data used consisted of Planet Scope satellite imagery of Bependi Island provided by the P2O–LIPI team.

Tide Data

Tide data were obtained from the Indonesian Archipelago Tide Tables published by the Indonesian Navy's Hydrographic and Oceanographic Center in 2018.

Satellite Image Correction

After downloading the satellite imagery, the next step was to correct the glint effects in the downloaded images using the ENVI 5.3 application and to correct the tidal data using Microsoft Excel 2013.

Cropping and Masking of Satellite Images

Cropping and masking are performed to limit the analysis area in the image to be processed.

Bathymetric Map and Map Layout

The bathymetric map and the map layout were created using ArcGIS 10.5 and ENVI 5.3. The layout serves as a supplementary feature that explains the map's content, which contains important information.

Statistical Tests

Statistical tests were conducted using *Microsoft Excel* to assess the accuracy of the resulting bathymetric model.

3. Result and Discussion

Tidal Correction

To correct tidal data, you can use Microsoft Excel. The steps involved in correcting tidal data include: The first step in correcting tidal data is to locate the depth data and tidal data to be processed. Depth data was obtained from secondary data resulting from a field survey of Bependi Island conducted by the P2O-LIPI Team, while the tide data to be processed was obtained from the 2018 edition of the Indonesian Archipelago Tide Tables published by the Indonesian Navy's Center for Hydrography and Oceanography. Once the tide data was obtained, the values were entered into Microsoft Excel (Bastian, 2013).

The next step to correct the tide values is to determine the Mean Sea Level (MSL) by inputting tide data for 30 days and calculating the average value of the obtained tide data. After obtaining the MSL value from the calculation of the average tidal values over 30 days, the next step is to input the field data, tidal data, and MSL data into a new sheet; then, the depth data obtained from the field survey is converted to negative depth values.

Tide data were obtained from Biak Island, assuming no phase differences or resonance between Biak Island and Bependi Island, since no tide data are available for Bependi Island. The tidal type on Biak Island is a Mixed Tide, Prevailing Semidiurnal, which means that in the waters around Biak Island, there are two high tides and two low tides in a single day, but with different heights and periods. The Mean Sea Level (MSL) value derived from the tidal data is 1.10.

Glint Effect Correction on Satellite Images

Correction for the glint effect on satellite image data was performed using the ENVI 5.3 application (Figure 1). Glint correction is used to improve image quality by eliminating or minimizing the effects of sunlight reflection (glint) that strikes ocean waves perpendicularly. Glint correction is performed by identifying areas of glint variation and glint-free areas,

which are then converted into an equation model to obtain a good regression value (R2 close to 1) because it has a high accuracy value and indicates that the resulting logarithm can eliminate glint (Hutabarat & Evans, 1985).

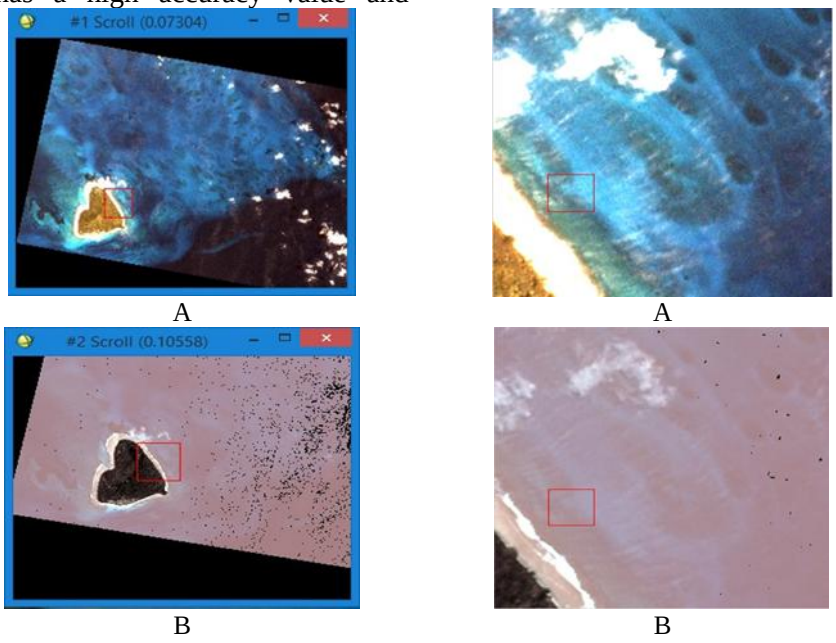

Figure 1. Image appearance before and after sunglint correction
A) Uncorrected glint image, B) Glint-corrected image

Increasing glint can eliminate information below the water column. Sunglint reflections and the water column will interfere with the interpretation of objects on the water's bottom substrate. Furthermore, sunglint correction also aims to facilitate the interpretation and extraction of information about underwater objects by eliminating the effects of reduced or increased energy intensity due to changes in the distance between the Earth and the Sun (Asakura, 2010).Glint-corrected images will display objects in the water column.

Depth Model Creation

Absolute depth is built based on linear regression between pixel values (raster values) obtained from the band ratio processing process with field measurement data. The image data processing practice is carried out using the ENVI application in two ways: a) Manually using the bandmath tool and b) Using SPEAR TOOLS. The stages in creating a depth model are as follows: The ENVI 5.3 application is opened to create a band comparison formula. The band values are taken from the glint correction stacking results previously performed.

Enter the resized image in the Relative Water Depth menu in SPEAR TOOLS using ENVI 5.3. Then, enter the latitude and longitude values by clicking on the image, then right-clicking and selecting pixel locator. Next, enter the appropriate depth value at the previously entered lat/long point.

Satellite imagery-based depth modeling is performed using band ratios. Because there is a logarithmic relationship between depth differences and visible light penetration strength, the band ratio function is used, and the band ratio formula refers to the formula developed (Khomsin, 2004).

The results of linear regression testing for the depth model using SPEAR TOOLS show a coefficient of determination (R2) of 0.968. The results of linear regression testing for the depth model using the band ratio formula show that the logarithm of band 1 (blue) and the logarithm of band 2 (green) is 0.9215. The R2 value of the band ratio between the logarithm of band 2 (green) and the logarithm of band 3 (red) is 0.5921. The R2 value of the band ratio between the logarithm of band 3 (red) and the logarithm of band 1 (blue) is 0.7307 (Bastian, 2013).

Making a Bathymetric Map

After correcting for glint effects, calibrating the depth of the satellite imagery to be processed, and performing tidal corrections, the next step is to create a bathymetric map, as shown in Figure 2.

The bathymetric map of Bependi Island was created using ArcGIS 10.5. Figure 4 shows that Bependi Island is located in Papua Province. To create a bathymetric map, tidally corrected depth data must be entered. Furthermore, the imagery used to create the bathymetric map was derived from sunglint-corrected imagery, and an absolute depth model was constructed to obtain the best depth model (Anzari & Surbakti, 2017).

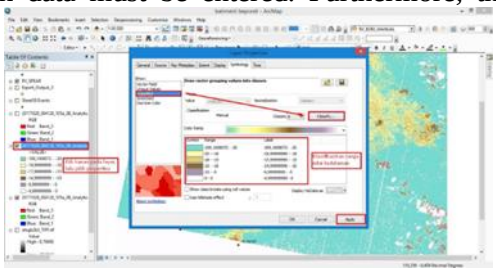

Figure 2. Creating a depth value range classification

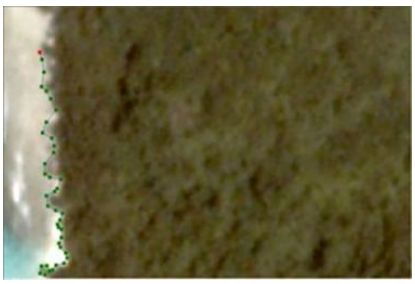

Figure 3. Digitization of land areas

Figure 4. Converting polyline features to polygons

After inputting the data into ArcGIS, depth contours were created on the bathymetric map using the appropriate interval. The contour interval indicates the difference in elevation or angle between two adjacent contour lines. Depth contours function as imaginary lines in a region or area on the map, connecting and showing points on the map that have the same depth (Hasbi, 2007).

If the contour lines are the same color, they will be connected to each other, indicating the same depth in a particular area of the body of water. Furthermore, the resulting contour lines also show color differences due to differences in depth values within the waters of Bependi Island. The purple contour line indicates a water depth of 15 m, the yellow line indicates a water depth of 6 meters and the turquoise line indicates a water depth of 2 meters (Budiyanto, 2002).

Lay outing the Map Display

Once a map is successfully created, it must be accompanied by a legend so readers can understand the map's purpose and content. Furthermore, to enhance its aesthetic value, the layout should be as creative as possible to capture the reader's attention without obscuring important information (Figure 5).

Figure 5. Setting paper size and map orientation

Statistical Test (Regression Test)

To test the accuracy of the data, a statistical test was performed using a regression test. The regression test was conducted by examining the coefficient of determination (R2), correlation (r), and standard error (SE). The data used for the regression test were the previously generated relative and absolute depth data (Khomsin, 2004). The regression test was conducted to assess the accuracy of the processed data by determining the appropriate combination of bands to create a bathymetric map of Bependi Island. The regression test also compared manually processed data with data processed automatically using ENVI 5.3. The regression test was conducted by examining the R2, correlation (r), and standard error (SE) values.

From the results of the regression test using the manually processed data using the band ratio formula, the highest R2 value was found in the logarithmic ratio bands of band 1 (blue) and band 2 (green), at 0.92. The R2 value obtained using SPEAR TOOLS was 0.97. Meanwhile, the lowest R2 value is found in the logarithmic ratio bands of band 2 (green) and band 3 (red), namely 0.59. This proves that the penetration ability into the water body of the red band is not as good as the blue and green bands, therefore the regression results with depth data produce a lower coefficient of determination and correlation than the combination of the ratio of the blue and green bands (Ardiansyah, 2015).

4. Conclusion

It can be concluded that before making a bathymetric map, it is necessary to correct the tidal data to get the true depth and also to correct the glint effect to minimize the effect of sunlight reflection. The depth of the waters on Bependi Island ranges from 1 meter to 36 meters. In making bathymetric maps, regression tests were carried out to determine the level of accuracy of the data processed with field data. The regression test is seen from the values of the determination coefficient (R2), correlation coefficient (r), and standard error (SE). The results of data that are manually processed to obtain absolute depth have a higher level of accuracy compared to data that is processed automatically.

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