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Gravity inversion by means of growing bodies

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ABSTRACT

This paper presents a gravity inversion method for determining the volumes of bodies with pre-established density contrasts. The method works step-by-step on a prismatic partition of the subsurface volume, expanding the anomalous bodies to fit the observed gravity values in a systematic exploration of model possibilities. The process is treated in a 3-D context; at the same time, it can determine a simple regional trend. Moreover, positive and negative density contrasts are simultaneously accepted. The solution is obtained by a double condition: (1) the ℓ_2-fitness to the observed gravity data (model fitness) and (2) the minimization of the total (weighted) anomalous mass (model smoothness). A positive parameter is used to balance the two minimization terms. The method is applied to a simulated example and also to a real example: the volcanic island of Gran Canaria (Canary Islands, Spain). In both cases, the results obtained show the possibilities of the method.

INTRODUCTION

The inverse gravimetric problem, namely the determination of a subsurface mass density distribution corresponding to an observed gravity anomaly, has an intrinsic nonuniqueness in its solution (e.g., Al-Chalabi, 1971). Moreover, data must be considered as insufficient and inaccurate. Nevertheless, particular solutions can be obtained by including additional information about the model parameters (subsurface structure) and about the data parameters (statistical properties of the inexact data, e.g., Gaussian distribution). The inversion methods vary in accordance with the amount of information about the subsurface structure (from very precise geological information to light mathematical conditions) and, mainly, with the kind of model parameters selected (geometrical parameters or densities).

For the gravity inversion methods which consider the densities of the elements of a regular subsoil partition as unknowns (with nondiscrete values), the linear approach seems to be a better choice (e.g., Camacho et al., 1997). In this case, the solution fits the observed data very well, but its geometrical properties are somewhat diffuse because of the rather smooth variation of the resulting anomalous densities. Otherwise, the methods which look for the geometrical properties of anomalous bodies with fixed density contrast (e.g., Pedersen, 1979; Barbosa et al., 1997) correspond to a nonlinear context and offer interesting results, limited to the validity of the hypothesis used.

Generally, the usual inversion methods look for analytical solutions by means of linear approaches or iterative methods for linearizable problems. Unfortunately, linearized techniques depend strongly on the accuracy of initial estimates of the model parameters (Rothman, 1985). For the fully nonlinear treatment, the methods of exploration of the model space often give the best option (Tarantola, 1988). This exploration process can be conducted randomly (Silva and Hohmann, 1983) or systematically.

We present an inversion method that can be included in this last group of systematic exploration. A strong hypothesis is adopted: the subsurface anomalous structure is characterized by prescribed mass density contrasts. Therefore, the problem consists of determining the geometry of the anomalous volumes corresponding to those density contrasts. For that, the subsurface volume is divided into a fixed discrete 3-D partition of prismatic elements, and the anomalous volumes are constructed by means of an "expansion approach." In this sense, our proposal is related to the "bubbling" method of Zidarov (1990) and the "open-reject-fill" method of René (1986).

As opposed to Zidarov's (1990) approach, in our approach step-by-step, prismatic elements are selected by means of systematic testing of each possibilities of model growth, and added to the existing elements. In his paper, René (1986) developed a 2-D expansion approach by using a "maternal" structure formed by square "seeds" that grow by incorporating only contiguous elements. The René method does not require additional hypotheses but uses only positive (or only negative) density contrasts, and models with both positive and

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