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Aspects Of The UNB_TopoDens Lateral Density Global Model In Brazil

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Abstract:
This study aims to present the main numerical and graphical aspects of the global variable lateral density model UNB_TopoDens, in the continental region of Brazil. The point spacing is 5'x5' of spherical arc, totaling 101,006 stations. The resulting mean lateral density and its standard deviation were 2424.7 kg/m³ and 200.4 kg/m³, respectively. These values are quite close to those of the regional lateral density model LTD_Brazil, with a lateral density of 2459 kg/m³ and a standard deviation ranging between 8 and 351 kg/m³. The numerical variations between the UNB_TopoDens models and the classic model (Harkness) with a constant global density of 2670 kg/m³ showed variations between 4 and 22% in the national territory. The graphical representations include the numerical differences between the UNB_TopoDens and Harkness models, as well as their visualization in percentage, facilitating the identification of regions with discrepancies between the two mentioned models. The methodology employed allowed the objectives of this study to be achieved.
Key Word: *Lateral density; Global model; UNB_TopoDens; ETOPO1; EIGEN-6C4.*

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I. Introduction

According to Hinze (2003), one of the most widely recognized parameters in geosciences is the average density (ρ_m) of surface rocks in the continental crust, typically assumed to be 2670 kg/m³ (2.67 g/cm³). This value originates from a compilation by William Harkness (1891), who synthesized various studies conducted between 1811 and 1882 to determine a global average for surface rock density. The figure of 2670 kg/m³ is generally accepted as representative of the density of shallow crystalline continental rocks with granitic composition, whose densities range from 2500 to 2800 kg/m³, with an approximate mean of 2670 kg/m³.

Sheng et al. (2019) provide a detailed description of the UNB_TopoDens global model, which characterizes laterally variable topographic densities. The primary challenge in constructing this model lies in the heterogeneous availability of density data worldwide. While some countries and continents possess high-resolution lateral topographic density models, many regions still lack such datasets. To address this gap, several regional and global density models have been developed, primarily using gravity field inversion methods (Bear et al., 1995; Toushmalani & Saibi, 2015; Tenzer et al., 2018). However, the results obtained through gravitational inversion may often be redundant or numerically indeterminate, rendering them unsuitable for various geophysical and geodetic applications.

The UNB_TopoDens model (Sheng et al., 2019) aims to globally represent laterally variable topographic density for two main purposes: To enable more rigorous compensation of topographic effects at a global scale and to serve as a first-order dataset for countries or regions lacking well-documented and defined density distributions.

Several techniques exist for directly estimating density distributions, with the most promising being those derived from seismic velocity data, as employed in the CRUST1.0 model. This model provides density information throughout the crust and upper mantle on a global 1°×1° grid (Laske et al., 2012). Nonetheless, CRUST1.0 is affected by various limitations that may render it unsuitable for certain geoscientific applications. An additional benefit of developing a global model of laterally variable topographic density is the ability to evaluate the representativeness of the 2670 kg/m³ value as a global average. Although this value has been nearly universally adopted, the UNB_TopoDens model offers a means to assess its validity. It is important to note that in the UNB_TopoDens formulation, the value of 2670 kg/m³ was assigned to all data-deficient regions, and therefore should not be considered in the evaluation of a new global average. Furthermore, inland water bodies were excluded from the calculation due to classification issues. Consequently, it is intuitively evident that an ideal global model should be primarily composed of regional density maps.

Hartmann & Moosdorf (2012) developed the GLiM global lithological model, integrating various regional datasets. However, GLiM divides the lithosphere into 15 structural units without providing corresponding density values, necessitating the assignment of appropriate densities to make the model useful. The lithological framework of the UNB_TopoDens density model was derived from the lithological models of Carmichael (1989) and Tenzer et al. (2011). The key difference between these models lies in the datasets used to assign average density values and their respective dispersions. Table 1 refers to the TopoDensC model, which uses Carmichael's densities, while Table 2 presents the TopoDensT model, based on Tenzer et al.'s data. A comparison of sample counts reveals that Carmichael's dataset is predominantly composed of igneous rocks, with significantly fewer samples for sedimentary rocks and virtually no data for metamorphic rocks or other important lithologies such as limestones, evaporites, and pyroclastic rocks. This limitation led the developers of UNB_TopoDens to adopt TopoDensT as the reference model. It is essential to recognize that the most effective method for determining density values is in situ measurement and laboratory analysis. This approach allows for the consideration of factors such as porosity, fracturing, and mineralogical variations. With a representative dataset, it becomes possible to evaluate the average density and its dispersion. For lithologies with limited variability, where dispersion cannot be reliably assessed, it is assumed that the range of values falls within a 95% confidence interval for standard deviation estimation. Assuming a normal distribution and that the median density value represents the mean, the standard deviation can be calculated using Equation 1 (Vaníček & Krakiwsky, 1986).

$$\sigma_\rho = \frac{\rho_{max}-\rho_{min}}{2 \cdot \sqrt{\xi_{\chi^2(1,95\%)}}} \quad (1)$$

σ_ρ, standard deviation for a given lithological class;
ρ_{max}, maximum density value within the class;
ρ_{min}, minimum density value within the class;
$\xi_{\chi^2(1,95\%)}$, vcritical value of the one-dimensional Chi-square distribution at the 95% confidence level;

The mean density and standard deviation for the lithologies in the UNB_TopoDens model were calculated by combining the lithological classes from Tenzer et al. (2011) using Equations 2 and 3.

$$\bar{\rho} = \frac{\sum \rho_i}{\sum (n_i - 1)} \quad (2)$$

$\bar{\rho}$, mean density of the lithological model;
ρ_i, mean density of lithological class i;
n_i, number of samples in lithological class i;

$$\sigma_{\bar{\rho}} = \sqrt{\frac{\sum[(n_i-1).\sigma_i^2]}{\sum(n_i-1)}} \quad (3)$$

$\sigma_{\bar{\rho}}$, standard deviation of the mean density of the lithological model;
$\sigma_{\rho_i}^2$, variance of the mean density of lithological class i;

For regions lacking lithological information, a mean topographic density value of 2670 kg/m³ (Hinze, 2003) and a standard deviation of 800 kg/m³ (estimated based on the range of all density values in the model) were assigned, as noted by Sheng et al. (2019). Figures 1 and 2 present the global aspects of the mean values and their respective dispersions, respectively, of the UNB_TopoDens laterally variable topographic density model, based on a 5’×5’ spherical grid, as described by Tenzer et al. (2021).

Table 1 – Carmichael dataset (Adapted from Sheng et al, 2019).

Model lithology	ρCm (kg/m³)	σC (kg/m³)	Max ρCm (kg/m³)	Min ρCm (kg/m³)	Sample size
Acid Plutonic	2660	60	2720	2600	334
Acid Volcanic	2510	130	2640	2380	94
Basic Plutonic	2950	140	3090	2810	98
Basic Volcanic	2740	470	3210	2270	323
Carbonate Sedimentary	1650	50	1700	1600	-
Evaporite	2870	50	2920	2820	-
Intermediate Plutonic	2860	120	2980	2740	68
Intermediate Volcanic	2650	130	2780	2520	197
Metamorphic	2860	60	2920	2800	-
Mixed Sedimentary	2180	160	2340	2020	-
Pyroclastic	2230	220	2450	2010	-
Siliciclastic Sedimentary	2220	230	2450	1990	107
Unconsolidated Sediments	1770	280	2050	1490	-

Table 2 – Tenzer et al. dataset (Adapted from Sheng et al, 2019).

Model lithology	ρTm (kg/m³)	σT (kg/m³)	Max ρTm (kg/m³)	Min ρTm (kg/m³)	Sample size
Acid Plutonic	2227	221	2448	2006	783
Acid Volcanic	2227	221	2448	2006	783
Basic Plutonic	2854	147	3001	2707	304
Basic Volcanic	2768	162	2930	2606	340
Carbonate Sedimentary	2484	211	2695	2273	156
Evaporite	2695	278	2973	2417	11
Intermediate Plutonic	2791	121	2912	2670	201
Intermediate Volcanic	2567	171	2738	2396	449
Metamorphic	2768	131	2899	2637	789
Mixed Sedimentary	2330	267	2597	2063	1782
Pyroclastic	2112	268	2380	1844	1673
Siliciclastic Sedimentary	2526	220	2746	2306	1584
Unconsolidated Sediments	2074	278	2351	1796	59

Figure 1 – Global aspect of the UNB_TopoDens lateral density model (Tenzer et al, 2021).

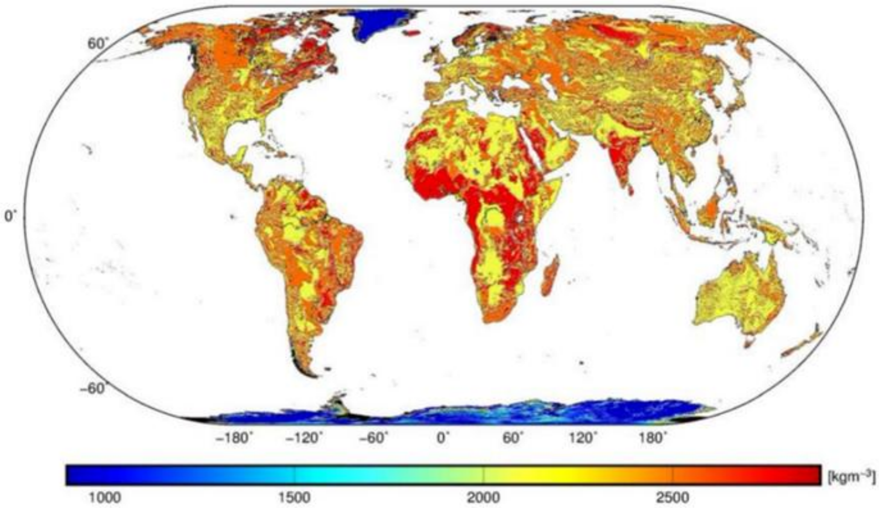
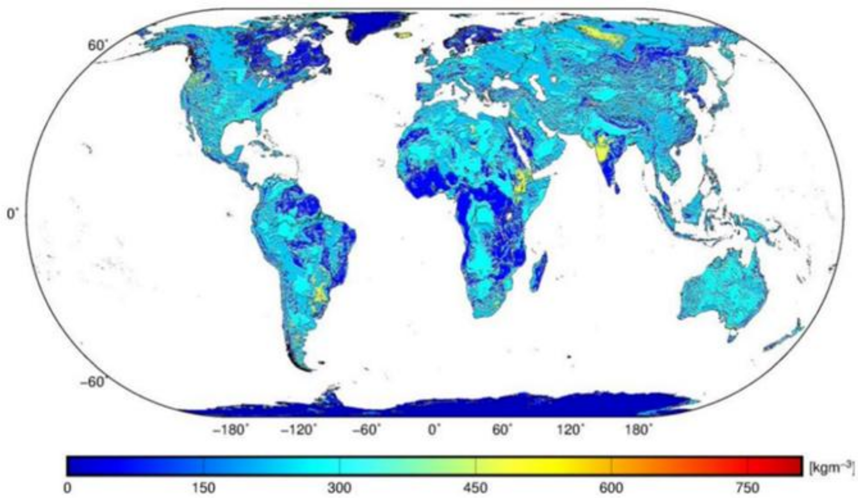


Figure 2 – Global aspect of the uncertainties in the UNB_TopoDens lateral density model (Tenzer et al, 2021).

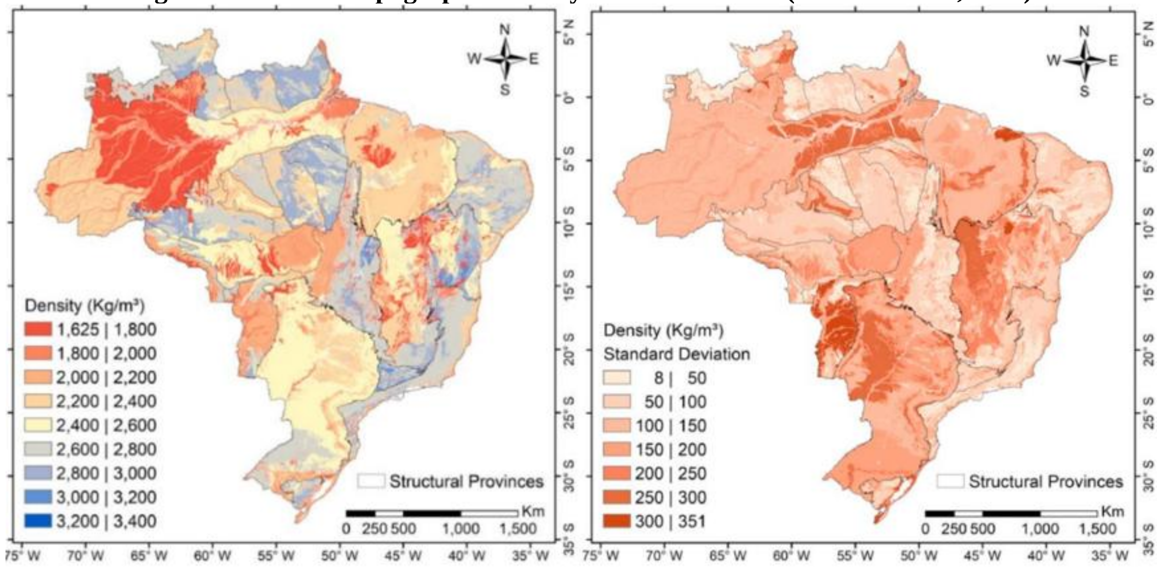


In its initial version, the UNB_TopoDens model presents a global framework of laterally variable topographic densities distributed over a dense grid, constructed without the use of gravitational inversion techniques. The final products of this first approximation include topographic density values at three distinct grid resolutions (30″, 5′, and 1°), along with their associated standard deviations at the same spatial intervals. In addition to these products, two new estimates of global mean topographic density were calculated and compared: 1867 kg/m³ (including Antarctica) and 2247 kg/m³ (excluding Antarctica), relative to the commonly accepted value of 2670 kg/m³. The UNB_TopoDens model was globally validated using data from the CRUST1.0 model and regionally compared against three independent datasets (Canada, CONUS, and the Czech Republic/Slovakia).

Following these comparisons, the UNB_TopoDensT variant demonstrated marginally superior performance and is recommended over the UNB_TopoDensC version. On a global scale, the UNB_TopoDens model exhibits a mean difference of 29 kg/m³ and a root mean square error (RMSE) of 163 kg/m³. The primary discrepancies between the UNB model and various regional models stem from differing conceptual approaches to areas covered by water and ice. For instance, in Brazil, flooded inland regions were assigned a water density value of 1020 kg/m³. Further reflection and refinement are required, involving considerations of water and ice depth, as well as a more detailed subdivision of the 15 original lithological units defined in the GLiM model (Sheng et al., 2019).

Medeiros et al. (2021), as illustrated in Figure 3, developed a lateral topographic density model for Brazil (LTD_Brazil), incorporating consolidated density values and their respective dispersions for each rock type included in the model. The topographic mass density data were compiled at a spatial resolution of 30″ × 30″ arcseconds. The model is based on rock density data obtained through an extensive literature review and lithological information extracted from a 1:2,500,000-scale geological map provided by the Brazilian Geological Survey (CPRM). One of the findings reported by Medeiros et al. (2021) indicates that, for Brazil, the average topographic density is 2459 kg/m³ (LTD_Brazil), which differs from the commonly adopted value of 2670 kg/m³ for the Earth's crust (Hinze, 2003). The estimated results from the LTD_Brazil model were compared with those from the UNB_TopoDens model to identify spatial differences. The observed discrepancies are likely associated with the more detailed lithological unit definitions and the differences in scale or reference maps used in comparison to the global model.

Figure 3 – Lateral Topographic Density Model for Brazil (Medeiros et al, 2021)

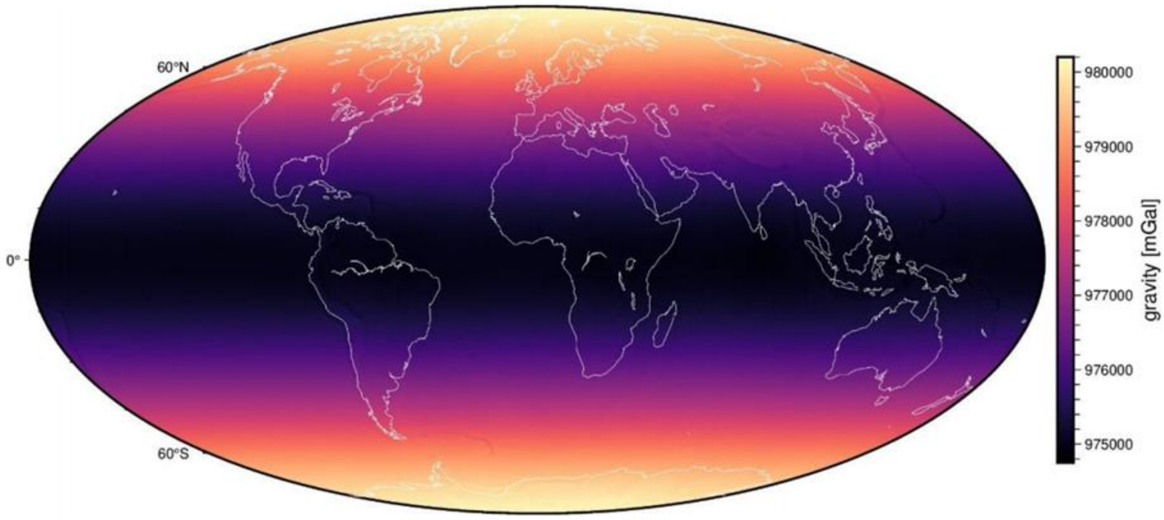


In August 2008, the National Geophysical Data Center (NGDC), a division of the National Oceanic and Atmospheric Administration (NOAA), developed the ETOPO1 Global Relief Model (Figure 4) as an improvement over ETOPO2v2. ETOPO1 provides two versions: Ice Surface (representing the surface of the Antarctic and Greenland ice sheets) and Bedrock (representing the base of the ice sheets). Both versions were generated from a wide range of global and regional digital datasets, harmonized to common horizontal and vertical datums, and subsequently evaluated and edited as needed. The bathymetric, topographic, and coastline data used in ETOPO1 were sourced from NGDC, the Antarctic Digital Database (ADD), the European Ice Sheet Modeling Initiative (EISMINT), the Scientific Committee on Antarctic Research (SCAR), the Japan Oceanographic Data Center (JODC), the Caspian Environment Programme (CEP), the Mediterranean Science Commission (CIESM), NASA, the National Snow and Ice Data Center (NSIDC), the Scripps Institution of Oceanography (SIO), and the Leibniz Institute for Baltic Sea Research (LIBSR). ETOPO1 is vertically referenced to mean sea level and horizontally referenced to the World Geodetic System 1984 (WGS84). Its spatial resolution is 1′ × 1′ (NOAA, 2009).

Figure 4 – Global Aspect of the ETOPO1 Relief Model (NOAA, 2009)

Foerst et al. (2014) describe EIGEN-6C4 (Figure 5) as a static global combined gravity field model up to degree and order 2190, developed jointly by the German Research Centre for Geosciences (GFZ) in Potsdam and the Groupe de Recherche de Géodésie Spatiale (GRGS) in Toulouse. The combination of satellite and terrestrial datasets was performed using normal equations (up to degree 370), derived from observation equations of spherical harmonic coefficients. A brief overview of the techniques used to generate this combined static gravity field model is provided by Shako et al. (2013). The resulting solution up to degree/order 370 was extended to degree/order 2190 in blocks, incorporating data from the DTU10 Global Gravity Field and Mean Sea Surface – Arctic Improvements.

Figure 5 – Global Aspect of the EIGEN-6C4 Gravity Model (Forest et al, 2014)



This study aims to present the main characteristics of the lateral topographic mass density model, UNB_TopoDens, within the Brazilian territory. Particular emphasis is placed on the numerical and graphical identification of regions where the UNB_TopoDens model converges with or diverges from the classical model—defined by a constant global mean density of 2670 kg/m³, as proposed by Harkness (1891)—as well as the average lateral density value derived from UNB_TopoDens for Brazil.

The motivation for this work stems from the widespread use of Harkness's constant density value by researchers and practitioners in various stages of geodetic and geophysical studies. By highlighting spatial zones of greater or lesser sensitivity between models, this study enables users to better assess the implications of adopting variable density models across the Brazilian continental domain.

Additional aspects addressed include the relationship between the UNB_TopoDens model and orthometric heights of topographic masses, using the global altimetric model ETOPO1 as a positional reference, and the corresponding gravity values derived from the global gravity field model EIGEN-6C4. These comparisons contribute to a more comprehensive understanding of how lateral density variations influence altimetric and gravitational modeling in Brazil.

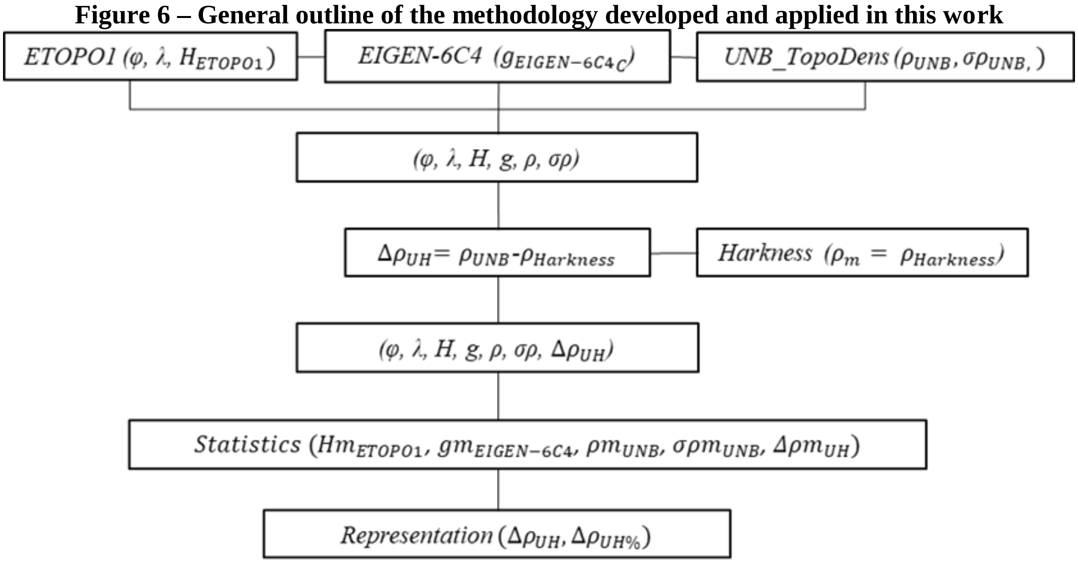
II. Material And Methods

The methodology developed in this study is summarized in Figure 6, assuming a predefined location of interest for its application. The first stage involves defining the data groups to be used, based on the purpose of the study. Essential to this process are the global density values from the UNB_TopoDens model (including their standard deviations), considering the relationship between topographic masses above mean sea level and their effects on the gravitational field. The global relief model ETOPO1 was adopted for geodetic positioning (latitude and longitude) of the stations and their respective orthometric heights.

Given the relationships between gravity values and lateral densities, the global gravity field model EIGEN-6C4 is employed to associate and/or identify potential combined effects among the three data groups. In the second stage, the three datasets are compiled into a single file, ensuring that all stations (points) share the same geodetic position (latitude and longitude), along with the corresponding information: orthometric height, density, density standard deviation, and gravity.

During the third stage, numerical differences between the UNB_TopoDens density model and the classical average value of 2670 kg/m³ (Harkness, 1891) are calculated, and these differences are added to the unified dataset from the previous stage. Next, in the fourth stage, fundamental statistics are calculated for the variables grouped in stage three, aiming at their quantification and qualification. The fifth stage is dedicated to graphical representations of the variations between the UNB_TopoDens and classical (Harkness) density models.

Figure 6 – General outline of the methodology developed and applied in this work



III. Result

The application of the developed methodology, as presented in the previous section, begins with defining a location of interest for its application, in this case, the continental territory of Brazil. The reference for evaluating the behavior of the UNB_TopoDens model is the global mean density (ρm) of 2670 kg/m³ (Harkness, 1891). The computational tools used in this study were: Google Chrome (data search and access), Microsoft Office 365 (editing, calculations, graphs, and statistical tables), MathWorks Matlab (grouping, formatting, and processing), and Golden Software Surfer (graphical representations). For data processing, we opted for spacing the stations in a regular grid of 5'x5' of spherical arc, which resulted in 101,006 points covering the entire Brazilian territory. The horizontal and vertical datums, common to the global models UNB_TopoDens (UNB, 2023), ETOPO1 (NOAA, 2009), and EIGEN-6C4 (ICGEM, 2019), are, respectively, the World Geodetic System 1984 (WGS84) ellipsoid and the mean sea level (geoid). These datums have the same basic conception as the Geocentric Reference System for the Americas (SIRGAS2000), which is officially used by Brazil (IBGE, 2015). Therefore, the positioning of the stations was considered without the need for geodetic connections, based on the scope of the present work and the grid spacing. The global models and their respective aspects can be viewed in the following sequence of Figures: ETOPO1 (Figure 7), EIGEN-6C4 (Figure 8), and UNB_TopoDens (Figures 9 and 10).

Figure 7 – Aspect of the ETOPO1 altimetric model in Brazil.

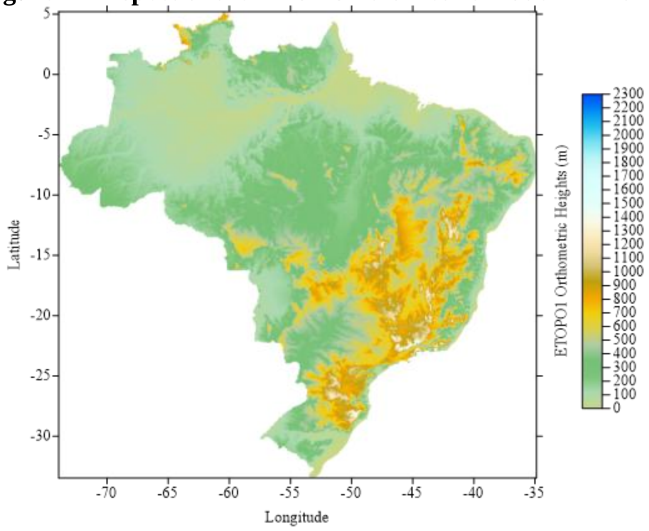


Figure 8 – Aspect of the EIGEN-6C4 gravity model in Brazil.

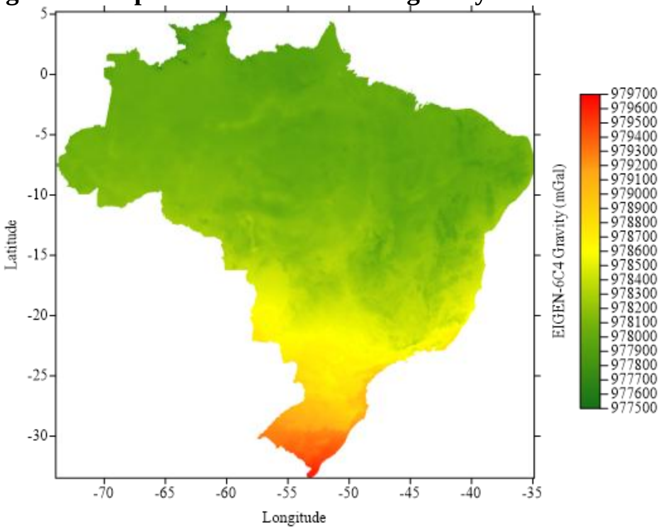


Figure 9 – Aspect of the UNB_TopoDens lateral density model in Brazil.

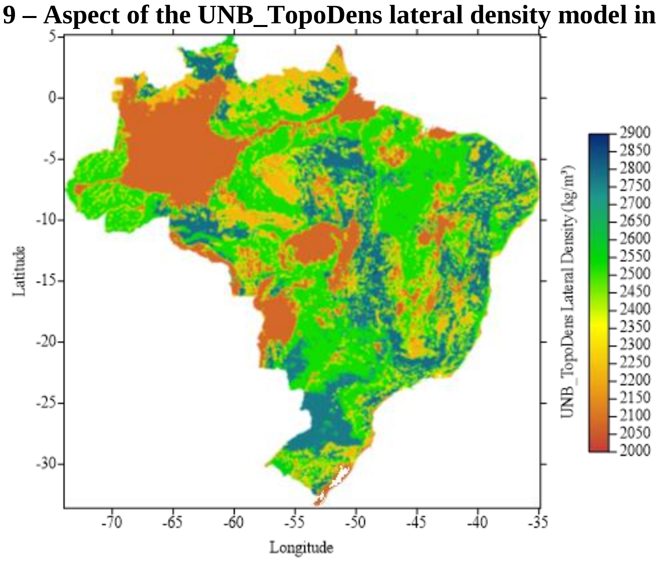
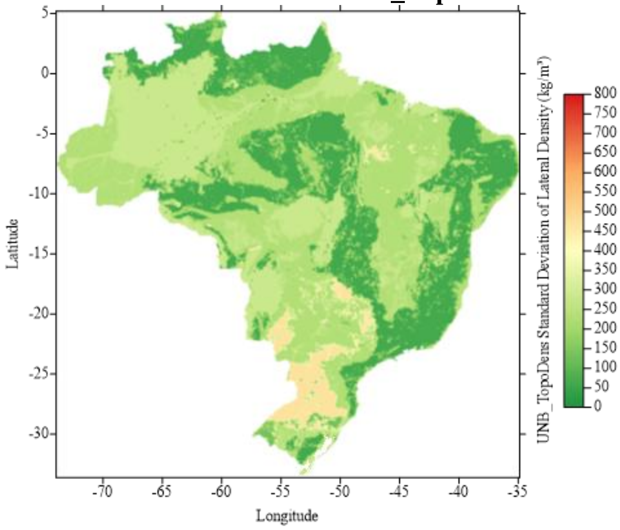


Figure 10 – Aspect of the standard deviations of the UNB_TopoDens lateral density model in Brazil.



The clustering of data from global models of density and their respective standard deviations (UNB_TopoDens), topography (ETOPO1), and gravity (EIGEN-6C4) was performed and recorded in a file comprising 101,006 entries (points). Subsequently, the numerical differences between the global density model and the Harkness model were computed and incorporated into the aforementioned data file. The results of the statistical calculations are presented in Table 3. In order to assess possible linear dependencies among the variables under study, correlation coefficient and variance-covariance matrices were calculated, as shown in the results presented in Tables 4 and 5.

Table 3 – Statistics of Global Models and Mean Density (Harkness)

Descriptor / Variable	*H (m)*	*g (mGal)*	ρ_{UNB} *(kg/m³)*	$\sigma\rho_{UNB}$ *(kg/m³)*	$\Delta\rho_{UH}$ *(kg/m³)*
N (points)	101,006	101,006	101,006	101,006	101,006
Minimum	0	977,532.4	2,074	0	-596
Maximum	2,261.4	979,650.4	2,854	800	184
Range	2,261.4	2,118	780	800	780
Mean	327.3	978,196.9	2,424.3	200.4	-245.7
Standard Deviation	262.05	292.08	271.16	108.21	271.16

Table 4 – Correlation coefficients between the global models (UNB and Harkness).

Variable	*H*	*g*	ρ_{UNB}	$\sigma\rho_{UNB}$	$\Delta\rho_{UH}$
H	1				
g	0.23	1			
ρ_{UNB}	0.28	0.14	1		
$\sigma\sigma\rho_{UNB}$	-0.07	0.24	-0.25	1	
$\Delta\rho_{UH}$	0.28	0.14	1	-0.25	1

Table 5 – Variance-Covariance Matrix between the Global Models (UNB and Harkness).

Variable	*H*	*g*	ρ_{UNB}	$\sigma\rho_{UNB}$	$\Delta\rho_{UH}$
H	68,668.24				
g	17,726.44	85,307.72			
ρ_{UNB}	19,928.92	11,472.96	73,527.45		
$\sigma\rho_{UNB}$	-1857.58	7472.58	-7,410.61	11,708.43	
$\Delta\rho_{UH}$	19,928.92	11,472.96	73,527.45	-7,410.61	73,527.45

The frequency histograms—lateral densities (Figure 11), standard deviations of lateral densities (Figure 12), numerical differences between the global and Harkness lateral density models (Figure 13), and percentage differences between the global and Harkness lateral density models (Figure 14), allow for the observation of amplitude ranges (classes) with higher and lower frequencies of variation in lateral density values.

Figure 11 – Frequency Histogram of Lateral Densities (ρ_{UNB}).

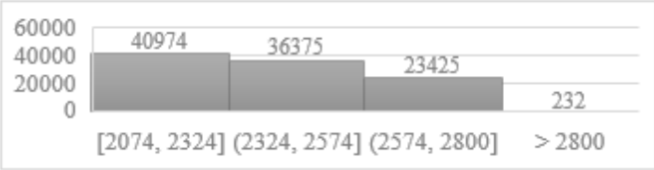


Figure 12 – Frequency Histogram of Standard Deviations ($\sigma\rho_{UNB}$).

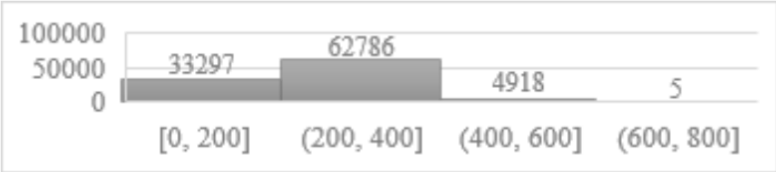


Figure 13 – Frequency Histogram of Differences ($\Delta\rho_{UH}$).

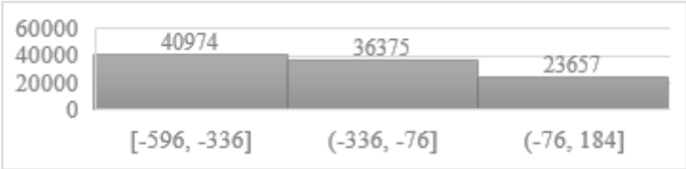


Figure 14 – Frequency Histogram of Percentage Differences ($\Delta\rho_{UH\%}$).

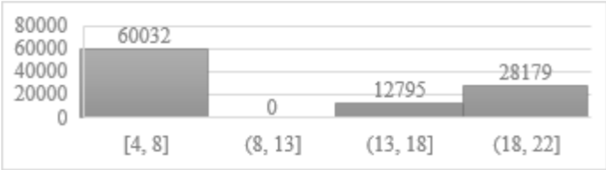


Figure 15 presents the main result and objective of the present study, namely, to effectively demonstrate the behavior of the global density model UNB_TopoDens in comparison to the classical model (Harkness) across Brazilian territory.

Figure 15 – Differences Between the Lateral Densities of the UNB and Harkness Models.

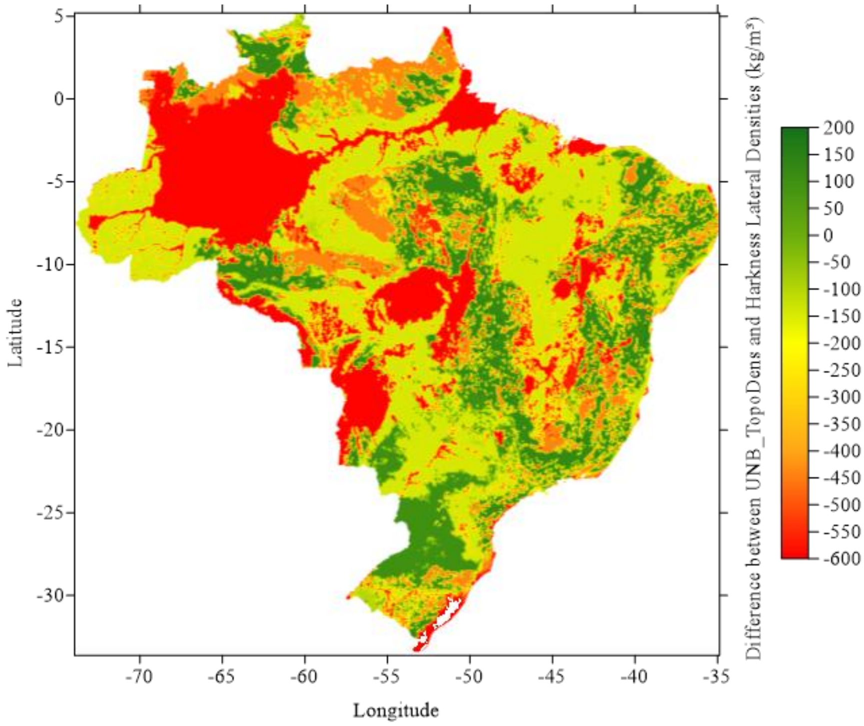
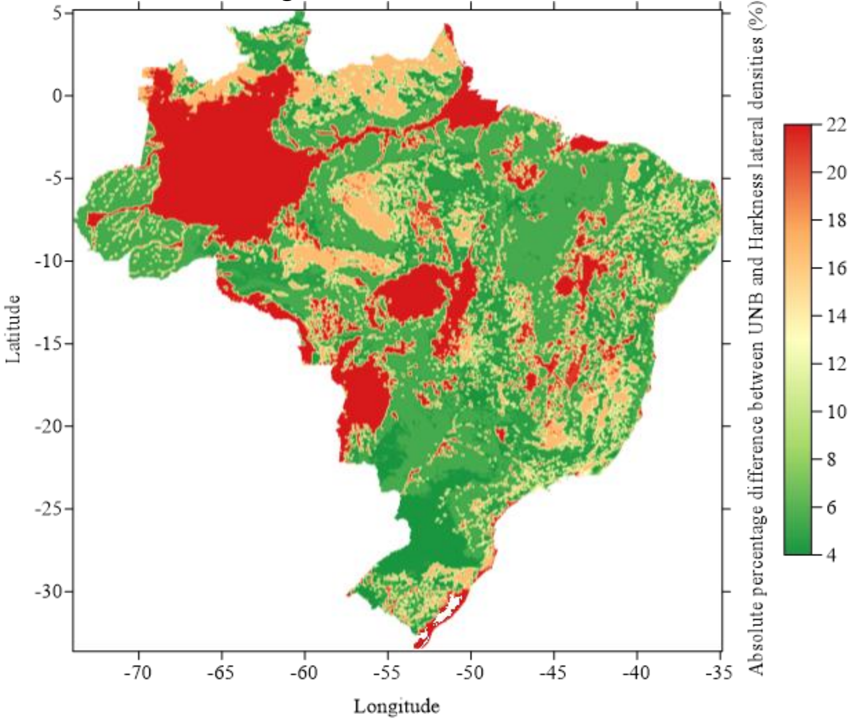


Figure 16 illustrates the same aspect of the behavior of the global and mean models shown in Figure 15. However, in this case, the variation values have been converted into percentage values (absolute/positive), allowing the user to directly assess the degree of similarity between the models.

Figure 16 – Absolute Percentage Differences Between the UNB and Harkness Models.



IV. Discussion

Analysis of the results begins with Table 3, based on the following average values calculated for the 101,006 points covering the entire continental territory of Brazil used in the experiment: orthometric height (Hm = 327.3 m), gravity (gm = 978,196.9 mGal), laterally variable density from the global model UNB_TopoDens (ρm_{UNB} = 2,424.3 kg/m³), standard deviation of the laterally variable density from the UNB_TopoDens model ($\sigma\rho m_{UNB}$ = 200.4 kg/m³), and the numerical difference between the UNB_TopoDens model and the classical mean density model by Harkness ($\Delta\rho_{UH}$ = -245.7 kg/m³).The first analysis concerns the average values of lateral density and its standard deviation, compared to the global UNB_TopoDens model applied worldwide (2,247 kg/m³, with standard deviation ranging from 0 to 800 kg/m³; Sheng et al., 2019). A lateral density difference of approximately 7.3% is observed. Regarding the standard deviation, based on Figure 12 (frequency histogram of $\sigma\rho_{UNB}$), only 5 points exceed 600 kg/m³, while 95% of the points fall below 400 kg/m³. These figures indicate that the UNB_TopoDens model yields more favorable average results for Brazil than its global version. Similarly, these values can be compared to the averages from the Brazilian regional model LDT_Brazil (Medeiros et al., 2021), which reports a lateral density of 2,459 kg/m³ and a standard deviation ranging from 8 to 351 kg/m³, demonstrating effective compatibility between the models.

The average values of height and gravity may serve as reference benchmarks for future studies due to their broad coverage. The main variables involved in this study had their correlation coefficients and variance-covariance matrix calculated, as shown in Tables 4 and 5. The correlation coefficients between height, gravity, and lateral density from the UNB_TopoDens model yielded values of 28% and 14%, respectively, confirming the expected linear correlation among these variables. Regarding covariances, values remained positive in relation to lateral density but turned negative for its standard deviation and height. As for the differences $\Delta\rho_{UH}$, their behavior mirrors that of ρ_{UH}, since, as expected statistically, it merely involves the addition of a constant to the original model. The behavioral difference between the UNB_TopoDens model and the classical Harkness model can be assessed through their numerical differences ($\Delta\rho_{UH}$), as shown in Figure 15. The $\Delta\rho_{UH}$ values range from -600 to 200 kg/m³, with an amplitude of 800 kg/m³—approximately 30% of the reference value of 2,670 kg/m³. The frequency histogram in Figure 13 shows that 40.6% of the points fall within a $\Delta\rho_{UH}$ variation range of -596 to -336 kg/m³, 36.0% between -336 and -76 kg/m³, and 23.4% between -76 and 184 kg/m³. Figure 14 presents $\Delta\rho_{UH}$ in percentage values, indicating that approximately 60% of these differences lie between 4% and 8%, around 12% between 8% and 18%, and 22% between 18% and 22%. Accordingly, Figure 16 displays

$\Delta\rho_{UH}$ variations in percentage terms, enabling identification of regions where the UNB_TopoDens and Harkness models show discrepancies (ranging from 4% to 22%). The regions with the greatest discrepancies include lithologies with densities lower than the reference value of 2,670 kg/m³, as $\Delta\rho_{UH}$ = -245.7 kg/m³. Cross-referencing with Table 2 reveals that 10 out of the 13 lithological classes in the UNB_TopoDensT model have average values below the reference. Whether or not these discrepancies are acceptable will likely depend on the intended application of the model.

To complement this analysis, we return to the beginning (Tables 1 and 2) and discuss the behavior of the lithological models that originated UNB_TopoDens. Tables 6 and 7 present, respectively, the correlation coefficients between the reference density values of the UNB_TopoDens lithological models (T and C), Tenzer et al. (2011) and Carmichael (1989), and their dispersions (standard deviations). It is evident that the correlation between the models is degraded (around 66%, whereas ideally it should be 100%) due to the lack of available samples for the Carmichael model. Regarding the behavior of standard deviations, the two models show a correlation coefficient of approximately 3%, indicating statistical independence. Thus, the findings align with the proposal by Sheng et al. (2019) regarding the use of Tenzer et al.'s (2011) lithological model in UNB_TopoDens.

Table 6 – Correlation Coefficient between UNB_TopoDens T and C Models.

Modelo ρ	*DensT*	*DensC*
DensT	1	
DensC	0,661	1

Table 7 – Correlation Coefficient of the Standard Deviations between UNB_TopoDens T and C Models.

Modelo σρ	*DensT*	*DensC*
DensT	1	
DensC	0,030	1

V. Conclusion

Considering the objectives of the present study, the presentation of the main numerical and graphical aspects related to the behavior of the global lateral density model UNB_TopoDens, its relationship with the classical Harkness model, based on the developed methodology, its application, and resulting outcomes, this study is regarded as a success. It is suggested that future experiments may involve, for instance, the UNB_TopoDens model with denser data resolution grids, incorporating elevation and gravity models. Investigations into error propagation associated with the use of global models will undoubtedly be of great value to various user communities, especially the scientific community.

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