SIMPOSIO SIRGAS 2021
Del 29 de noviembre al 01 de diciembre de 2021

Analysis of the RTM effect for the future IHRS PPTE station from the integration of different methods, with harmonic correction and use of global density model

Tiago Lima Rodrigues
Universidade Federal do Paraná, Programa de pós-graduação em Ciências Geodésicas, Curitiba-PR, Brasil

Introduction

The definition and realization of the International Height Reference System (IHRS) were proposed in 2015 based on Resolution No. 1 of the International Association of Geodesy (IAG). Conventionally, the vertical component will be given by the geopotential number. Regardless of the technique adopted to calculate the geopotential value at each station, in order to obtain the high frequency effects of the gravity field, residual terrain modeling (RTM) is a widely used technique (Forsberg, 1984).

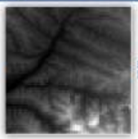
In the context of spatial domain methods, for the practical solution of Newton's Integral, the topographic continuous masses are discretized using elementary mass bodies for which the gravitational effect can be calculated analytically or numerically. Currently, there are approaches based on the use of point-masses, tesseroids, prisms and polyhedra (Yang, Hirt, Pail, 2020).

In terms of strategies for the IHRS the RTM is an open problem, being recommended the identification of the best configuration, contrasting the results with complementary and independent data (Sanchéz et al., 2021).

Therefore, this work aimed to analyze the integration of different approaches, with harmonic correction and the use of the CRUST 1.0 global density model to calculate the RTM effect in the future IHRS PPTE station in Brazil.

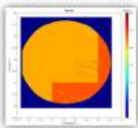
Methodology and numerical tests

MERIT DEM: Multi-Error-Removed Improved-Terrain DEM – 90m
(http://hydro.iis.u-tokyo.ac.jp/~yamada/MERIT_DEM/)



Earth2014 DEM 5' x 5'– 9000m
(http://ddfe.curtin.edu.au/models/Earth2014/data_5min/GMT/)
Bilinear 90m

Residual DEM – 90m

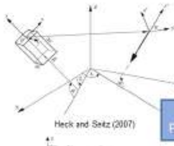


CRUST 1.0 Global Crustal Model
1° x 1°
https://igppweb.ucsd.edu/~gabi/crust1.html

RTM experiment setups

Integration radius for each approach

Setup 1		Setup 2		Setup 3		Setup 4	
	°		°		°		°
Polyhedron	--	Polyhedron	--	Polyhedron	--	Polyhedron	0.02
Prism	1.85	Prism	--	Prism	--	Prism	--
Tesseroid	--	Tesseroid	1.85	Tesseroid	--	Tesseroid	1.85
Point-mass	--	Point-mass	--	Point-mass	1.85	Point-mass	--
Setup 5		**Setup 6**		**Setup 7**		**Setup 8**	
	°		°		°		°
Polyhedron	0.02	Polyhedron	0.03	Polyhedron	0.07	Polyhedron	0.5
Prism	--	Prism	--	Prism	--	Prism	--
Tesseroid	--	Tesseroid	--	Tesseroid	--	Tesseroid	--
Point-mass	1.85	Point-mass	1.85	Point-mass	1.85	Point-mass	1.85



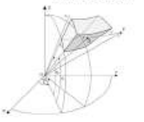
Heck and Seitz (2007)

$$\zeta_{RTM}(x,y,z) = G\rho(\lambda,\varphi,\Delta z)\Delta x\Delta y\Delta z\left[\frac{1}{l_0} + \frac{3(x_0-x)^2 - l_0^2}{24 l_0^5}\Delta x^2 + \frac{3(y_0-y)^2 - l_0^2}{24 l_0^5}\Delta y^2 + \frac{3(z_0-z)^2 - l_0^2}{24 l_0^5}\Delta z^2 + O(\Delta^4)\right]$$

$$l_0 = \sqrt{(x_0-x)^2 + (y_0-y)^2 + (z_0-z)^2}$$

$$\zeta_{HC} = -\frac{4\pi G\rho(\lambda,\varphi,\Delta z)\Delta z^2}{\gamma}$$

HC - mass condensation technique (Forsberg,1984) + Poisson's Equation with horizontal gradients equal to zero



Heck and Seitz (2007)

$$\zeta_{RTM}(r,\lambda,\varphi) = G\rho(\lambda,\varphi,\Delta z)\Delta\lambda\Delta\varphi\Delta r\left[K_{000} + \frac{1}{24}(K_{002}\Delta\lambda^2 + K_{020}\Delta\varphi^2 + K_{200}\Delta r^2) + O(\Delta^4)\right]$$

$$\lambda_0 = \frac{(\lambda_1+\lambda_2)}{2},\ \varphi_0 = \frac{(\varphi_1+\varphi_2)}{2},\ r_0 = \frac{(r_1+r_2)}{2} \qquad \Delta\lambda = \lambda_2-\lambda_1,\ \Delta\varphi = \varphi_2-\varphi_1,\ \Delta r = r_2-r_1 = h_1$$

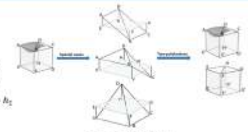
$$l_0 = \sqrt{r^2 + r_0^2 - 2rr_0\cos\psi_0}$$

$$\zeta_{HC} = -\frac{4\pi G\rho(\lambda,\varphi,\Delta z)\Delta r^2}{\gamma}$$

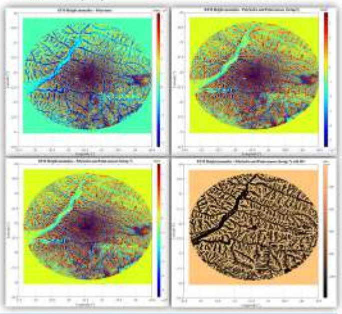
$$\zeta_{RTM}(r,\lambda,\varphi) = G\rho(\lambda,\varphi,\Delta z)\Delta\lambda\Delta\varphi\Delta r[K_{000} + O(\Delta^4)]$$

Point-masses with Tesseroid formulation

Tsoulis (2012) polyhedra algorithm + detection of special cases (Yang, Hirt and Pail, 2020)

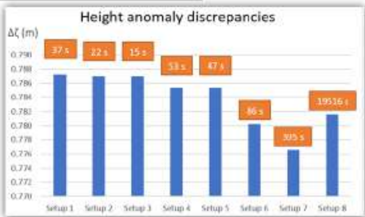


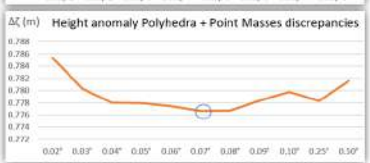
Yang, Hirt, Pail (2020)



$\zeta_{XGM2019e_{2190}} = -4.5682\ m$, $\zeta_{RN/GPS} = -5.3585\ m$
Mean tide System

$$\Delta\zeta = \left(\zeta_{XGM2019_{2190}} + \zeta_{RTM}\right) - \zeta_{RN/GPS}$$





Forsberg, R. A Study of Terrain Reductions, Density Anomalies and Geophysical Inversion Methods in Gravity Field Modelling. The Ohio State University: Columbus, OH, USA, 1984.
Heck B.; Seitz K. A comparison of the tesseroid, prism and point-mass approaches for mass reductions in gravity field modelling. **J. Geodesy**, v. 81, pp.121-136, 2007.
Sanchéz, L.; Agren, J.; Huang, J.; Wang, Y. M.; Makinen, J.; Pail, R.; Barzaghi, R.; Vergos, G. S.; Ahlgren, K.; Liu, Q. Strategy for the realisation of the International Height Reference System (IHRS). **J. Geodesy**, v. 95, n. 33 pp. 1-33, 2021.
Tsoulis, D. Analytical computation of the full gravity tensor of a homogeneous arbitrarily shaped polyhedral source using line integrals. **Geophysics**, v. 77, pp.1–11, 2012.
Yang, M.; Hirt, C.; Pail, R. TGF: A New MATLAB-based Software for Terrain-related Gravity Field Calculations. **Remote Sensing**, v. 12, n. 7, pp. 1-21, 2020.