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Gravity inversion in spherical coordinates using tesseroids

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Satellite observations of the gravity field have provided geophysicists with exceptionally dense and uniform coverage of data over vast areas. This enables regional or global scale high resolution geophysical investigations. Techniques like forward modeling and inversion of gravity anomalies are routinely used to investigate large geologic structures, such as large igneous provinces, suture zones, intracratonic basins, and the Moho. Accurately modeling such large structures requires taking the sphericity of the Earth into account. A reasonable approximation is to assume a spherical Earth and use spherical coordinates.

In recent years, efforts have been made to advance forward modeling in spherical coordinates using tesseroids, particularly with respect to speed and accuracy. Conversely, traditional space domain inverse modeling methods have not yet been adapted to use spherical coordinates and tesseroids. In the literature there are a range of inversion methods that have been developed for Cartesian coordinates and right rectangular prisms. These include methods for estimating the relief of an interface, like the Moho or the basement of a sedimentary basin. Another category includes methods to estimate the density distribution in a medium. The latter apply many algorithms to solve the inverse problem, ranging from analytic solutions to random search methods as well as systematic search methods.

We present an adaptation for tesseroids of the systematic search method of "planting anomalous densities". This method can be used to estimate the geometry of geologic structures. As prior information, it requires knowledge of the approximate densities and positions of the structures. The main advantage of this method is its computational efficiency, requiring little computer memory and processing time. We demonstrate the shortcomings and capabilities of this approach using applications to synthetic and field data. Performing the inversion of gravity and gravity gradient data, simultaneously or separately, is straight forward and requires no changes to the existing algorithm. Such feature makes it ideal for inverting the multicomponent gravity gradient data from the GOCE satellite.

An implementation of our adaptation is freely available in the open-source modeling and inversion package Fatiando a Terra (http://www.fatiando.org).