Geoid Model Estimation without Additive Correction Using KTH Approach for Peninsular Malaysia

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Overview

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Introduction

- Geoid Model – Vital information in determination of orthometric height via GNSS technology
- Determination of precise geoid model – global agenda.
- There are several approaches can be used in determination of geoid height such as Remove Compute Restore, UNB Stoke Helmerts and KTH approach.
- In this study, the geoid height is computed using KTH approach.

KTH APPROACH

- Initiated by Lars E. Sjöberg in 1984.
- Also known as Least Square Modification of Stokes'
- The main goal of this approaches is to minimize the expected global mean squares errors.
- Surface gravity anomaly without any reduction process is used in this approaches.

$$N = \underbrace{\boxed{\tilde{N}}}_{\text{Estimation Geoid}} + \underbrace{\boxed{\delta N_{comb}^{Topo} + \delta N_{dwc} + \delta N_{Tot}^{Atm} + \delta N_{Tot}^{Ell}}}_{\text{Additive Correction}}$$

KTH APPROACH

- The most fundamental formula in computing geoid height is Stokes's formula (Hofmann & Moritz, 2005).

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

- Gravity anomaly –located on geoid surface.
- Assume that no masses outside the geoid.

KTH APPROACH

- Modified Stokes' Formula (KTH approach)

$$\tilde{N} = \frac{R}{4\pi\gamma} \iint_{\sigma_0} S_L(\psi)\, \Delta g^{o} d\sigma - \frac{R}{2\gamma} \sum_{n=2}^{M} (Q_n^L + s_n)\, \Delta g_n^{GGM}$$

Where:

S_L = Modified Stoke's function $S_L = S(\psi) - \sum_{n=2}^{L} \frac{2n+1}{2} s_n P_n(\cos\psi)$

Q_n^L = Molodensky truncation coefficient $Q_n^L = Q_n(\psi_o) - \sum_{n=2}^{\infty} \frac{2k+1}{2} s_k E_{nk}(\psi_o)$

s_n = Modification parameters

Δg^{O} = Land Observed Gravity Anomaly

Δg_n^{GGM} = GGM Gravity Anomaly

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KTH APPROACH

- Most important element in modified Stoke's formula is Modification Parameters (s_n)
- Modification Parameters (s_n) need to determine accurately.
- S_n solve by Least Square.
- The quality of S_n is depending to the quality of land observed gravity data, radius of integration cap (Ψ_o) and the characteristics of the GGM.

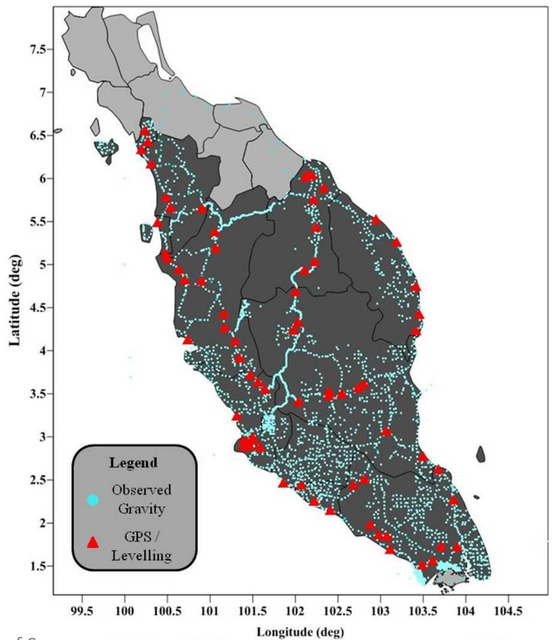
DATA USED

- **Land Observed Surface Gravity data**

➢ 3500 Land Observed Surface Gravity data.

➢ QC using cross validation

➢ 3224 passed and used in geoid determination



DATA USED

- **Global Geopotential Model**
  - ➢ GOCO01s – pure satellite
  - ➢ Composed : GOCE + GRACE
  - ➢ Degree and order up to 224

DATA USED

- **Digital Elevation Model**
  - ➢ Combined 3arc second DSMM Digital Elevation Data (DTED) and 30 second SRTM data
  - ➢ Mountainous area :- DSMM DTED
  - ➢ Flat area:- SRTM data
  - ➢ Used for interpolation and converting point to grid free air anomalies

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DATA USED

- **GNSS/GPS leveling**
  - 70 GNSS/GPS levelling points
  - Used to external and independent tools to estimate the accuracy of geoid height in absolute sense.
  - GNSS/GPS levelling point was observed on the Benchmark or Standard Benchmark

NUMERICAL COMPUTATION

- The modification parameter (s_n) need to be determine accurately
- Elements that contribute in accuracy of modification parameter (s_n) are:
  - Upper Limits of the GGM **(M)** and Stokes' Function **(L)**
  - Spherical cap **(Ψ_o)** and correlation distance **(Ψ)** around computation points
  - Estimation errors in observed land gravity data **($\sigma_{\Delta g}$)**.

NUMERICAL COMPUTATION

- Elements examined in the determination of the Modified Coefficient Parameter

M=L	Integration Cap (Deg)	Correlation Length (Deg)	Terrestrial Error (mGal)
30			
60	0.1	0.05	0.40
120	0.5	0.10	1.00
150	1.0	0.20	5.00
180	2.0	0.30	10.00
max	3.0	0.40	20.00

- One of the input condition parameters is replaced while the remaining condition parameters are fixed.
- The second condition parameter will be replaced and the process is repeated.

RESULT AND ANALYSIS

- The optimum modification coefficient parameter will be determined by comparing the result of the computed Gravimetric Geoid Model with known GPS/levelling datasets used in this study.

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RESULT AND ANALYSIS

Step	Parameter	Different Option					
1	M=L	30	60	120	150	**180**	max
	Spherical Cap	3.0					
	Correlation Length	0.1					
	Terrestrial Error	0.4					
	Min	0.670	0.496	0.286	0.131	**0.121**	0.114
	Max	2.662	2.212	1.380	0.999	**0.939**	0.939
	Average	1.444	1.148	0.582	0.354	**0.338**	0.337
	RMSE	1.524	1.231	0.629	0.388	**0.368**	0.368
2	Spherical Cap		0.1	0.5	1.0	2.0	**3.0**
	M=L	180					
	Correlation Length	0.1					
	Terrestrial Error	0.4					
	Min		0.373	0.331	0.357	0.327	**0.121**
	Max		0.992	1.326	1.436	1.191	**0.939**
	Average		0.632	0.563	0.656	0.517	**0.338**
	RMSE		0.650	0.594	0.696	0.546	**0.368**

RESULT AND ANALYSIS

Step	Parameter	Different Option					
3	Correlation Length		0.05	0.10	0.20	0.30	**0.40**
	M=L	180					
	Spherical Cap	3.0					
	Terrestrial Error	0.4					
	Min		0.134	0.121	0.116	0.121	**0.116**
	Max		0.968	0.939	0.916	0.896	**0.882**
	Average		0.106	0.100	0.096	0.094	**0.092**
	RMSE		0.381	0.368	0.362	0.357	**0.356**
4	Terrestrial Error		0.40	1.00	**5.00**	10.00	20.00
	M=L	180					
	Spherical Cap	3.0					
	Correlation Length	0.4					
	Min		0.882	0.754	**0.689**	0.709	0.755
	Max		0.116	0.042	**-0.028**	-0.001	-0.050
	Average		0.330	0.305	**0.291**	0.289	0.285
	RMSE		0.356	0.330	**0.321**	0.324	0.335

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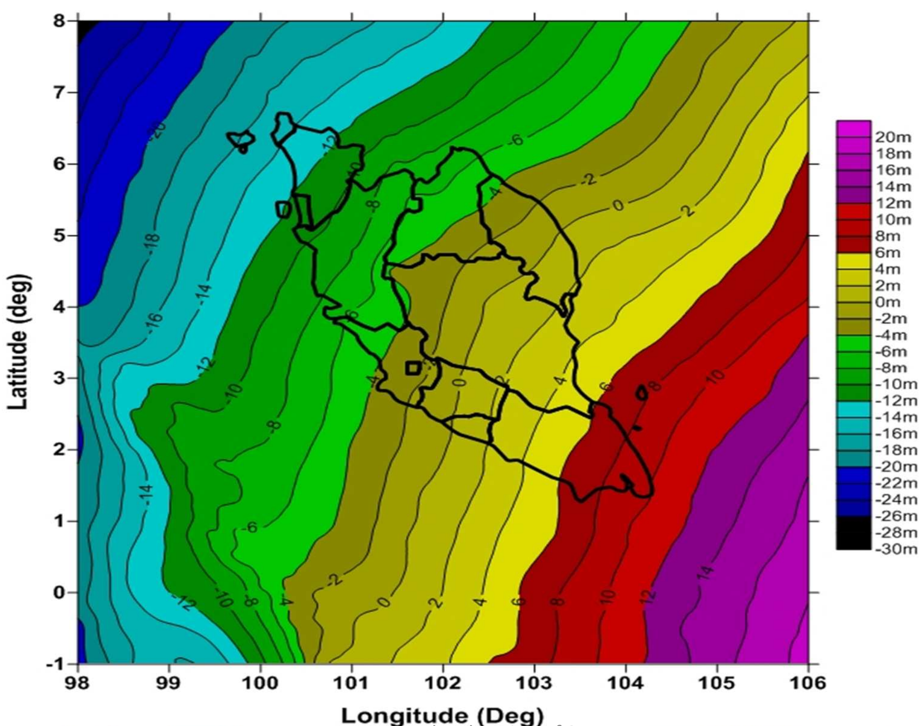
CONCLUSION

- An estimated gravimetric geoid model of Peninsular Malaysia was developed using the KTH approached without additive corrections.
- The estimated geoid model of Peninsular Malaysia is computed based on a set of pre-determined modification coefficients.
- The optimum set of condition parameters: **M=L= 180**, $\mathbf{\Psi_0=3.0^o}$, $\mathbf{\Psi=0.4^o}$ and $\mathbf{\sigma_{\Delta g}= 5.0}$ **mGal.**
- The accuracy of estimated gravimetric geoid model of Peninsular Malaysia is **±32.1cm**

CONCLUSION



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Thank you for your attention!

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