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Efficient gravity data inversion for 3D topography of a contact surface with application to the Hellenic subduction zone

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ABSTRACT

We develop the theoretical foundations, numerical algorithms and computer programs to retrieve the 3D geometry of a density interface from gridded gravity data. The solution depends on constraining assumptions on permissible density values. An integral equation is solved by a new method of local corrections to find the density interface. The method is efficient and does not require trial-and-error forward modeling. We also discuss a method, based on upward and downward continuation, to isolate gravity effects from selected depth ranges. Both new methods are applied to create a model of the Moho surface for the Hellenic subduction zone. The resulting model is discussed relative to available seismic data and previous gravity analysis.

1. Introduction

The usual approach to find 3D topography of a contact surface is forward gravity modeling. One changes an initial model in an interactive way to diminish gravity residuals. Recently this approach has been applied, for instance, to study a geological structure of the Hellenic subduction zone in Casten and Snopek (2006) by means of the package IGMAS for interactive gravity modeling, in Makris and Yegorova (2005) and in Snopek and Casten (2006). The package IGMAS (Götze and Lahmeyer, 1988) uses polyhedral bodies for 3D forward modeling, Makris and Yegorova (2005) and Snopek and Casten (2006) apply other programs (GRAVMAG and 3GRAINS, respectively), both based on rectangular prisms. The disadvantages of the forward modeling approach are particularly obvious, if we regard the package IGMAS. One changes the model of the geological section from one profile to another, but changes in one vertical section influence the gravity field along other profiles. Each section takes into account a lot of geological and seismic a priori information, but the number of parameters, per section, is much larger than the number of profile observations, it is not reasonable from the viewpoint of stability. The problems of non-uniqueness and instability of gravity data inversion are not likely to be solved by a forward modeling approach.

A different approach is applied by Tirel et al. (2004) to obtain the Moho topography to the north of Crete; the linearized inverse problem is solved by means of the Fourier transform (Parker, 1972; Oldenburg, 1974). In our investigation we use a different procedure, we solve an integral equation for a function determining the geometry of an unknown contact surface. The kernel of this equation, evaluating the gravitational effect of a contact surface, depends in a nonlinear way on the sought function. We solve the full nonlinear 3D inverse problem by means of the method of local corrections (Prutkin, 1983, 1986) without any linearization. This method does not make use of nonlinear minimization, which reduces

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