High Resolution Technology of Shuttle Radar Topography Mission for Geoid Model

Tang K.M., Zulkarnaini M.A., and Ami Hassan M.D.

Abstract**—**Currently, more sophisticated technology affects variety of consumables for specific implementations instance of online searching through website for part of earth geoid model generating. A lot of earth data available online access particularly from international agencies. Shuttle Radar Topography Elevation Model (SRTM) data was among online global data Digital Elevation Model (DEM) will be used. Together with SRTM data, terrestrial data for gravity and levelling will be engage for this empirical study. Meanwhile, usefulness applications for least square modification stoke formulae. Apart from this, different resolution comparison of SRTM data with local vertical datum will be done for Klang Valley. From result obvious shows that high resolution of SRTM will be obtained better result in term of empirical standard deviation.

Keywords**—**SRTM, least square modification, stokes formulae, geoid model.

I. Introduction

Recently, a lot of earth surface information can be gathered by online searching especially from international recognized agency. It can be done by using internet medium or technology. One of famous online tools for earth surface information is Google Earth. It is easy and user-friendly as well as obvious information on any locations. However, Geographic Information System (GIS) was strength trends with various scales at the behind of operation.

Consequently, other source of earth information particularly for specific purpose usage was online terrain or topographic earth surface information. For instance Shuttle Radar Topography Mission (SRTM), GTOPO30, GLOBE and ETOPO are called global Digital Elevation Models (DEM). All these DEM data are delegated with various acquisition data in their structure and user consider with impact of error for implementation [1].

For empirical investigation, SRTMs data will be highlighted in this paper rather than other DEMs data in term of standard deviation. SRTM data able to provide full essential task on terrain or topographic at earth surface and associated with others purpose application instance of engineering works. Main factor for on terrain or topographic data accuracy was data source of global DEM resolution [2]. Obviously, more accurate information of DEM will generate better accurate output.

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Essential of contribution for this study will provide a lot of benefits particularly services for professionals. For instances, surveyor, engineer, geologist and hydrographer or oceanographer of their profession implementation instance of surveying, engineering, construction work, dredging and searching purpose. This paper will investigate SRTM resolution by comparing with local vertical height that was collected. The comparison and analysis will be made based on differential resolutions in term of empirical standard deviation. Moreover, it is useful for geoid model generation using least square modification of Stokes formulae.

II. Shuttle Radar Topography Mission (SRTM)

SRTM was part of domain global DEM which represent earth surface to determine terrain and downward continuation corrections on an undulation geoid model. Conversely, SRTM usually will be affected by inconsistent erroneous due to structuring with several acquisition data sources. It developed by 30” resolution topographic database for terrain correction and residual of terrain being used for any surface gravity data. Coverage of SRTM majoring with accurate elevation data on land areas with available of altimetry sources [3].

This global elevation model was developed in collaborative of the National Aeronautics and Space administration (NASA), Germany Space Agency, Italian Space Agency and National Imagery and Mapping Agency (NIMA) using satellite imaginary information. While for public domain, only a global terrain data with resolution of 30’’ (approximate 90 metre) are available and for 1” resolution requires approval by NIMA.

Nevertheless, SRTM does not cover water terrain areas i.e. bathymetric data. A new edition of STRM, i.e. SRTM30 was developed based on one (1) kilometre average of topographic DEM grid particularly in high attitude areas. Fig. 1 shows SRTM data being used for Klang Valley area with location latitude of $2°<\phi<4°$ and longitude of $100°30'<\lambda<102°$.

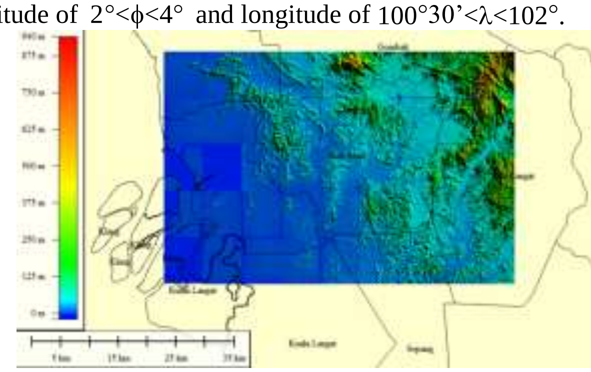

Fig.1 SRTM data of Klang Valley

III. Local Vertical Datum And Leveling Network

Vertical datum of Malaysia was established and embarked at Port Klang in 1908. Again, local survey datum was set up to Kuala Lumpur in 1912 with 8 months tidal observations. Whilst First Order Levelling Network was set up in 1967 and following with second vertical control network called Precise Leveling Network (PLN). An investigation and efforts have been done in 1977 where it is found that 40% of benchmarks were missing or damaged. Thus, all missing and damaged benchmark were establishing back with proper designs. Subsequently, all PLN stations were done with better accuracy and tidal observations network at the same time along coast of Peninsular to redefine vertical datum. Simultaneously, all benchmarks were performed with gravity measurement in order to derive orthometric corrections for leveling network had been erected.

Subsequently, Peninsular Malaysia Geodetic Vertical Datum (PMGVD) was set up in 1983 as new datum with 10 years tidal observation and Port Klang station was selected as reference station. Result shows that new mean sea level (MSL) adopted as 3.624 metre above zero tide gauge and PMGVD lower than local survey datum about 0.065 metre.

Consequently, precise leveling network was set up involving 5,443 benchmarks with 113 first orders leveling as well as 22 loops to cover the entire networks. Fig. 2 shows precise leveling network completed in 1999 and precise leveling network are fitted with 0.003 meter at first class order and 0.012 meter at second order spirit of levelling [12].

Fig.2 Precise Leveling Networks

IV. Gravity Data

Department of Survey and Mapping Malaysia (DSMM) had engaged gravity data with collection of first and third order terrestrial gravity data as well as airborne gravity data. All gravity data can be accessed from Malaysians Gravity Database. Reliable status of gravity data for whole Malaysia is shown in Fig. 3. This is obtaining better estimated accuracies for cross-over below 2 mgal [19].

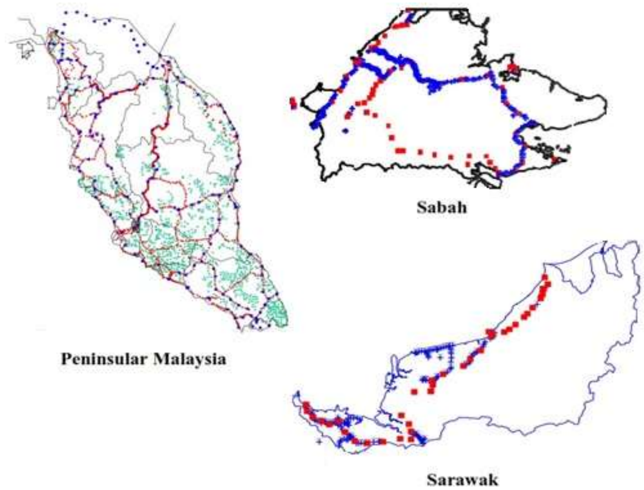

Fig. 3 Malaysian Gravity Data

Fig. 4 shown 1,266 terrestrial and airborne data used for this empirical study. All engaged data had been qualified and endorsed with global positioning system (GPS). All gravity anomalies data were required to be downward continued to surface by least square collocation using planar algorithm covariance model before applying Stokes formulae. This downward continued term refer to geoid surface which is equivalent to mean sea level [4].

Fig. 4 Point of terrestrial and airborne data for empirical study

Meanwhile, airborne gravity data measured according to equation as (1) in the field as following.

$$g = a - h'' - \delta g_{eot} - \delta g_{tilt} - y_0 + g_0 + \gamma_0 + 0.3086(h-N) \quad (1)$$

Where a is an acceleration along vertical, h" is vertical derived from GPS, g_0 is gravity reference, h is an ellipsoidal height, N is geoid height, δg_{tilt} is platform tilt correction, $\delta g_{eo}t$ is correction due to earth rotation and γ_0 is normal gravity at sea level.

In addition, airborne gravity data can be determined from a few kilometers height with gravimeter setup on plane. Nevertheless, it was no sufficient to geoid at sea level of free air anomaly by constant gradient of -0.3086 mGal/m. Thus, normal gravity for geoid model shall be expressed in (2) following. Every four (4) kilometers ellipsoid height will contribute 1 mGal bias [5]. It was more effects to mountains areas particularly.

$$\gamma = \gamma_0 + \frac{\delta\gamma}{\delta h}(H - N) + \frac{\delta^2\gamma}{\delta h^2}(H - N)^2 \qquad (2)$$

Where all parameters are same as defined in equation (1) with addition of H is the orthometric height, γ is normal gravity on ellipsoidal reference and $\frac{\delta\gamma}{\delta h}, \frac{\delta^2\gamma}{\delta h^2}$ are the first and second differential of normal gravity and height, respectively.

All airborne gravity data downward continuous equal to zero level. It's free of bias using least square collocation and represented on weighted averages and covariance functions with simple filtering which is low pass filtering operation.

V. Least Square Modifications Of Stokes Formulae

Geoid height determination was based on disturbing gravity data engaged with original Stokes formula [6-10] expressed on (3).

$$N = \frac{R}{4\pi\gamma}\iint_{\sigma o} S(\Psi)\, \Delta g\, d\sigma \qquad (3)$$

where;

R	is mean earth radius
γ	is normal gravity on ellipsoid reference
$S(\Psi)$	is stokes function
Δg	is gravity anomaly on geoid
$d\sigma$	is surface element of unit sphere σ

Klang Valley area had been integrated with low-frequency component of terrestrial gravity combined with SRTM data high-pass filtering. Thus, modification of stokes formula was applied to minimize potential of coefficients and gravity anomaly error during least square processing to increase quality of geoid with high aim quasi geoid to harmonic that geoid height. Modified stokes formula expressed equation on (4) [9-11].

$$N' = \frac{c}{2\pi}\iint_{\sigma o} S^L(\Psi)\Delta g d\sigma + c\sum_{n-2}^{L} b_n\, \Delta g_n^{GGM} \qquad (4)$$

where;

C	is $\frac{R}{2\gamma}$ (R and 2γ defined below)
R	is mean earth radius
γ	is mean normal gravity on reference ellipsoid
σo	is spherical cap
Δg	is mean of terrestrial gravity anomaly
$d\sigma$	is surface element
$S^L(\Psi)$	is modification of stokes function limited L
Ψ	is spherical distance
Δg_n^{GGM}	is Laplace harmonic of degree n for GGM
b_n	is $S_n + Q_n^L$; $2 \le n \le M$
S_n	is modification of parameter
Q_n^L	is Molodensky truncation coefficients of limited L

Application of Stokes formula is to reduce disturbing to sea level in order all the effect of tilts and biases are revoked. Thus, additive corrections will be added to geoid model by expression (5) following.

$$N = \frac{R}{4\pi\gamma}\iint_{\sigma o} S^L(\Psi)\Delta g d\sigma + \frac{R}{2\pi}\sum_{n=0}^{M}(Q_n^L + S_n)\Delta g_n^{GGM} + \delta N_{comb}^{T} + \delta N^{DWC} + \delta N_{comb}^{a} + \delta N^{e} \qquad (5)$$

where;

δN_{comb}^{T}	is combined topographic effect [13-14]
δN^{DWC}	is downward continuation effect [15]
δN_{comb}^{a}	is combined atmosphere effect [16]
δN^{e}	is ellipsoidal effect [13, 17-18]

VI. Results And Analysis

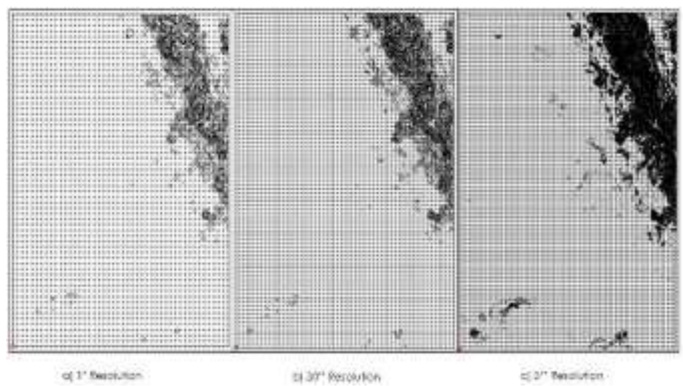

Fig.5 Comparison of different resolution SRTM

A total of 1,266 points throughout Klang Valley area were engaged with SRTM to produce vertical height (H) for geoid model.

Simultaneously, SRTM's vertical height will be associated with local datum i.e. Peninsular Malaysia Geodetic Vertical Datum (PMGVD).

Fig. 5 shows comparison of resolution SRTM dataset that had been used on this empirical study. Obviously, 3" resolution of SRTM data grant more vertical data and given influence of impression for contribution results.

Table 1 shows that residual of different resolution SRTM height with local vertical height.

Table 1: Vertical Height With Different Resolution Of Srtm

Values	H_{local}	$H_{SRTM\,1"}$	$H_{SRTM\,30"}$	$H_{SRTM\,3"}$
Maximum	186.158	86.983	66.782	39.806
Mini	-7.829	-86.977	-36.981	-17.147
Mean	25.722	5.696	5.299	3.871
SD	26.175	13.006	9.143	4.686
RMS	5.306	3.611	3.024	2.165

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TABLE 1 shows different resolution of SRTM that influence impression of generating geoid model. SRTM with resolution 3" is better than 30" and 1' as well as local vertical height. Root Mean Square (RMS) with 3" resolution SRTM is 2.165 metre compared with 1' resolution 3.611 metre. RMS of this study is expressed by (6).

$$\mathrm{RMS} = \pm\sqrt{\sum_{i=1}^{n}\frac{(H_{SRTM}-H_{LVH})^2}{n}} \qquad (6)$$

Where n is number of observation and H_{SRTM}, H_{LVH} are refer to SRTM and leveling heights, respectively.

VII. Conclusions

This empirical study aimed to analyze of resolution SRTM effect and determine vertical of height for multi disciplines of geodesy application particularly in geoid modeling. Three resolutions of SRTM were delegated and associated with local vertical height. These also together with leveling and gravity data provide from database. Results show that better resolution with 3" rather than 1' resolution on SRTM data to engaged. Definitely, more data gathering will minimize erroneous and will distribute among data with masses surrounding observation point.

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