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Gravitational Geopotential Study of the Brazilian Pre-Salt Region

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***Abstract* – This paper presents a study of the gravitational geopotential of the Brazilian Pre-Salt region based on the gravimetric data of the EGM 2008 and Topex models. From these data, maps of gravity anomaly, gravity disturbance, geoid height and bathymetric maps were constructed. The maps allowed us to evaluate the region's water depth and to locate the Pre-Salt region and its main producing fields in a strong and negative anomaly of gravity, both in the Topex model and in the EGM 2008 model. It was demonstrated that the Santos Basin presented greater disturbance and anomaly of gravity than the Campos Basin.**

***Keywords* – Gravity Geopotential, Pre-Salt, Gravity, Submarine Relief.**

I. INTRODUCTION

The space race was marked by the launch of the first artificial satellite Sputnik in 1957 by the Soviet Union. The launch marked the beginning of the space race, which was a dispute between the United States and the former USSR in the context of the cold war, which had as one of its consequences a great development in space technologies. Thus, the mapping of Earth's properties such as gravity has been taking place through observations of orbital perturbations from Earth's artificial satellites [1].

In the 1960s, technological and spatial innovation enabled the frequent use of artificial satellites from ground bases in determining of the Earth's gravity field on a global scale. The global geopotential models called GGM – Global Geopotential Model are available as coefficients of a series expansion of spherical harmonics that needs to be truncated to a certain degree. This expansion can be used to calculate the external gravitational field of almost the entire planet [2].

The surface geology is investigated based on variations in the Earth's gravitational field, caused by the difference in density between subsurface rocks. The difference in density that a rock has with its surroundings provides the concept of a causal body [3]. A causal body represents a subsurface zone with a different mass that generates disturbance in the gravitational field, this disturbance is called gravity anomaly [4].

The year 2007 marks the discovery of large volumes of hydrocarbons at great depths in the Santos Basin, Brazil. The oil found is considered light and of good quality, in contrast to a large part of the national reserve considered heavy. In general, the exploratory perspective of the pre-salt region is very good, as Petrobras has a long tradition in deep and ultra-deepwater exploration [5].

Pre-salt, as the name already suggests, is an oil reserve that exists before a layer of salt in the submarine soil, about the geological time scale. The pre-salt in Brazilian territory extends for approximately 800 km along Espírito Santo, Santa Catarina, Campos and Santos states, presenting expectations of large oil reserves, estimated at around 50 billion barrels of oil and gas, which would leave Brazil ranking sixth in the ranking of

largest holders of oil reserves in the world, behind only Saudi Arabia, Iran, Iraq, Kuwait and the United Arab Emirates [6].

The pre-salt discoveries are among the most important in the world in recent decades and their exploration has been increasing over the years, from 41,000 barrels per day in 2010 to the level of 1 million barrels per day, in 2016, thus showing a growth of about 24 times [7].

It is known that large areas such as the Pre-Salt region can be studied very economically through the use of satellites that orbit the planet collecting a large amount of data, such as gravity [8]. It can identify density contrasts as the regions of existing and less dense salt and sediments [9]. In this way, it has geological knowledge about the Petroleum System, it is possible to better understand the area of interest studied. Thus, the present work proposes the geopotential mapping of the Brazilian Pre-Salt region and its surroundings, correlating the results with the layers of salt and sediments present.

II. Materials And Methods

In a first step, we used the Geoid program (Figure 1), the data from the gravitational model EGM2008 were extracted from the points of interest referring to the sedimentary basins of Campos and Santos, with the geographic coordinates longitudinal from -47 to -37.8 degrees and latitudinal of -28 at -20 degrees, with a variation of 0.4 degrees.

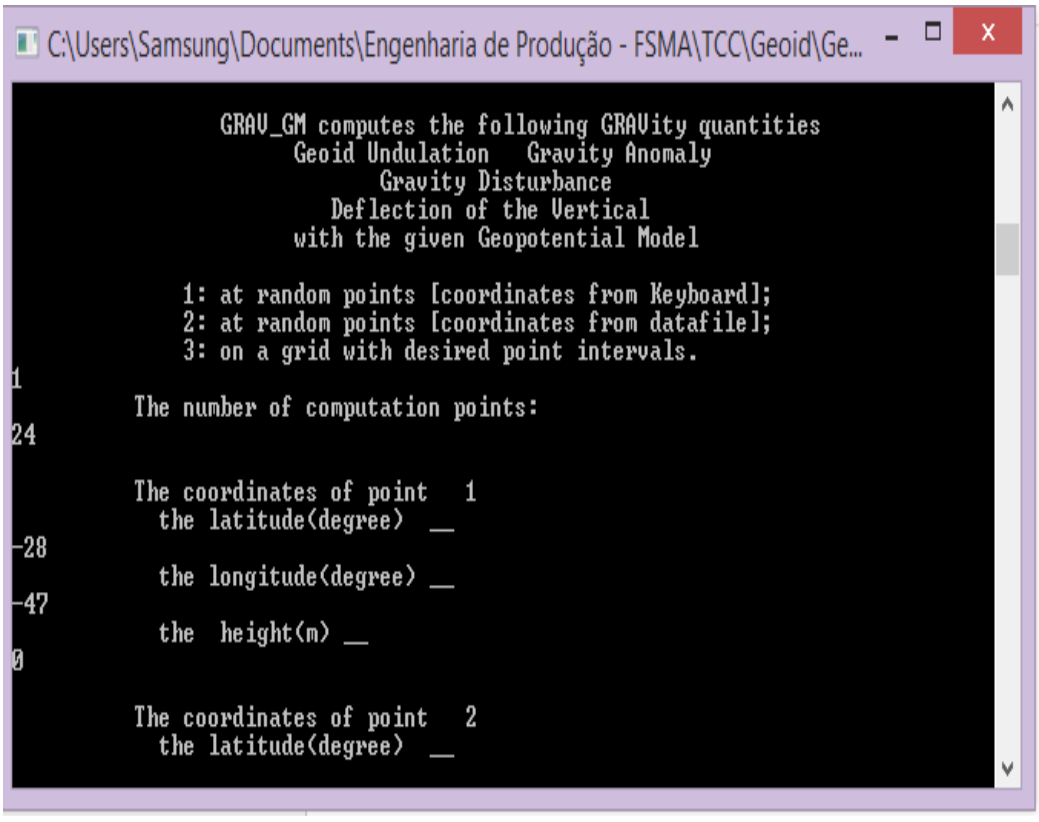

Fig. 1. EGM2008 gravitational model data extraction.

After the extraction, through the Oasis Montaj software, the data obtained from the EGM 2008 gravitational model was imported (Figure 2) and thus it was possible to make the maps of Geoidal Height, Gravity Anomaly and Gravity Disturbance as shown in Figure 3.

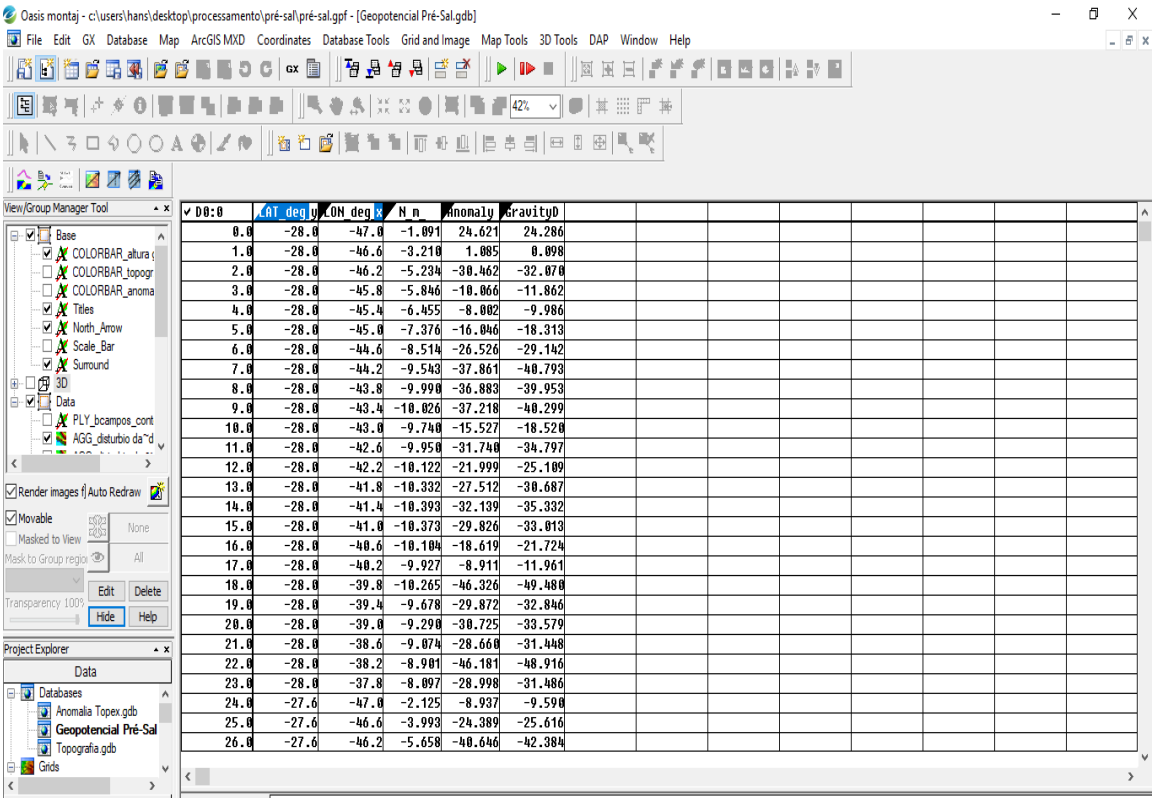

Fig. 2. Data extracted from EGM2008 imported into Oasis Montaj.

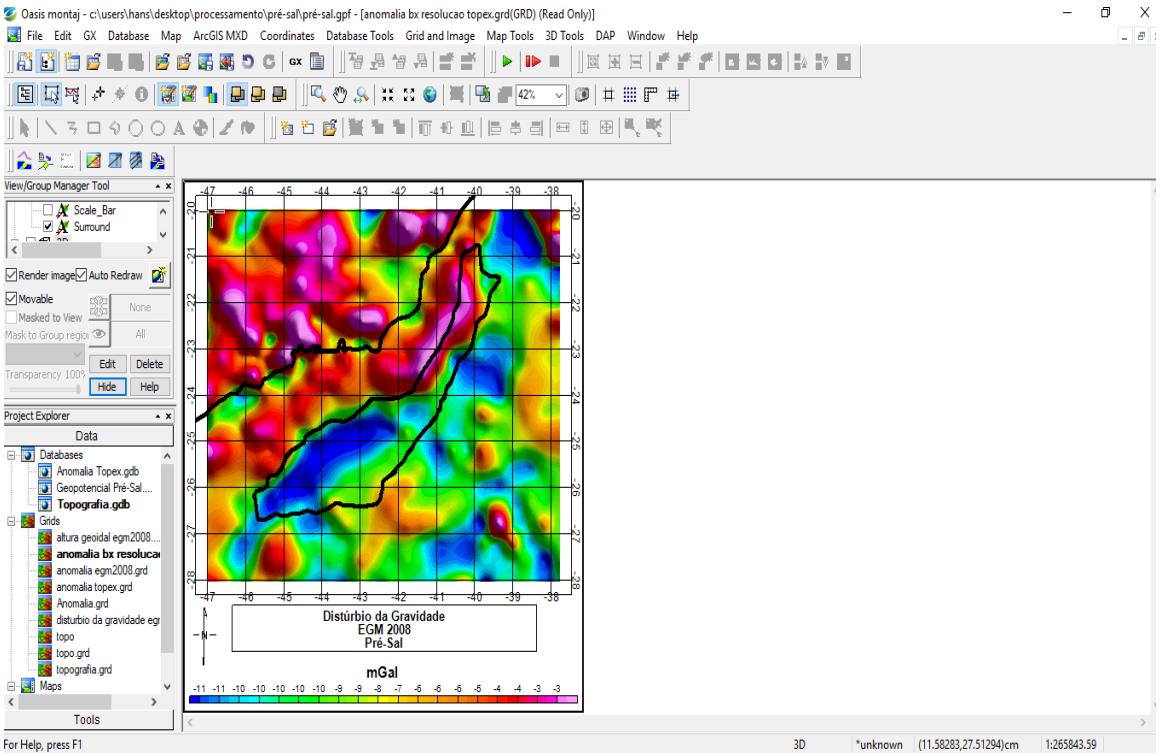

Fig. 3. Preparation of maps of the pre-salt region using the Oasis Montaj software.

III. RESULTS

With the data obtained, one of the maps constructed was the Geoid height map of the studied region. The Geoidheight map (Figure 4) is given by the difference, in meters, between the geoid and the ellipsoid.

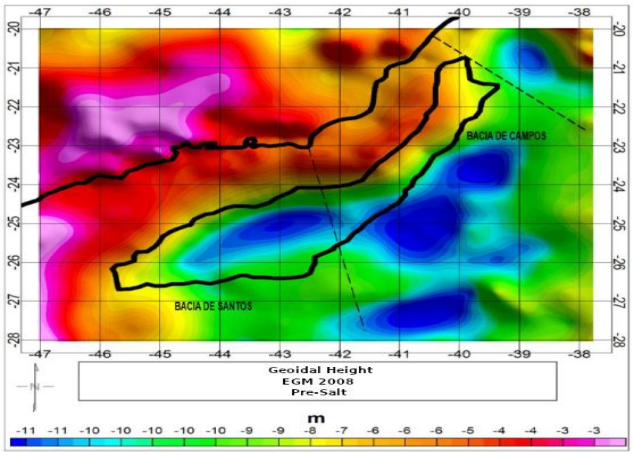

Fig. 4. 2D representation of the Geoidal Height using EGM2008 data.

The positive height region denotes geoid above the ellipsoid and, consequently, greater mass accumulation about the planet's average. If the geoid is below the ellipsoid denoting, the geoid height will be negative as can be seen in figure 4.

The geoid height map of the Pre-Salt region showed negative values throughout its extension, which denotes the geoid below the ellipsoid. For the entire pre-salt layer, values ranged from -11 m to -3 m. In the pre-salt part belonging to the Campos Basin there were higher values for the most part, as much of the region is located within the continental shelf and continental slope with smaller water depths. In the Santos Basin, the Pre-Salt region on the map showed lower values for the most part, as the region is mostly found in the oceanic crust with water depths exceeding 2,000 meters. Thus, a strong influence of marine relief on the region's geoid height can be seen.

Oilfields such as: Marlim, Marlim Leste, Marlim Sul and Barracuda located in the Campos Basin have an approximate geoid height between -10 m and -6 m. While oil fields such as Lula, Iara, Florim and Área de Iracema, which are located in the Santos Basin, have a geoidal height variation between -11 and -10 m.

The gravity anomaly map uses the difference between the gravity acceleration on the geoid and the gravity acceleration on the ellipsoid to be formed. This difference is called gravity anomaly, as can be seen in figure 5 obtained from EGM 2008 model.

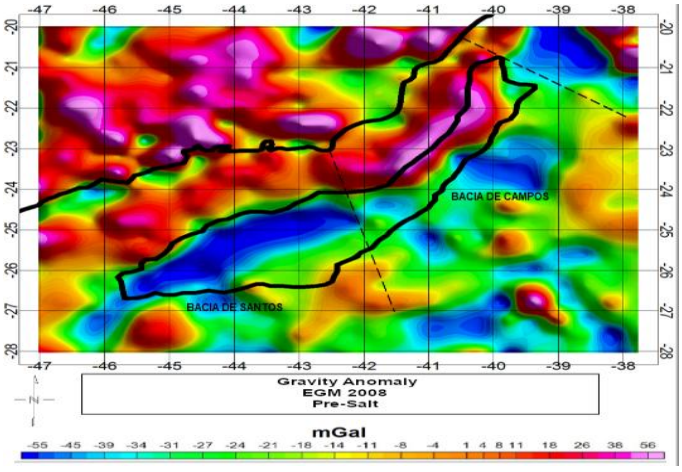

Fig. 5. 2D representation of the Gravity Anomaly using EGM2008 data.

It was possible to analyze and verify that the gravity anomaly ranged from -55 mGal to +56 mGal throughout the pre-salt region, showing that the anomaly with the highest negative value is in its predominance in the Santos Basin. Along the Campos Basin has positive values for most of its extension, especially the basin region that lies on the continental shelf.

However, a strong negative anomaly can be seen especially in the pre-salt part of the Santos Basin, which stronger than in its surroundings, due to the presence of the Salt-Tectonics Provinces formed mainly by gypsum, halite and anhydrite, which are geological materials of low densities.

As a verification of the accuracy generated by the previous maps on the gravity anomaly, the map in figure 6 was generated, using a new set of data obtained through the Topex model with a better resolution of 1 minute.

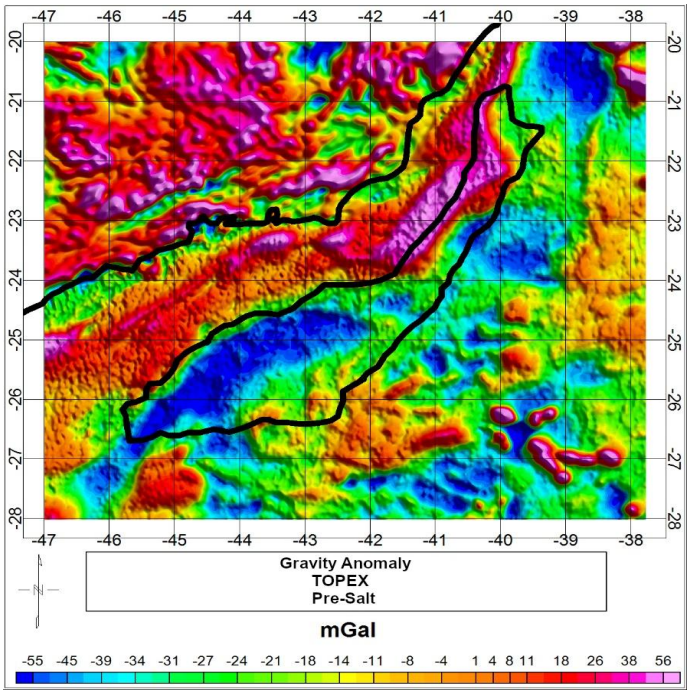

Fig. 6.2D representation of the Gravity Anomaly using Topex data.

The Gravity Anomaly maps of the two models EGM 2008 and Topex showed good agreement across the region studied. In the Topex model, the range of gravity anomaly values was similar, remaining from – 55 mGal to 56 mGal. The Pre-Salt region was well identified through a strong and negative anomaly around -50 mGal, with the except of the part of the Pre-Salt present in the Continental Shelf, which showed a positive anomaly.

With the best sharpness resulting from the better resolution obtained in the map generated with the Topex model, it could be observed that the Topex model gives us a better resolution in the anomaly maps, which would help us to better identify the points of interest in studies of small areas such as producing fields. As Topex does not provide data on gravity disturbance or geoid height, the EGM 2008 was used as the main model for making and studying the maps. On the other hand, the EGM does not provide us with bathymetry data, so the Topex data is used. However, to understand the pre-salt region as a whole, both models lead to similar results and are useful for studying the region.

The gravity disturbance map, shown in figure 7 was calculated using the difference in the geoid between normal gravity and projected gravity in the direction of normal to the ellipsoid.

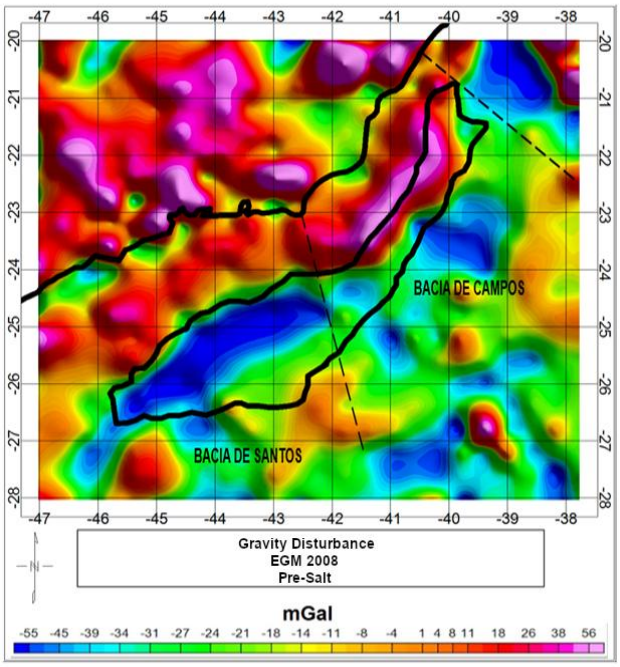

Fig. 7. 2D representation of the Severity Disorder through EGM2008 data.

The result of the Gravity Disturbance map was analogous to the result of the Gravity Anomaly map,with strong and negative values in the pre-salt region belonging to the Santos Basin and positive values in the Campos Basin region belonging to the continental shelf and slope.

The bathymetry or marine topography maps, presented in figures 8 and 9 shows the configuration of the entire terrain with all its natural features along its extension, it gives a description of the marine relief throughout the pre-salt region.

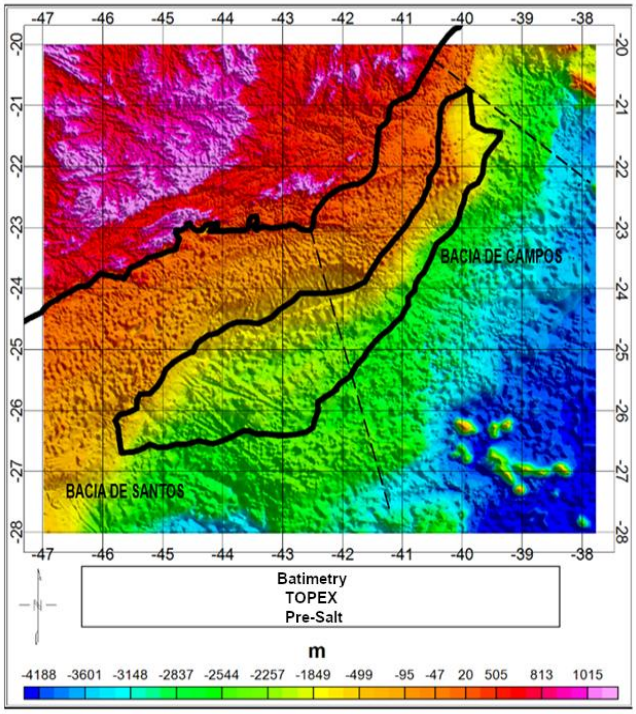

Fig.8.2D representation of Bathymetry using Topex data.

Through figure 9 it is possible to identify the underwater relief of the Pre-Salt region and its surroundings. It also allows the separation of the regions into depths (water depth) as shallow (up to 400 meters), deep (400 meters to 1,000 meters) and ultra-deep (above 1,000 meters). It is possible to notice that most of the Pre-Salt region is located in ultra-deep waters with water depths greater than 2,000 m.

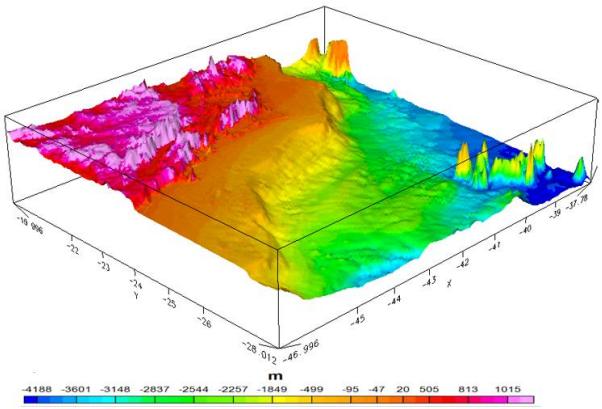

Fig. 9. 3D representation of Bathymetry using Topex data.

Through figure 9 it is possible to see the marine relief of the region with the continental shelf in red and orange, the slope region in yellow and the oceanic crust in green and blue.

VI. CONCLUSIONS

In the present work the mapping of the Gravity Anomaly, Geoidal Height of the pre-salt region, Gravity Disturbance and Bathymetry were mapped. The generated maps were related to known structures in the Pre-Salt region, as well as some Pre-Salt oil fields. This correlation allowed the identification of regions with contrasting density and variation in the water depth.

The Santos Basin about to the Campos Basin presented values with a higher negative degree of disturbance and gravity anomaly, it was possible to observe that the range with higher water depth is also found in this region, making the pre-salt part more difficult to access.

With the support of 2D and 3D bathymetric maps,this study also allows the separation of the regions of Pre-Salt intowater depths as shallow (up to 400 meters), deep (400 meters to 1,000 meters) and ultra-deep (above 1,000 meters). Most of the Pre-Salt region has been identified in ultra-deep waters.

In addition to characterizing the region well in terms of water depth and density contrasts, the generated maps can be used in cartographic and geodetic studies of the Santos and Campos Basin region and also enables the conversion of the geometric altitude referred to the ellipsoid provided by the GPS in orthometric altitude referred to sea level which is the altitude used in maritime operations.

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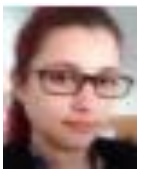

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