Bouguer and terrain corrections in one step through forward modeling in Python

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ABSTRACT

Usually the effect of the mass between the reference surface and ground surface is removed in two stages in standard gravity reductions, Bouguer slab and terrain corrections. In this study we compute the correction that combines both of these elements by Introducing a 2d quadtree discretization which has fine cells around the observation points. The Gravity effect of cells due to discretization between the ground surface and the base surface is modeled by the Newton integral. Digital height information for the desired area and its surroundings is extracted using shuttle radar topography mission (SRTM) photos with a resolution of 90 meters. This process is performed by a database in the Python environment (SimPEG). The method is tested on a region in Central Zagros and Central Iran. Since in this discretization method it is possible to reconstruct all the space below the topographic surface, we see better results compared to the usual methods.

Keywords: Gravity, Bouguer, topography, discretization, Python, SRTM

INTRODUCTION

Typically, a geophysical process involves the stages of operation design, data mining, processing and interpretation. In Gravity, in order to process the data, tide correction and drift corrections are performed, then Free air, latitude, Bouguer and topography corrections are performed. The slightest error in any of the correction steps can have a significant impact on the responses.

Typically, Bouguer and topographic corrections are performed in two separate steps. There are several ways to topography reduction. For example, methods such as the Fourier transform method and the concentric circle method can be mentioned.

Apparently, the terrain correction was first considered by Hayford and Bowie, around 1912, in interpreting gravity anomalies in the US. The problem of how to estimate the terrain correction was tackled by the geodesists Cassini, Bullard, and Lambert in the 1930s. Hammer developed a practical approach for performing terrain corrections out to about 22 km from the station.

Hammer improved on the method of Hayford to simplify terrain corrections. His “Hammer net” was used for 70 yrs. to make terrain corrections.

Bouguer correction is generally done by the Bouguer slab method. This method is associated with significant error due to the assumptions it considers.

In this research, the elimination of the effects of mass and topography between the ground surface and the base surface in a simultaneous process is done by modeling the progress of the model space.

Study area

The geographical location of the study area is between 49 degrees, 28 minutes and 51 degrees, 37 minutes longitude, and 33 degrees, 8 minutes and 34 degrees 54 minutes latitude. The study area is shown in Figure (1) in the blue square. Geologically, this region is limited to four blocks, including Golpayegan in the southwestern part, Aran in the northeastern part, Kashan in the southeastern part and Qom in the northwestern part.

Data information

The gravity data are measured by a CG5 gravimeter in the survey area by the National Cartographical Center (NCC). The gravity grid includes 399 data points covering an area of approximately 200 km in 200 km square (Fig. (1) blue square). The grid spacing is about 5 km and the gravimetric base station of Delijan stablished by national Cartographic center of Iran is used as the absolute gravity value. The coordinates of the points are obtained by trigonometric calculus with 0.03 m accuracy.

Given that, the distance of data collection in the central part of the study area (Mahallat) is about 400 meters, so we expect to be able to reach a depth of one kilometer in the central part.

Methodology

For terrain correction having a dense DTM is an essential requirement. Fulfilling this requirement, we downloaded the SRTM Tiff pictures from USGS Site. The opted square for extracting the heights is shown in Fig. (1) (Black square). The resolution of the ground surface heights in these Tiff files is 1 arc-second (90 m).

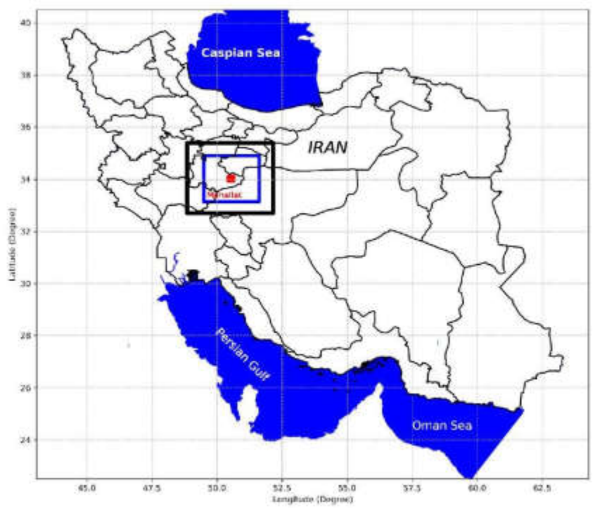

Figure 1. Red Square: Mahallat region, Blue Square: Study area, Black square: Topographic data range

The extracted topography from SRTM and computed free-air anomalies are depicted in Fig. (2).

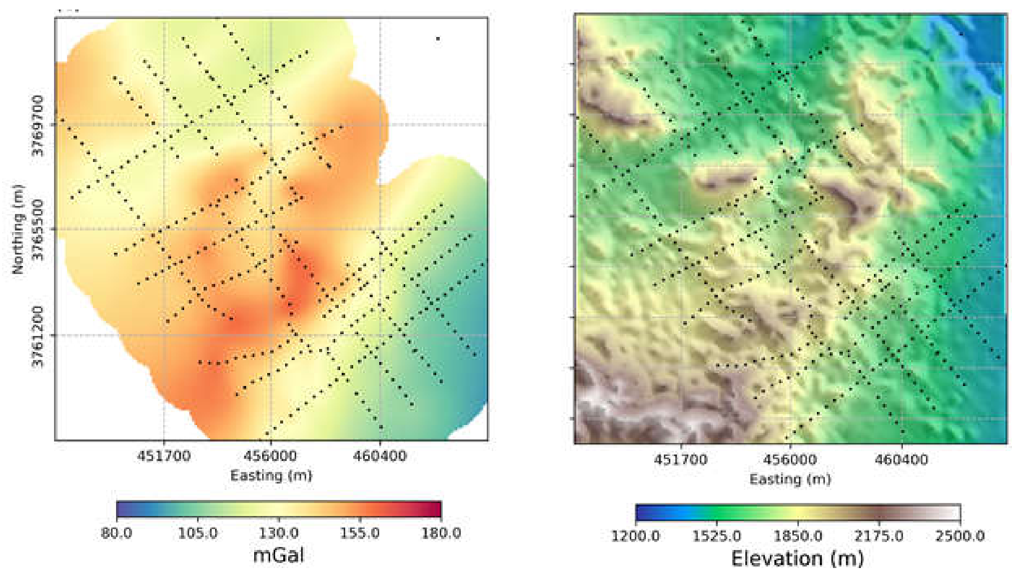

Figure 2. left: free air anomaly, right: extracted topography from SRTM

Simultaneous topographic and Bouguer corrections are performed with the following assumptions and steps,

- For each observation we want to subtract the gravitational attraction due to the mass between the reference surface and the topographic surface assuming a constant density (2.67 gr/cm^3),
- Assuming a flat geoid for our complete region (200km x 200km survey), Interpolate the topography (in our case extracted from the SRTM) to estimate the elevation at the center of each cell.
- The volume space between reference surface and the ground surface is discretized by adaptive quad tree mesh defined and used by Davis et al., (2010). This meshing method has a high flexibility so that it is possible to make the mesh smaller in areas close to the border.
- After refining the mesh, the topographical heights should be interpolated for the surface cell centers. The quad-tree mesh with 90m core-cell-size is opted for the terrain correction (Fig. (3)). Linear interpolation is applied to assign the height from extracted SRTM terrain to the cell center of quad tree mesh.
- For each observation location, compute the gravitational attraction of the cells to give the final Bouguer correction. In doing this we extended the topography beyond the 200km x 200km region of the SRTM to ensure that the grid has gone far enough to capture the effects of a constant density slab.
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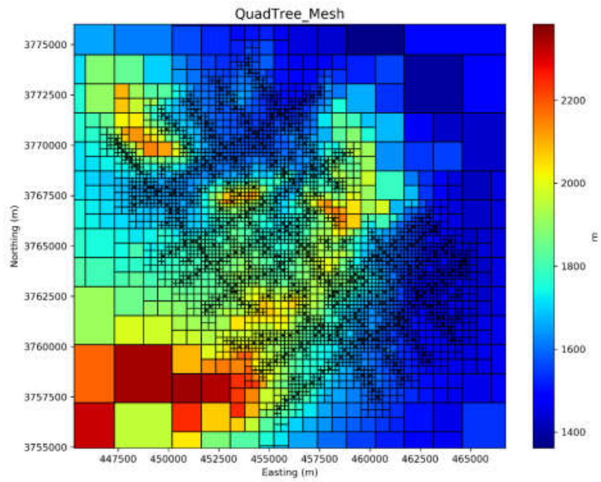

Figure 3. The quad-tree mesh with 90m core-cell-size for the terrain correction

After these steps the gravity effect of each cell is computed by using following equation,

$$g_z(\boldsymbol{r}_0) = \gamma\rho \int_v \frac{z-z_0}{|\boldsymbol{r}-\boldsymbol{r_0}|} dv \qquad (1)$$

leading to the gravity field at one data point d_i due to the sum of the gravity effects of the cells:

$$d_i = \sum_{j=1}^{m} \gamma \left\{ \rho_j \int_{\Delta v_j} \frac{z-z_0}{|\vec{r}-\vec{r}_0|^3} \, dv \right\} = \sum_{j=1}^{m} \rho_j \, G_{ij} \quad (2)$$

where *d* is the gravity data at observation points, ρ density of each cell, γ is the universal gravity constant, *i* and *j* are the indices of the observation point and the cell center respectively, z is the depth and r is the distance vector from observation point to the cell center. Adopting a Cartesian coordinate system having its origin at the Earth's surface, then *x*-axis pointing towards grid north, *y*-axis pointing towards grid east, and *z*-axis pointing vertically downward.

For computing this integral (eqn. 2) the forward gravity integral script available through SimPEG has been applied. The complete Bouguer anomalies will be obtained by subtracting the terrain corrections (forward gravity) from the free-air anomalies.

Real data

The expressed method is used for the real gravity data to carry out the Bouguer slab and terrain corrections in one step. We applied this process for the region and computed the Bouguer anomalies. The results are shown in Fig. (3) for free-air anomalies, terrain correction and Bouguer anomalies respectively.

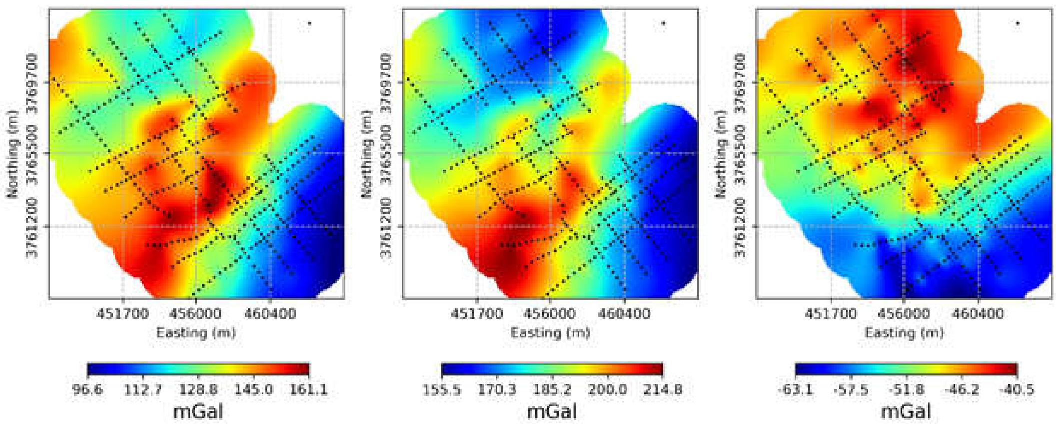

Figure 4. left: free-air anomalies, middle: forward modelling, right: Bouguer anomalies

CONCLUSION

There are two important points in the method performed: The first is to perform Bouguer and topographic corrections in one step through forward modeling, the model space between the base level and the ground level and the second is the high accuracy of the results obtained due to the flexibility of the meshing method in the SimPEG base.

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