Accuracy Analysis of Indonesian Geoid Model Based On Grids

F Ladivanov\textsuperscript{1} *, R I S Munthaha\textsuperscript{1,a}, Y Aryadi\textsuperscript{1}

\textsuperscript{1}Center of Geodetic and Geodynamics Control Networks, The Indonesian Geospatial Information Agency, Bogor, 16911, Indonesia.

Abstract. Providing geospatial data and information services like the Indonesian geoid model is one of the important things on implementation of The Regulation of Head of the Geospatial Information Agency (BIG) No. 15 of 2013 about Indonesia Geospatial Reference System 2013 (SRGI2013). The geospatial information service requires innovation to fulfill the needs of the user. The provision of Indonesian geoid model with various grid resolutions is one of the forms of renewal that designed to meet the needs of users based on the accuracy level that needed. Each geoid model with a different grid resolution will produce different geometries as well. Therefore, the value of geoid undulation on a certain coordinate will be different according to the grid resolution. Based on that case, this paper will analyze the accuracy of The Indonesian geoid model based on the various grid resolution. Grids resolution that used in this case is 36”, 1’, 2.5’, and 5’. The accuracy of the geoid model is obtained from the standard deviation of the difference between geometric undulation values and gravimetric undulation values in 186 control points. The result of this study shows that Indonesian geoid model with the grid resolution 36”, 1’, 2.5’, and 5’ have the geoid accuracy 5.129 cm, 6.472 cm, 9.584 cm, dan 13.942 cm sequentially. Based on that result, we can conclude that the less grid resolution of geoid model will produce a higher accuracy of the geoid model. In addition, this study could be a consideration for every user to use the Indonesian geoid model based on their need and specification.

1. Introduction

1.1. Research Background

Geospatial Information Agency (BIG) has the main duties and functions in holding Geospatial Information (IG). Law Number 4 of 2011 concerning Geospatial Information, as well as in Presidential Regulation Number 94 of 2011 concerning Basic Tasks and Functions of the Geospatial Information Agency (BIG) states that BIG is responsible for organizing Basic Geospatial Information (IGD) and Thematic Geospatial Information (IGT). Geospatial information must be bound to a particular reference system. One of the IGs that must be held is the Basic IG (IGD) which includes the National Gravity Control Net (JKGN). The availability of JKGN serves as a point of reference or reference in surveying and measuring gravity. The purpose of the gravity survey and measurement is the availability of gravity data that will be useful in geoid modelling as a national vertical geospatial reference system. Based on BIG Head Regulation Number 15 of 2013, the 2013 Indonesian Geospatial Reference System or SRGI2013 states that the vertical geospatial reference system used in Indonesia is a geoid that is assumed to be an equipotential plane which mathematically coincides with the mean sea level in ideal conditions (Wellenhof & Moritz, 2005). The geoid is formed due to variations in the earth's gravity so that sufficient gravity data is needed and covers all regions in the world to be able to produce an ideal geoid.

*Corresponding author.
The urgency of Indonesian geoid availability aside from being a vertical geospatial reference system is also useful for high system unification in all regions. For practical purposes, the Indonesian geoid that has been formed can be used to determine high data that has a physical realization, for example, construction and engineering needs. Indonesian Geoid has become an urgent and non-negotiable need. The availability of Indonesian geoid has become a very varied need for users from various walks of life and for various interests. Therefore, Indonesian Geoid is always being updated both in terms of quantity, quality, and service.

Service is one of the main components that must be considered for the convenience and satisfaction of users in accessing Indonesian geoid data. Even today Indonesian geoid data can be accessed easily through the SRGI website. The service in its renewal always considers the needs of users. Indonesia's multi-grid geoid model is a form of renewal that has been designed to address the diverse needs of users. Indonesia's multi-grid geoid model is a form of providing Indonesian geoid data with grid spacing that varies from 36 seconds (36"), 1 minute (1'), 2.5 minutes (2.5'), and 5 minutes (5') in the form raster. The raster form was chosen as the appropriate data format for the backend system of the SRGI web. The resulting raster data is then calculated based on the comparison of gravimetric undulation values from raster data with geometric undulations at the geoid validation control points.

1.2. Problem Identification
Geoid modelling has been carried out by the Field of Gravity and Tidal Control Nets, Geospatial Information Agency (2020) which produced the Indonesian Geoid model as a National Vertical Geospatial Reference System. However, the implementation of geoid data services through the website requires a raster format geoid model to be loaded into the back-end system of the SRGI2013 website server. Then taking into account the varying needs of users, the geoid model is also distinguished based on the grid resolution. Therefore, in this study an analysis of the accuracy of the Indonesian geoid model based on grid resolution was carried out

1.3. Purposes and Objectives
The purpose of this research is to analyze the accuracy of the Indonesian geoid model that has been converted in a raster format (previously ASCII format) to the point of geoid validation based on differences in grid resolution. The purpose of this study is to obtain the accuracy value of the Indonesian geoid model for each grid resolution.

1.4. Scope of Research
In this research, conversion and griding of Indonesian geoid model was carried out from grid format (.grd) with a grid resolution of 36" to ASCII format (.txt) with grid resolutions of 36", 1 ', 2.5' and 5 'using the Generic Mapping Tools (software) script GMT. The ASCII format file is then converted again to the Raster format using commercial software (SAGA). The resulting raster data were analyzed for its accuracy against the geoid validation points resulting from levelling measurements.

1.5. Literature Review
Geospatial Information Agency as an Agency that has duties and functions in the administration of geospatial in Indonesia, so it is obliged to provide a geospatial reference system in Indonesia. Therefore, the Center for Geodesy and Geodynamic Control Nets, the Geospatial Information Agency, is modelling the Indonesian geoid as Indonesia's vertical geospatial reference system. Pahlevi et al. (2018) have researched Updating the Indonesian Geoid Model. In the study of Pahlevi et al. described the methods and stages in Indonesian geoid modelling. One of the stages is the validation of the Indonesian geoid model to test the accuracy of the Indonesian geoid model. The stages of geoid validation are performed by comparing the values of geometric undulations and gravimetric undulations at geoid validation points. The author also uses this geoid validation point as the Indonesian geoid raster validation point with a validation point of 186 points. But what is compared is the undulation value of the GMP interpolation and the undulation value of the rasterized result.
The software used in this research to rasterize the Indonesian geoid model from the Ascii format (*.txt) in the form of a Raster (*.tiff) is the System for Automated Geoscientific Analysis Geographic Information System (SAGA-GIS). Based on Olaya (2004), SAGA is one of GIS data processing software that is open source and can be used in modelling and analysis of geospatial data. One feature of SAGA is the conversion of vector data into raster data. The advantage of this feature in SAGA software is the ease of doing data processing. In other GIS software, vector data must be displayed before processing. Whereas in SAGA software, vector data is not displayed but is stored in a temporary database so that data processing will be lighter and faster. This has become the basis for the selection of SAGA software in making Indonesian geoid raster models due to the geoid model vector data that amounts to millions of points.

2. Data and Methodology

2.1. Data and Research Tools

The research tools used include:
1. Generic Mapping Tools (GMT) Software
2. System for Automated Geoscientific Analyses (SAGA) Software
3. ArcGIS Software
4. Ms. Excel Software
5. Ms. Word Software

The data used in this study are:
1. Indonesian Geoid Model data in grid format (final_geoid_2019_2.grd); and
2. Geoid validation control data points are 186 points

2.2. The Indonesian Geoid Model

The Geospatial Information Agency (2020) has updated the Indonesian Geoid modelling using Gravsoft software (Forsberg, 2008) which has been modified and developed by DTU-Denmark. This software modification aims to make the processing parameters used more suitable to be applied in Indonesia. Indonesian geoid modelling uses 3 wave components, namely long, medium, and short waves. The longwave component used is the global EGM 2008 360 degrees geoid model. The intermediate wave component is generated from the free-air gravity anomaly data from the airborne gravity survey and the terrestrial grid gravity survey. The shortwave component used is the Digital Elevation Model (DEM) obtained from Shuttle Radar Topography Mission (SRTM) data with a spatial resolution of 15 meters (land area) and National Bathymetry data (BATNAS) for the sea area. The method of geoid modelling is a combination of remove-restore and Fast Fourier Transformation (FFT).

The final result of this Geoid Indonesia modelling is a grid file with a resolution of 0.01°. The area size of Indonesia’s geoid grid is 20° LS - 20° LU and 90° BT - 150° BT. The accuracy of Indonesian geoid model can be seen in Table 1.

| Region     | Validation Points | Min (cm) | Avg (cm) | Max (cm) | Std (cm) |
|------------|-------------------|----------|----------|----------|----------|
| Jawa       | 186               | -12.8    | 0.03     | 30.4     | 5.1      |
| Bali       | 184               | -38.3    | -0.30    | 31.1     | 10.3     |
| Sumatera   | 26                | -8.38    | 21.4     | 51.3     | 17.3     |
| Sulawesi   | 53                | -60.1    | -10.5    | 41.3     | 22.4     |
| Kalimantan | 35                | -35.7    | 23.3     | 69.5     | 24.7     |

Source: Technical Draft of Indonesian Geoid Modelling 2020

The Indonesian geoid model on the islands of Nusa Tenggara, Maluku and Papua has not yet been calculated precisely because of the unavailability of validation control points.
2.3. Validation Control Points
Validation control points for this study amounted to 186 (one hundred eighty-six) points spread along the Semarang-Yogyakarta route as shown in figure 2.1.

![Figure 2.1. The spread of validation control points](image)

The validation control points play a role in analyzing the accuracy of the resulting geoid model. This accuracy was obtained based on a comparison between geometric undulations at each validation control point and gravimetric undulations from the resulting geoid model. Geometric undulation is the difference between geometric height and orthometric height. Geometric height is produced from static relative observations of the Global Navigation Satellite System (GNSS) while orthometric height is produced from meticulous flat measurements.

2.4. Methodology
In general, the stages of the research are carried out as a flowchart in figure 2. below:

![Figure 2.2. General research flow chart](image)
The flow chart in Figure 2.2. illustrates the stages carried out in this study. Starting from collecting data on long wave, short wave, and medium wave components to be modeled into Indonesian geoids. Indonesian geoid modeling uses the Fast Fourier Transform (FFT) method. The results of this modeling are data in the form of a grid containing information on the geoid undulation value. The resulting grid is 0.01 degrees or 36". The Indonesian 36" geoid model will then be converted into 1", 2.5" and 5". The Indonesian geoid model, which has several grid resolutions, is converted into raster data for the Indonesian geoid model. The quality of the raster data generated was tested using geoid validation control points in the Central Java area. The final result of this research is the statistical results of the accuracy of the Indonesian geoid model based on the grid resolution and the analysis of this accuracy.

3. Result and Analysis

3.1. Multi-Grid Indonesian Geoid Model

The Indonesian geoid model has a spatial resolution of 36". The Indonesian Geoid model with the grid format (*.grd) was converted to ASCII (*.txt) format in several types of grids, namely 1', 2.5', and 5'. This conversion process is carried out using GMT software. This grid difference is intended to meet various types of user needs. The difference in geoid grids will result in different grid geometries. Indonesian Geoid Geometry can be seen in Table 3.1.

| Table 3.1. The Geometry of Indonesian Geoid Model |  |
|-----------------------------------------------|--|
| **Geometry of Indonesian Geoid Model (Grid 36")** |  |
| Grid Size | 6001 columns x 4001 rows |
| Cells | 24010001 |
| Area Limits | Lat : 20° S - 20° N  
Long : 90° E - 150° E |
| Cell Size | 0.01° = 36" |
| **Geometry of Indonesian Geoid Model (Grid 1')** |  |
| Grid Size | 3600 columns x 2400 rows |
| Cells | 8640000 |
| Area Limits | Lat : 19.99167° S - 19.99167° N  
Long : 90.0083° E - 149.99167° E |
| Cell Size | 0.016667° = 1' |
| **Geometry of Indonesian Geoid Model (Grid 2.5')** |  |
| Grid Size | 1440 columns x 960 rows |
| Cells | 1382400 |
| Area Limits | Lat : 19.979167° S - 19.979167° N  
Long : 90.02083° E - 149.979167° E |
| Cell Size | 0.041667° = 2.5' |
| **Geometry of Indonesian Geoid Model (Grid 5')** |  |
| Grid Size | 720 columns x 480 rows |
| Cells | 345600 |
| Area Limits | Lat : 19.9583° S - 19.9581737° N  
Long : 90.04167° E - 149.9580937° E |
| Cell Size | 0.083333° = 5' |
3.2. Rasterization

The backend system from the SRGI web that was developed for the geoid data service menu, is only compatible with raster format geoid data models. Therefore, Indonesia's multi-grid geoid in ASCII (*.txt) format must be converted to raster format. This conversion is done using SAGA open-source software. The stages of conversion into raster format are to enter Indonesian geoid ASCII data in the form of point clouds, then converted to grid form in SAGA software, after that export Indonesian Geoid grid in raster format with GeoTIFF format. Results from Indonesian geoid raster data from several grids are shown in Figure 3.1.

![Figure 3.1. Indonesian Geoid Model in Raster Format](image)

In Figure 3.1 it can be seen that the geoid undulations of the four rasters with different grids show the same pattern. However, it does not explain in detail related to differences in the raster data of each grid. In Figure 3.2, Geoid raster data is enlarged to see the difference in grid resolution between raster data.
In Figure 3.2 it can be seen that the larger the grid will form a larger cell size as well. In one cell/grid on Indonesian geoid raster data will have one geoid undulation value. However, in this case, due to the different grid sizes, the geoid undulation values obtained will also be different. Therefore, it is necessary to test the accuracy of Indonesian geoid raster data with various grid resolutions to determine the accuracy of raster data with varying grid resolutions.

3. Validation of The Geoid Model
Geoid validation aims to determine the accuracy of each Indonesian Geoid Model raster data produced. The accuracy is obtained from the calculation of the standard deviation of the difference between the geometric undulation values at the validation control points totaling 186 points and the gravimetric undulation values of each raster data. Analysis of the accuracy of raster data is calculated using Microsoft Excel software. The differences of the undulation values can be seen in Figure 3.3.
The difference is obtained between geometric geoid undulations and gravimetric geoid undulations, which then do statistical calculations. The calculated statistics include finding the maximum, minimum, average and standard deviation of the geoid undulation.

Statistical results from geoid validation are presented in Table 3.2.

| Grid  | 36" | 1'  | 2.5' | 5'   |
|-------|-----|-----|------|------|
| Min   | 13.2| 14.6| 29.0 | 46.6 |
| Max   | 29.9| 9.73| 46.6 | 46.5 |
| Mean  | -0.01| 0.63| 0.99 | 3.47 |
| Std   | 5.13| 6.47| 9.58 | 13.94|

In Table 3.2 it can be seen that the geoid raster with the smallest grid of 36 " has the best accuracy of 5.129 cm while the raster with the largest grid size of 5" has a geoid accuracy of 13,942 cm. This indicates that the smaller the grid resolution, the higher the accuracy of the undulation value obtained. The difference in the accuracy of the Indonesian Geoid Model based on the grid can be taken into consideration by users in using Indonesian geoid services.

4. Conclusions

Studies conducted show that each data grid has a different geometry. The undulation value at certain coordinates will vary based on the grid resolution of the geoid model used. Validation of the geoid model for each grid resolution shows that the accuracy of the grid resolution of 36 ", 1", 2.5 " and 5" resulted in accuracy of 5.129 cm, 6.472 cm, 9.584 cm and 13.942 cm, respectively. This indicates that
the greater the value of the grid the more accurate it will be. The difference an accuracy can be used as a consideration by users in using Indonesian geoid services according to the needs and specifications of the job.

5. References

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