Study of gravity anomalies in the Bragantina region: comparison between terrestrial and satellite gravity data.

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Abstract

We present in the article the gravity anomalies observed in the Bragantina microregion, in the Northeast region of the state of Pará. This region presents an igneous basement and granite intrusions observed in some areas. In order to evaluate the gravity distribution and gravity anomalies in the regions of the city of Tracuateua (PA), we compare and validate the distribution result of the gravity data existing in the region from two acquisition platforms: terrestrial and satellite. We applied spatial gravity corrections to obtain anomalies from terrestrial gravity data. We found equivalents behaviors for the Free-air anomaly, the datasets only differ 3 mGal in amplitude. For the Bouguer anomaly, however, differences were found regarding the amplitude of the anomaly, and may be related to different values of crustal density or altitude values in relation to the topography used for Bouguer correction. For both platforms of data, the gravity anomalies have the same shape, varying in amplitude only. This validates and shows the precision of the satellite gravity data referring to the GOCE satellite mission for this region.

Introduction

The gravity method is commonly used in the study of sedimentary basins for oil and gas exploration due to the density contrast between the sedimentary package and basin basement produce a gravity signal that contains consistent information about the basin geometry. However, for the regions near the oceanic zones, the gravity signal can provide information corresponding to intrusive bodies, the contour of sedimentary basins and anomalies caused by isostatic compensation, resulting due to the topographic difference or variations in the thickness of the earth's crust.

Although the observed gravity signal is the result of a superposition of sources, the strength of the Earth's gravitational field tends to decrease as altitude increases (Long & Kauffman, 2013), which allows estimation of gravity anomalies. The Free-air anomaly consists of the difference between the actual gravity and the theoretical gravity (calculated in relation to the ellipsoid that fits better the Earth' shape) being a measure of the subsurface mass, including topographic masses, tending to detect geological characteristics outside of the isostatic equilibrium (Hinze et al, 2013). The Bouguer anomaly, on the other hand, does not correlate strongly with the topography. However, this anomaly has limitations that can affect interpretation.

For terrestrial gravity acquisitions, gravity data provides information about the local or regional gravitational field, such as intrusive or mineralized zones. This setback makes the gravitational field understanding in a global scale difficult. Recently, the use of satellites to study our planet has allowed continuous data acquisition in many areas and also it has provided more data and services that benefit scientific and technological studies. Because of this, satellites have become an important tool for understanding Earth, aiding in the acquisition of terrestrial and marine gravity data and in areas missing from relevant gravity information.

In this context, we evaluated the distribution of Free Air and Bouguer gravity anomalies from the satellite GOCE (Gravity Field and Steady-State Ocean Circulation Explorer) data. The terrestrial gravity data belong to both IBGE (Insituto Brasileiro de Geografia e Estatística) Geodetic Database and ANP (Agência Nacional do Petróleo) Exploration and Research Database.

Methodology

The GOCE mission, the satellite mission of the European Space Agency (ESA) for gravity studies, was dedicated to determine the Earth's gravity field with accuracy of up to 1 mGal and to model the Geoid with high spatial resolution, making significant advances in the field of geophysics (Adapted from Freeden et. al, 2015). The data set was accessed through the ICGEM (International Center for Global Earth Models) online platform and it is distributed through models. In this work, we used the EINGEN-6C4 model, defined by the combination of data from GOCE, GRACE (Gravity Recovery and Climate Experiment) and LAGEOS (Lasers Geodynamics satellites) missions from NASA, as well as aerial and terrestrial data.

Gravity Corrections

The IBGE terrestrial gravity data come from the Geodetic Station (EG) and Level Reference (RN) reports, available on the IBGE online platform. We also adopted the gravity data from the Exploration and Research Database of the National Petroleum Agency (BDEP/ANP) used in Vieira (2015), with information regarding the distribution of local gravity and absolute value of Free-air and Bouguer gravity anomalies.

For the IBGE data, we performed gravity corrections to obtain the resulting anomalies. The calculation of the gravity anomalies takes into account the effects due to altitude, solid tide (Longman, 1959) and the theoretical value of gravity calculated for a reference geoidal system. We used the geodetic system of 1967 (GRS67), with the gravity formula given by

$$\gamma(\varphi) = 978031.85\ (1 + \mathrm{A}sen^2\varphi + \mathrm{B}sen^4\varphi) \qquad (1)$$

where φ represent the latitude, $A = 0.00527889510$ and $B = 0.000023462$.

The application of the Free-Air, Bouguer and Terrain corrections produces the desired anomaly. The complete Bouguer anomaly is calculated by the expression

$$\Delta G_B = g_{obs} - \gamma(\varphi) + 0.3086h - 0.04191\rho h + C_r \quad (2).$$

The expressions 0.3086h, 0.04191ρh and C_r represents the Free-air, Bouguer and terrain correction factors. The h represents the difference between the measured altitude and the adopted reference level and ρ represents the mass density of the upper continental crust, with an adopted value of $\rho = 2.67$ cm^3.

Subsequently to the gravity corrections, we obtained a set of values referring to the anomalies. The gravity values came from the ICGEM platform.

Area of study

We applied this methodology in the Bragantina micro region of the state of Para (Figure 1). Among the existing municipalities, we mention Bragança, Capanema and Tracuateua. The city of Tracuateua, for example, has a strong igneous basement, with granite dikes appearing in nearby regions (Palheta, 2001; Rosseti et. al, 1989). This site will have greater prominence in relation to the gravity study carried out.

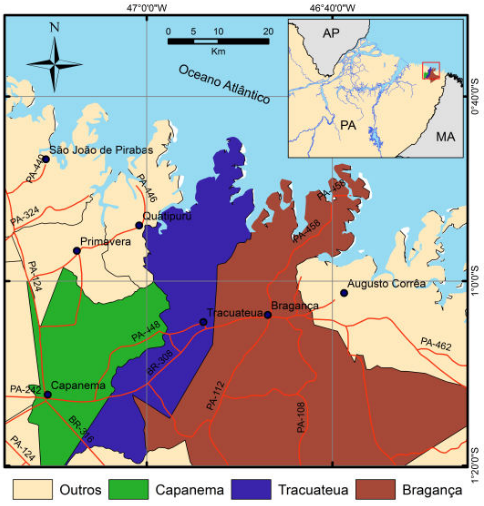

Figure 1 – Geographic localization map of the Tracuateua region.

Research made by Palheta (2001) shows that the geology of the region comprehends rocks of the intrusive Tracuateua suite, sediments of the Barreiras Group and unconsolidated sediments coverings of different natures, showing different geotectonic domains (Figure 2).

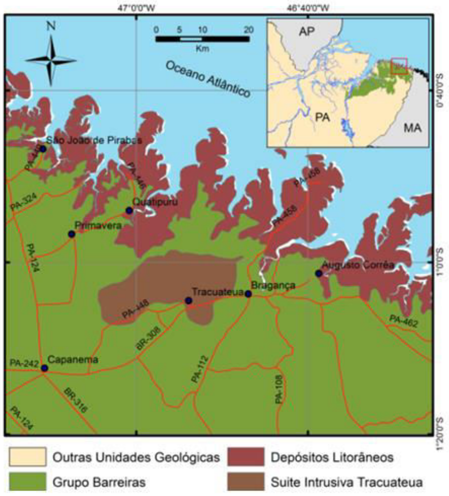

Figure 2 – Geologic map of Bragantina micro region featuring the Tracuateua city.

The Tracuateua intrusive suite consists of biotite associated to plutonic dikes, with reduced porosity and density estimated between 2.6 and 2.8 g/cm^3 (Palheta, 2001). Massive argillites, conglomerates and clayey sandstones form the rocks belonging to the Barreiras Group. This group covers rocks from the intrusive suite and the Pirabas Formation, and sediments from other deposits cover it (Rosseti ET AL, 1989).

The maps of Figures 1 and 2 are based on Cartographic Base of Para, from CPRM Data.

Results

The distribution of gravity for the region shows high values in the southwestern part of the studied region and low values in the central northeastern part of the area.

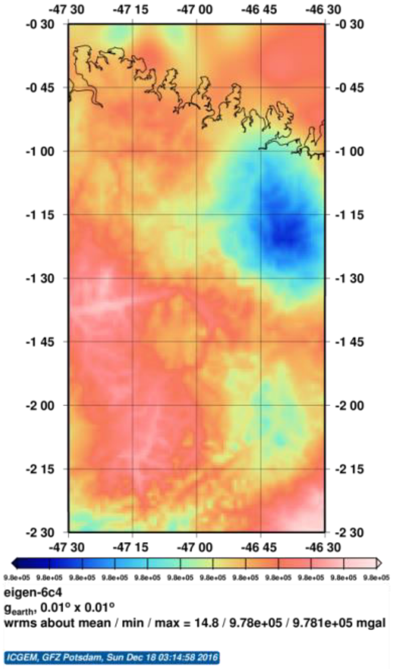

Figure 3 – Observed gravity map. Source: ICGEM.

This region presents elevations relative to the northern part. In relation to the northeast part of the region, the observed gravity values are relatively smaller. These gravity values are in the range of 978059.2 and 977064.3 mGal.

For the two terrestrial datasets, the Free-air anomaly showed equivalent form, high values in the elevated regions and lower values in zones near the ocean. For satellite data, the anomaly was well-behaved (Figure 4).

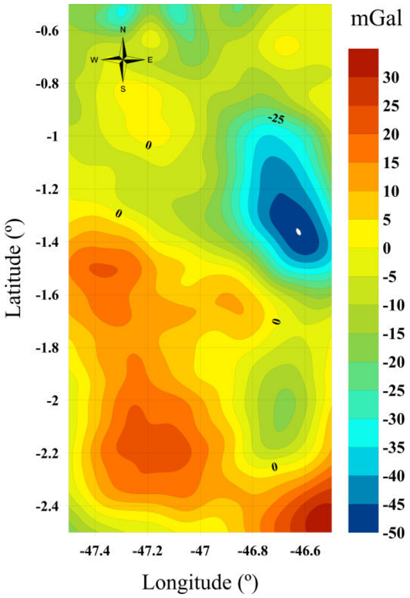

Figure 4 – Free-air anomaly map. Source: ICGEM.

For terrestrial data, there were distortions in areas where the anomaly is minimal, and it may be associated to the small sources or altitude difference used for the corrections. The amplitude difference is at 3 mGal. The map for terrestrial data is shown in Figures 5.

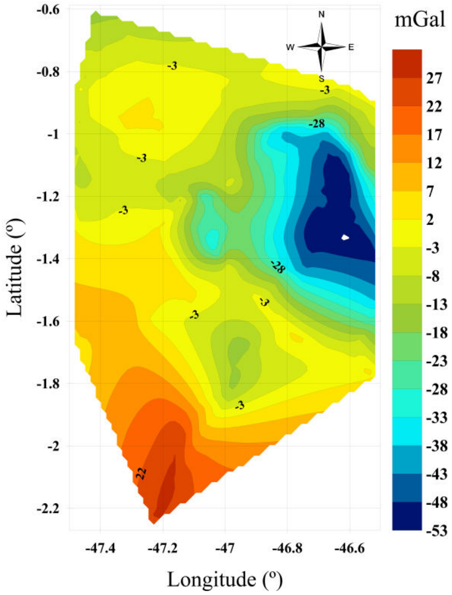

Figure 5 – Free-air anomaly map from terrestrial gravity data.

Although the Free-air anomaly is not suitable for most terrestrial geological problems, when it contains the effect of non-compensated topographic masses, it is possible to identify the effect of underground masses for exploration surveys (Heinze et. al, 2013).

The Bouguer anomaly, on the other hand, tends to have strong negative values where the Free-air anomaly is negative. In regions with high mountains or continental areas of altitudes close to 300 m, the values for this anomaly are negative and around 100 to 30 mGal.

For the region of study, the maximum elevation is 149 meters. However, in this region of elevation, there is the Intrusive Suite. The Bouguer anomaly produced by the satellite data (Figure 6) showed a shape similar to the Free-air anomaly also created by satellite data, indicating different values of amplitude. The high values are located in the elevation region, while the low values are present near the oceanic zone.

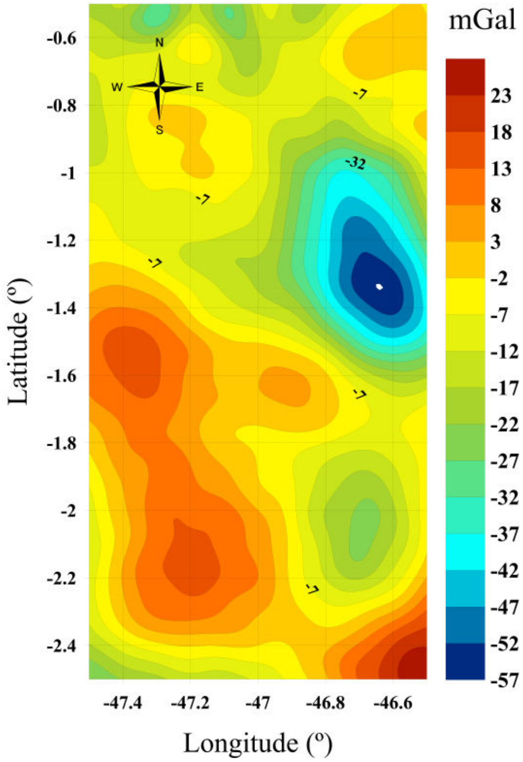

Figure 6 – Bouguer anomaly map. Source: ICGEM.

The Bouguer anomaly obtained from terrestrial gravity data showed a relatively similar shape to the Bouguer anomaly from the satellite platform data. It also showed approximated amplitudes for the maximum and minimum values, but smaller. The distortions displayed on the Freeair anomaly map were not present. Although absent from information in the southeast part of the map, the amplitude difference may be related to smaller intrusions in the region; Different altitude values used in the Bouguer correction and or terrain correction; and different values for the Bouguer density used in the correction. The Bouguer anomaly map from terrestrial data is shown in figure 7. The amplitude difference is around 2 mGal.

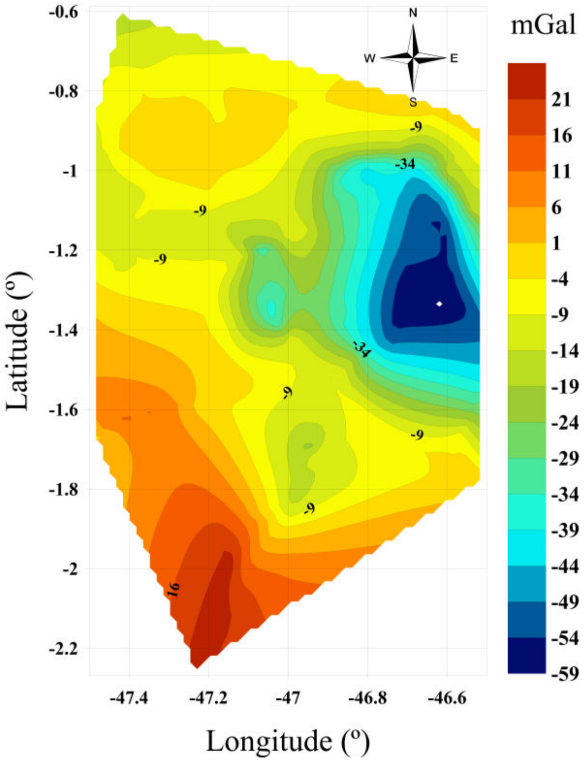

Figure 7– Bouguer anomaly from terrestrial gravity data.

Conclusions

In this work, we evaluated the distribution of local gravity in Bragantina region, which includes cities such as Bragança, Capanema and Tracuateua. The latter presents granitic dominance in its basement, as well as sediments of the Barreiras Group. The distribution of gravity and gravity anomalies was based on terrestrial and satellite gravity data, the latter available on the ICGEM online platform. We performed the spatial gravity corrections to obtain gravity anomalies in part of the terrestrial gravity data, using the altitude values provided by the Geodetic Data Bank of IBGE reports. We compared the Free-air and Bouguer anomaly values for the terrestrial and satelital gravity data sources. For the Free-air anomaly, we found similarities in shape, but discordance in amplitude, presenting distortions in the contours close to the -20 mGal range. This difference in amplitude and low anomaly values could be related to isostatic compensation. However, it also may be caused by different altitude values used in the Free-air correction. for Bouguer anomaly, we also find similar form among the two datasets. This anomaly behaved in concordance for the values of amplitude, showing no distortions. we have shown that for the studied region, the satellite gravity data provided relevant and equivalent information to those already existing in terrestrial gravity data, indicating relatively equal forms and amplitudes ranging from 2 to 3 mGal.

In another moment, we will show the influence of the Mohorovicic discontinuity on the gravity signal, presenting the regional-residual separation.

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