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Joint 3D inversion of gravity and magnetic data with geological constraints - an alternative approach

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Quite a popular approach now by interpretation of gravity data is a linear one – an attempt is made to find a density distribution d(x,y,z) below the Earth's surface. This approach has clear disadvantages. First, we face the problem of dimensionality: one looks for 3D function based on 2D data set (measurements on the Earth's surface), the degree of non-uniqueness is extremely high, and no regularization can save the situation. The number of unknowns is many times higher than the number of observations; otherwise, we obtain a very rough model of the lower half-space. Second, the linear approach is not reasonable from the geological point of view. It implies that density varies from one point to another. Usually, we assume big volumes with nearly homogeneous density – layers, blocks, intrusions. It looks more understandable, to search for geometry of density interfaces: 3D topography of contact surfaces and shapes of restricted bodies (intrusions). Third, in the framework of the linear approach even for a synthetic field of two separate objects we obtain clouds of points with slightly increased density. It is hardly ever possible, to isolate objects, particularly when one of them is located above another one.

We suggest an alternative approach for the linear one. Our approach has been successfully applied for several case histories including a local gravity anomaly Kolarovo and a bigger area of the Thuringian Basin, where both gravity and magnetic data are inverted. First, we separate sources into deep, intermediate and shallow ones, using subsequent upward and downward continuation. All components are inverted separately. We address a problem which we name the problem of low frequencies: deep objects generate long wavelengths, but the converse implication is not necessarily true. For instance, the effect of the basin structure contributes substantially into low frequencies, though it is caused by shallow sources. However, our numerical experiments with intermediate wavelengths for the Thuringian Basin have shown, that if we explain negative anomalies with topography of near-surface layers, the obtained solution is not supported by boreholes data. Upper part of a geological section is usually well studied, therefore, it is not always possible, to shift sources upward, because it can contradict to available geological information.

For each local anomaly, its interpretation includes several steps. We subtract the model of the regional field (2D harmonic function). Then, we approximate the residuals with 3D line segments, it provides reliable estimates for mass and center of mass coordinates. For the Kolarovo anomaly of 25 mGal, residuals by approximation have RMS = 0.57 mGal. Here we find very few parameters (14 for two segments) according to several thousand observations, which is quite stable. Finally, we transform a chosen set of line segments into a restricted object or a contact surface with the same field (in the situation where a solution of the inverse problem is unique). We have obtained a model for intermediate wavelengths in the Thuringian Basin, which includes three restricted bodies (granitic intrusions) and a density interface with topography below them.