Rapid 3D inversion of gravity and gravity gradient data to test geologic hypotheses

Forward modeling of potential fields is a useful way to incorporate the interpreter's knowledge about the geology of the interpretation area into the model. However, this can be a very tedious task. This is specially true when modeling in 3D and trying to fit multiple components, e.g., in gravity gradiometry. The interpreter is required to simultaneously supervise the data fit and the construction of geologically realistic 3D bodies. This problem is partially solved by methods of geophysical inversion, which automatically fit the data. Conversely, inverse problems introduce other challenges of their own. Most geophysical inverse problems are ill-posed because their solutions are neither unique nor stable. Thus, they require the introduction of prior information, usually through regularizing functions. Moreover, 3D inverse problems are very computationally expensive. Recent developments in potential field inversion have proposed different regularizing functions to transform the ill-posed problem into a well-posed one. Also, several techniques, like data compression and parallel computation, have been applied to overcome the computational complexity. We call attention to the method of potential field inversion by planting anomalous densities. This method uses an iterative algorithm to automatically grow the anomalous bodies around user-specified prismatic elements called “seeds”, which have fixed density contrasts and positions. These seeds provide a first estimate of the skeletal outlines of the presumed anomalous bodies. Then, the inversion iteratively concentrates mass around this “skeleton” in a way that both fits the observed data and yields compact bodies. Therefore, the interpreter can easily impose prior information on the inversion through the seeds. The interpreter needs only to supply a few seeds that specify the sources' skeleton, eliminating the exhaustive task of specifying the complete geometry of multiple sources. Moreover, the interpreter is liberated from the time-consuming procedure of yielding a reasonable fit to the data. Due to its high computational efficiency, the method of planting anomalous densities can be used to quickly test geologic hypothesis of different locations and density contrasts for presumed sources. To test a hypothesis, one would choose the locations and density contrasts of the seeds accordingly and verify if the inversion result is able to fit the observed data. If it is not able, then the hypothesis can be rejected and a new one can be formulated and tested. Otherwise, there is no reason to reject the hypothesis on the basis of the geophysical data. Thus, the method can be viewed as a an enhanced forward modeling. The method of planting anomalous densities can be used with both gravity and gravity gradient data. This makes it an ideal tool to interpret compact geologic bodies using the new generation GOCE data. We present applications to synthetic and real data that illustrate the usefulness of our method.