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Joint Interpretation of Bathymetric and Gravity Anomaly Maps Using Cross and Dot-Products.

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0.1 Summary

We present the results of joint map interpretation technique based on cross and dot-products applied to bathymetric and gravity anomaly gradients maps. According to the theory (Gallardo, Meju, 2004) joint interpretation of different gradient characteristics help to localize and empathize patterns unseen on one image interpretation and gives information about the correlation of different spatial data. Values of angles between gradients and their cross and dot-product were used.

This technique helps to map unseen relations between bathymetric and gravity anomaly maps if they are analyzed separately. According to the method applied for the southern segment of Eastern-Brazilian coast bathymetrical and gravity anomaly gradients indicates a strong source-effect relation between them. The details of the method and the obtained results are discussed.

0.2 Introduction

We applied this method to investigate the correlation between bathymetric and gravity anomalies at the southern segment of the Eastern-Brazilian coast. Gridded satellite global marine gravity data and bathymetrical data were used.

The studied area is located at the Eastern- Brazilian coast between the 20°W and 30°W meridians and 15°S and 25°S parallels. The volcanic events responsible for the uncommon width of the continental shelf at the Abrolhos bank also were responsible for the formation of the Abrolhos islands and seamounts including the major Vitoria-Trindade chain. According to the literature this volcanic structures are expected to have a corresponding gravity anomaly (McKenzie, 1976, Zembruscki, S.G. 1979).

The main objective of this study is to develop and test joint image interpretation method to compare spatial data and analyze its relations.

0.3 Theory and Method

0.3.1 Data sources

The bathymetrical satellite data were derived bathymetry 2-minute grid of the ETOPO2v2 obtained from NOAA's National Geophysical Data Center (http://www.ngdc.noaa.gov).

The satellite marine gravity 1-minute gridded data were obtained from the Satellite Geodesy at the Scripps Institution of Oceanography, Smith & Sandwell (1997; http://topex.ucsd.edu.

Gravity anomaly data were re-gridded using the ETOPO2v2 grid.

All calculations and maps were made using MatLab 2007 software.

0.3.2 Cross-Product

Cross-product is the result of multiplication of bathymetric and gravity anomaly gradient magnitudes by the sine of the angle between them.

According to the definition of gradient cross-product minimal values are expected to be found in points where the angle between gradients is close to zero or where one or both of the gradient magnitudes have values close to zero. It creates an ambiguity and a problem for data interpretation since there is no exact correspondence between bathymetric structures and gravity anomalies.

0.3.3 Dot-Product

Dot-product is the result of multiplication of bathymetric and gravity anomaly magnitudes by the cosine on the angle between them.

According to the definition of dot-product, values close to zero can be generated by near perpendicular orientation of the gradients or small magnitudes of one or both gradients. So, the results are mutually increased in areas with larger magnitudes or smaller angles between gradients. Due to this mutual amplification dot-products are less affected by the ambiguity of cross-product explained above. The same statistical separation of cross-product was used to support the conclusions.

0.3.4 Statistics and Significance Criteria

Statistical analysis was made in order to sort the data into two groups to reduce ambiguity effect: first group – data with magnitudes that could be considered *anomalous* (where the main minimizing source is the angle between the gradients and the second group – data with magnitudes variations that could be considered as (non significant or *background* (where cross-product value is determined by the small magnitude). It was chosen to use the mean value and standard deviation (*std*) to sort the data in such two groups. These values were determined for bathymetric and gravity anomaly gradient magnitudes creating two data sets – one where one or both gradient magnitudes are one standard deviation larger than the mean value with a total of 7831 (*anomalous*) and a second one where both magnitudes differ smaller than one standard deviation from the mean value with 85584 (*background*). Statistical analysis of distribution patterns for both groups was made.

0.4 Examples of Method Application

0.4.1 Map of Angles Between Gradients

Figure 1 shows the map of angle values.

The angle values were divided into 4 equal intervals. The statistical distribution of angles between gradient in the given intervals is the following (percents of the total): 0 to 60° – 51.39% of the values; 60° to 90° –12.08%; 90° to 120° –14.92%; 120° to 180° –21.18%.

It can be seen that 51% of the gradients have a small angle between them, 72% of gradients can be considered as parallel (72%) with angles smaller than 60° or bigger than 120° between them.

After statistical separation in the *anomalous* group almost 91% of the gradients have an angle smaller than 60° while in the *background* group just 48.6%.

From these results we can make a conclusion that the majority of the bathymetric and gravity anomaly gradients are related.

Regions with higher gradient magnitudes are characterized by cosine values close to 1 (indicating a small angle between them).

The size of the areas characterized by small angles between gradients exceed the size of bathymetric and gravity anomaly isolines characterizing the area of influence of the structures and their effects.

Regions with no significant anomalies show uncorrelated value spots.

0.4.2 Map of Cross-Product

The resulting map shows small spots of higher cross-product magnitudes following magnitude isolines. About 90% of the values are close to minimum.

As was mentioned before, we can presume that areas where bathymetry and gravity anomaly gradient cross-products have smallest magnitudes there is a good correspondence between them indicating a good correspondence between shapes.

According to these results for the studied area the shapes and positions of bathymetric structures and gravity anomalies are well correlated suggesting strong correlation between source and its effect.

0.4.3 Map of Dot-Product

The resulting map resembles bathymetric and gravity anomaly isolines.

All the sea mounts, banks, continental slope and other notable geomorphologic structures and gravity anomalies are well delimitated in the dot-product map eliminating uncorrelated areas where gradient orientations can be considered as near perpendicular.

The dot-product map of the studied area suggests a strong source-effect between bathymetry and gravity anomaly.

0.5 Conclusions

The joint image interpretation technique uses three different criteria that are sensitive to different gradient properties.

Angles between gradients are a good indicator of areas where data are related and it is not sensitive to the magnitudes of the gradients. Angles maps can be used to find areas with direct and inverse relation between mapped properties and contour areas of influence of anomalies unseen on gradient magnitude maps alone. Statistical measures of distribution of angles can be an indicator of relation between data sets as show using significance criteria.

Cross-product map has a *spotted* character of contours. To reduce the effects of the ambiguity the separation into two groups proved to be useful. It helps to separate the cross-product values that are minimized due to gradient magnitudes from those that minimize due to sine values which is a measure of correlation between them.

Dot-product values contour areas where gradients are correlated.

According to joint image interpretation technique applied bathymetric structures especially the volcanic seamounts and banks in the southern part of East-Brazilian Coast are closely related to the observed gravity anomalies and can be interpreted as sources and effect. This technique also helps to evaluate the shape and dispersion of the gravitational effect from a bathymetrical source.

0.6 References

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