Evaluation of global geopotential model and its application on local geoid modelling of Java Island, Indonesia

Leni S. Heliani

Citation: AIP Conference Proceedings **1755**, 100005 (2016); doi: 10.1063/1.4958534
View online: http://dx.doi.org/10.1063/1.4958534
View Table of Contents: http://scitation.aip.org/content/aip/proceeding/aipcp/1755?ver=pdfcov
Published by the AIP Publishing

Evaluation of Global Geopotential Model and Its Application on Local Geoid Modelling of Java Island, Indonesia

Leni S. Heliani[1, a)]

[1]*Dept. of Geodetic Engineering, Faculty of Engineering*
Universitas Gadjah Mada, Indonesia

[a)]Corresponding author: lheliani@ugm.ac.id

Abstract. The geoid is the ideal height reference field that used as the basis of the height measurement and also transferring the GNSS height data to become the practically utilized orthometric height data. In this study, 7 Global Geopotential Models (GGMs) have been evaluated and applied for precise local geoid modelling of Java Island. The Evaluation had been done through the comparison, absolutely and relatively, with 44 co-site GPS-levelling data. Base on the evaluation results, the optimal GGM had been utilized on precise local geoid model using the standard remove-restore method and the residual geoid has been computed using the 2D-FFT method. Effect of degree and order of GGM to the local geoid have also been investigated. The comparison of The GGMs and GPS-levelling showed that the EGM2008 gave best results with the mean difference value of 0.99 and 0.701, absolutely and relatively, and also shows consistency over the distance. The effect of degree and order of EGM2008 to the accuracy of the local geoid model ranged from 0.706 to 0.596 m from degree 2190 and 750. Finally, the local geoid model derived using the full resolution of EGM2008 has been fitted to the local reference, in this case, the GPS-levelling data with an accuracy of 0.204m.

INTRODUCTIONS

Java Island is the one of the main islands in Indonesia with the population about 59% of Indonesian [1]. Like the main island, many development and infrastructure activities are done over the island that needs spatial data and information as a basis for their development. Modern and Extraterrestrial spatial data acquisition plays an importance role to solve the rapid need and high quality of spatial data, one of the methods is GNSS positioning method. Along with increasing the use of GNSS technology on the positioning and mapping, there is the need of geoid model over the island to transfer the practical un-utilized GNSS height data to become the practically utilized orthometric height data, names a GNSS height. Besides, the Geoid is also the ideal height reference field that used as the basis of the height/deep measurement on or in the Earth. By definition, the geoid is the equipotential gravity field that coincides with undisturbed/global average mean sea level [2].

On the development of precise local geoid model, tree geoids components are required, those are; long wavelength component derived from global geopotential model data, middle wavelength obtained from terrestrial gravity data and short wavelength from terrain model data [2,3]. On the other hand, several problems limit the precise local geoid modelling over the island; those are a limited number and uneven distribution of terrestrial gravity data, also the low resolution of terrain data [3].

In recent day, a satellite dedicated to gravity observation, such as CHAMP, GRACE, and GOCE, have possible to study the Earth gravitational field [4]. Several GGMs have been published and can be accessed easily. Those GGM have been developed from a combination of several satellite gravity data and surface gravity data over some area in the Earth, resulting in high resolution of GGM [5].

On the other hand, some terrestrial gravity data measurement have been carried out over Java Island through the project supported by Ministry of Science and Technology, Ministry of Education and Culture, Geospatial Information

Advances of Science and Technology for Society
AIP Conf. Proc. 1755, 100005-1–100005-6; doi: 10.1063/1.4958534
Published by AIP Publishing. 978-0-7354-1413-6/$30.00

Agency (BIG) also PT Pertamina (Indonesia Oil dan Gas Company) since years of 2008 – 2013. Along with the gravity measurement, the Static GPS measurement also has been done at some levelling control points. Those measurements increase the number of the terrestrial gravity data that available on the Indonesian Gravity (INDOGRAV) Database, that has been collected by Indonesian Gravity National Committee (KGN) coordinated by Center for Geological Research and Development (P3G) through GETECH project [6]. The INDOGRAV database has been using to develop the national wide geoid model, namely the Indonesian Geoid Model 1996 [7] and INDOGEOID03 [3] Those geoid model have been computed based on the OSU91A and EGM96 Geopotential Model [3,7].

DATA

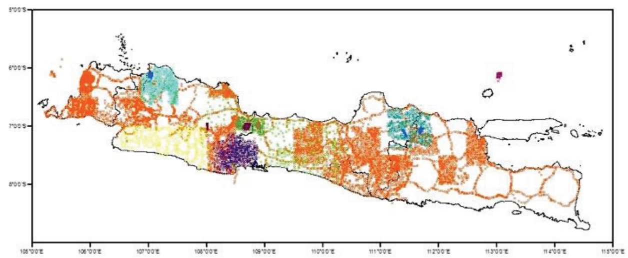


FIGURE 1. Distribution of terrestrial gravity used in this study base, signed by their project; JITEK (red and brown), UGM-MST (green and yellow), UGM-PTN (blue) and PERTAMINA (violet).

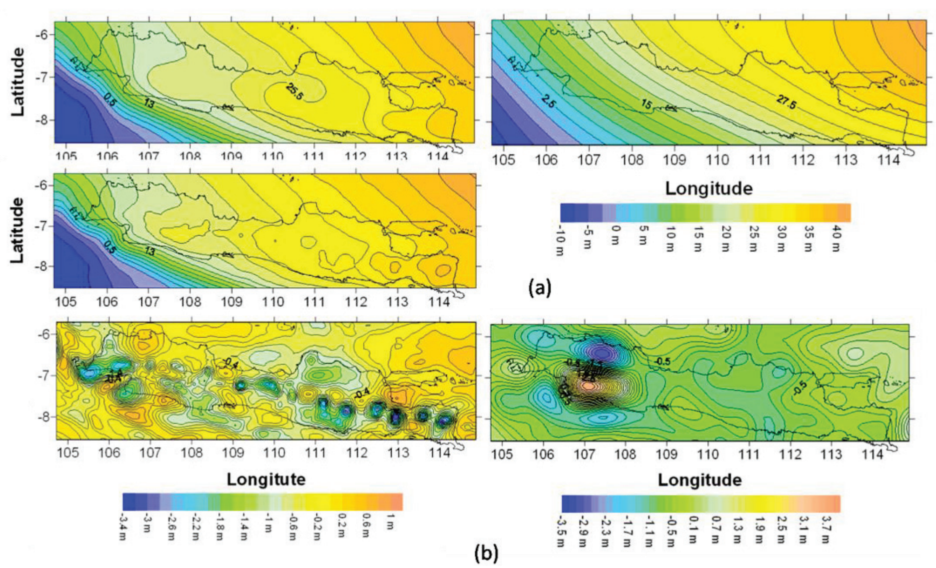


FIGURE 2. (a). Visual comparison of geoid height of EGM96, CHAMP01S and EGM2008, and (b). Geoid differences between EGM96 – EGM2008 and EGM08-CHAMP01S

The utilized data on this study, as follows:

1. Global Geopotential Models (GGMs) : seven GGMs have been evaluated, those are: EGM96, EIGEN-CG03C, EIGEN-GL04C, ITG-GRACE03, AIUB-CHAMP01S, GGM02C, and EGM2008. Those GGMs available through http://icgem.gfz-potsdam.de/ICGEM/ICGEM.html
2. Terrestrial Gravity: several data source/project have been used in this study, those are: INDOGRAV database, UGM-Ministry of Science and Technology Research Grand Project (UGM-MST), and UGM-Pertamina Research Grand Project (UGM-PTM). The distribution of data grouped base on the project, shown in Fig. 1.

3. GPS-levelling: 49 co-located GPS-levelling data over the are have been used for the evaluation and control point purposes, their distribution as also shown in Fig. 1.
4. SRTM30, it has been used for terrain correction computation and was obtained from http://topex.ucsd.edu/WWW_html/srtm30_plus.html, with resolution of about 1 km [8]

EVALUATION OF GGMs

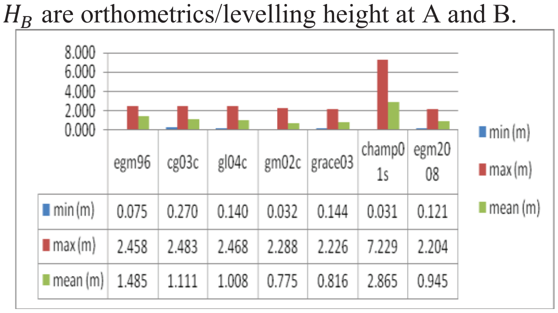
The evaluation of the GGMs has been done using two methods; (1) comparison among the GGMs and (2) absolute and relative comparison with available co-site GPS-levelling data. The evaluation among GGM showed that range value and general patterns of geoid height was almost similar. However, some detail patterns were shown clearly, especially for EGM2008 [11] that has a much higher order of 2190 compare to orde 360 and 100 for EGM96 and Champ01S, respectively. Detail patterns on the EGM2008 associated with high variation of topography in the mountainous region. Figure 2 showed a visual comparison of geoid height of EGM96, Champ01S and EGM2008, also the geoid height differences between the models. The differences in geoid height between the models range from -3.4 to 3.7 m, with large differences over the mountainous area for about +/- 3 m and less than +/- 1 m difference over the plate area.

Meanwhile, the absolute and relative comparison with GPs-levelling data, fulfilled the following equation, respectively [7]:

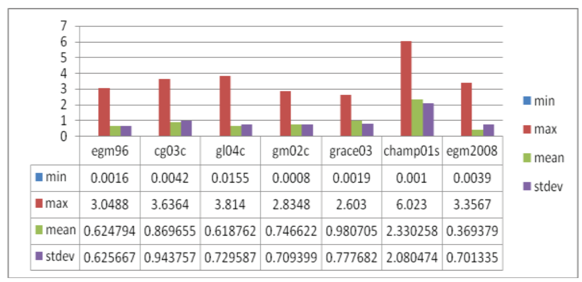
$$N_A = h_A - H_A) \tag{1}$$

$$N_B = N_A + (h_B - h_A) - (H_B - H_A) \tag{2}$$

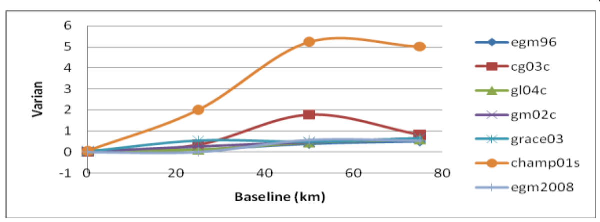
In this case, N_A & N_B are the GGMs geoid height at points A and B, h_A & h_B are Geometrics/GPS height and H_A & H_B are orthometrics/levelling height at A and B.



(a)



(b)



(c)

FIGURE 3. Graphics of differences in geoid height between the GGMs and GPS-levelling data, absolutely (a) and relatively (b) and the relationship of the baseline with their variant on the relative comparison (c).

The absolute comparison with GPS levelling data showed that minimal mean differences resulted using the GM02C, followed boy the GRACE02 and the EGM2008, these were 0.775, 0.816 and 0.945 n, respectively (Fig. 3.a). Whereas for the relative comparison, as shown in Fig. 2.b, indicate that the minimal mean differences obtained from the EGM2008, GM02C, and GRACE02, of 0.701, 0.709 and 0.777 consecutively. The Fig. 3.c shows that there was a consistent relationship between the baseline to their variant for several models, especially for EGM2008. Increasing on the baseline resulted in consistent increasing on variant value. Meanwhile for the CHAMP01 and CG03 showed that the increase in the baseline not followed by consistent increasing the variant value. As the EGM2008 showed consistent results on both comparisons, it has been selected for further computation/analysis of local geoid model of Java island.

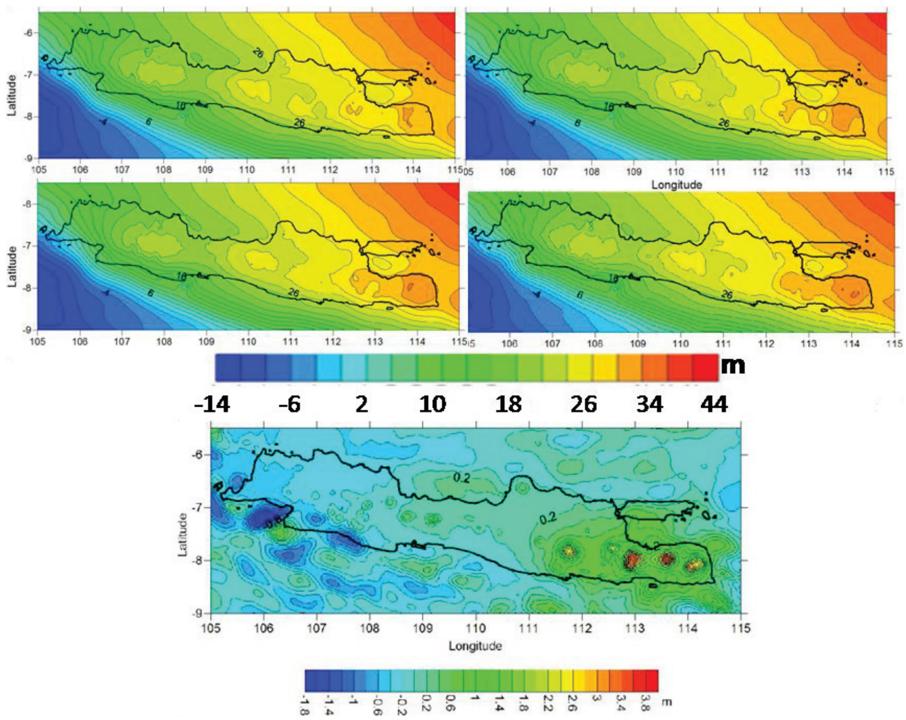


FIGURE 4. The local geoid model using long wavelength from degree of 360, 720, 1800 and 2190, respectively from left to right and above to middle, and differences in local geoid value between degree 360 with 2190 (bottom).

EVALUATION OF DEGREE AND ORDE OF EGM2008 TO THE ACCURACY OF THE LOCAL GEOID OF JAWA ISLAND

The local geoid has been determined using 2D-FFT method [9] and followed the standard remove-restore [2]. Three geoid components have been fulfilled using the SRTM30 data for short wavelength component using RTM method [10], the terrestrial gravity data for middle wavelength and EGM2008 as the long wavelength component. Several level of degree and order of EGM2008 have been used to know an effect of different GGM resolution to the accuracy of the local geoid. Here the local geoid of Java used a different degree of EGM2008 for its long wavelength component, have been obtained with the value range from -14 to 44 m. The pattern is shown for the EGM2008 (Fig. 4), the detailed pattern on local geoid also increased along with the increasing on the degree of EGM2008. It means that the local geoid using a degree of 2190 produced the most detailed geoid model, with increasing in geoid height value range from -1.8 to 3.8 m compare with one obtained using a degree of 360, as shown in Fig. 4.

The absolute accuracy of the locally derived geoid has been obtained a base on a mean difference value between the local geoid and 44 co-site GPS-levelling data, as shown in Tabel 1. The highest accuracy of about 0.5 m, was obtained for local geoid models using a degree of 2190 and the lowest of 0.7 is for geoid model using a degree of 360. Increasing in degree not always followed by increasing the accuracy of the local model or vice-versa. In this study, there is not reveal the systematic relationship between the used of degree with the accuracy of the local geoid, could be done to uneven distribution of terrestrial gravity over the Java island. Logically for the optimal degree was the closer distribution of utilized terrestrial gravity, the lower degree was used. As the local geoid obtained using a degree of 2190 has the highest accuracy, this model used for further steps/computations.

TABLE 1. Comparison of local geoid using different degree of EGM2008 with co-site GPS-levelling data

Degree	Min.	Max.	Mean
360	0,005	2,568	0,641
720	0,056	2,486	0,706
1080	0,005	2,463	0,671
1440	0,000	2,420	0,682
1800	0,026	2,418	0,686
2160	0,022	2,404	0,689
2190	0,007	2,493	0,596

Figure 5 shows the value and direction of the difference of each point between the local gravimetric geoid and the GPS-levelling data. There clearly shown a systematic pattern with mostly negative value occur in the northern part of Middle and East Java and mostly positive value occur in the middle and southern part of Java Island. Based on the evaluation result of Fig. 5, the average value of the differences in Table 4 could be caused by the difference in height reference system, between local gravimetric geoid referenced WG4 and GPS-levelling data referenced to local Mean Sea Level.

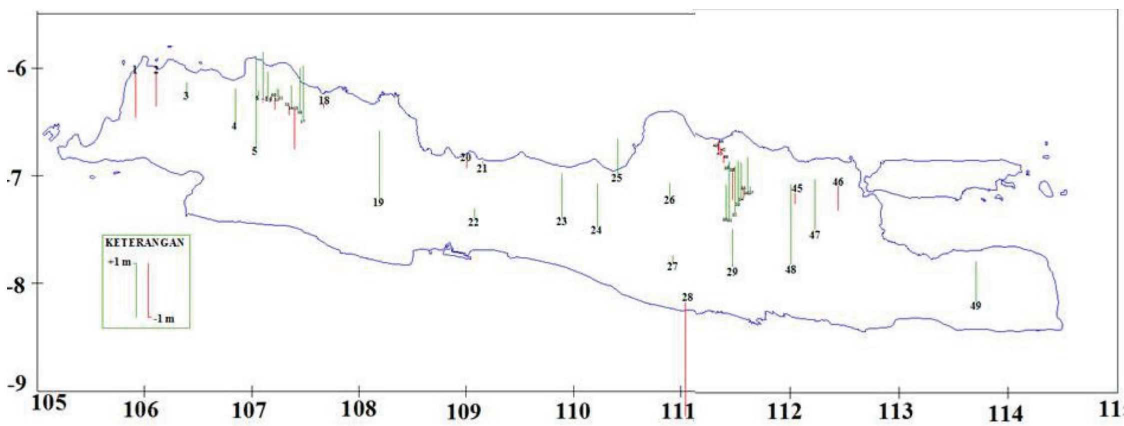


FIGURE 5. Distribution of GPS-levelling points and their difference value with local geoid (above) and with hybrid geoid (bottom).

SUMMARY AND CONCLUSIONS

Seven GGMs had been evaluated for application to local geoid modeling of Java Island, with the highest accuracy and consistent results obtained from EGM2008. Furthermore, the degree and order of EGM2008 had been evaluated their effect to the accuracy of local geoid model. The results showed that the accuracy of the local geoid was range from 0.7 m to 0.5 m derived using a degree of 720 and 2190, respectively, with the local geoid obtained using a degree of 2190 has the highest accuracy.

ACKNOWLEDGMENTS

This paper has been developed from many works with grants from Directorate General of Higher Education, Republic of Indonesia and PT Pertamina. I thank the Center for Geological Research and Development (P3G) as a source of some terrestrial gravity data, and Geospatial Infomation Agency (BIG) for collaboration on terrestrial gravity measurement. I also thank alumni Yanda, Riza, List, Heri, Ramadhan and Bagas for help on fields measurement and data processing.

REFERENCES

1. Anonyms, Population of Indonesia by Province 1971, 1980, 1990, 1995, 2000 and 2010 (in Indonesian), https://www.bps.go.id/linkTabelStatis/view/id/1267 (2015).
2. B. Hofmann and W.H. Moritz, *Physical Geodesy* (Springer Wein, New York 2005).
3. L. S.Heliani, "Determination of Indonesian Geoid from Combination of Surface Gravity, Satellite Altimetry and Global Terrain Model Data", Doctoral Dissertation, Kyoto Univesity, 2003.
4. N. K. Pavlis, S. A. Holmes, S. C. Kenyon, and J. K. Factor, 2008, J. Geophys Res **117**, B04406 (2008)
5. G.N. Guimarães, A. C. O. C. Matos, and D. Blitzkow, Journal of Geodetic Science **2**, 144-155 (2012).
6. GETECH, The South East Asia Gravity Project – Indonesia, Technical Report, University of Leeds, UK, June, 1995.
7. Kahar J. Kahar J, A. Kasenda and K. Prijatna, , "The Indonesian Geoid model 1996", In *Segawa J, Fujimori H, Okubo S (eds) Gravity, Geoid and Marine Geodesy*, International Association of Geodesy Symposia 117, (Springer, Berlin, 1997), pp. 613-620,
8. J. J. Becker, D.T. Sandwell, W. H. F. Smith, J. Braud, Binder, J. Depner, D. Fabre, J. Factor, S. Ingalls, S. H. Kim, R. Ladner, K. Mark, S. Nelson, A. Pharaoh, R. Trimmer, J. Von Rosengerg, G. Wallace, and P. Weatherall, Marine Geodesy **32**, 355 – 371 (2009).
9. C.C. Tscherning, R. Forsberg and P. Knudsen, "The GRAVSOFT package for geoid determination", Proc 1st IAG Continental Workshop of the Geoid in Europe, edited by Holota P, Vermeer M (International Assiciation of Geodesy, Prague, 1992), pp 327-334.
10. Forsberg R., Bull. Geod. **59**, 342 – 360 (1985).
11. F. G. Lemoine, D. E. Smith, L. Kunz, R. Smith, E. C. Palvis, N. K. Palvis, S. M. Klosko, D. S. Chinn, M. H. Torrence, R. G. Williamson, C. M. Cox, K. E. Rachlin, Y. M. Wang, Sc. Kenyon, R. Salman, R. G. Trimmer, R. H. Rapp, and S. Nerem, "The development of the joint NASA GSFC and DMA joint geopotential model". In: Segawa J, Fujimori H, Okubo S (eds) Gravity, geoid and marine geodesy, International Association of Geodesy Symposia 117, (Springer-Verlag Berlin Heidelberg, Berlin, 1997), pp. 461-469.