



Contribution of Complete Bouguer Anomalies to the Accuracy of Gravimetric Geoid Model

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1. INTRODUCTION

- In the KTH method, mean gravity anomalies obtained from terrestrial point-gravity data are stochastically combined with gravity anomalies obtained from a truncated satellite-only GGM.
- In the preparation step, gridded gravity anomalies should be constructed for an efficient numerical evaluation of the Stokes integral.
- gravity observations taken at randomly distributed points on the Earth's surface are reduced to the geoid.
- Then they should be interpolated to mean values assigned to grid centres using an interpolation technique.

1. INTRODUCTION

- There are two types of Bouguer anomalies: simple and complete.
- there is a very limited number of studies that investigate the effect of smoothing methods on the prediction of mean gravity anomalies and their impact on the accuracy of geoid determination.
- this study investigates how Bouguer approximations affect the accuracy of the mean gravity anomalies, and resulting geoid model in a high-mountainous area.

2. METHODS

◦ 2.1 Simple Bouguer Gravity Anomalies

Firstly, the free-air gravity anomaly Δg^{FA} on the mean sea level is computed by,

$$\Delta g^{\text{FA}} = g_P - \delta g^{\text{FA}} - \gamma_0 \quad (1)$$

where g_P is the observed gravity value at surface point P , and γ_0 is the normal gravity on the reference ellipsoid. δg^{FA} is the free-air correction, which is subtracted from g_P to obtain the predicted gravity value on the reference ellipsoid by assuming that the vertical gravity gradient is equal to that of the normal gravity field:

$$\delta g^{\text{FA}} = \frac{dg}{dh} \cdot H_P = -0.3086 \cdot H_P \quad (2)$$

2. METHODS

- **2.1 Simple Bouguer Gravity Anomalies**

Then, the simple gravity anomaly is computed by,

$$\Delta g^{\text{SB}} = \Delta g^{\text{FA}} - \delta g^{\text{BP}} = \Delta g^{\text{FA}} - 0.1119 H_p \quad (3)$$

where the δg^{BP} represents Bouguer plate which is assuming the topography flat and constant density around the computation point.

2. METHODS

- 2.2 **Complete Bouguer Gravity Anomalies**

The topography deviates from the ideal planar plate, whose thickness is defined by the height of the point. Therefore, the more rigorous complete Bouguer (CB) anomaly accounts for terrain effects (TC) as follows:

$$\Delta g^{CB} = \Delta g^{FA} - \delta g^{BP} - \delta g^{TC} \quad (4)$$

where δg^{TC} denotes the terrain effect, which accounts for topographic undulations relative to the Bouguer plate.

2. METHODS

After interpolation of Bouguer anomalies in points, two types of gridded free-air gravity anomalies are obtained,

which is based on simple Bouguer reduction:

$$\Delta g_{ij}^{FA} = \Delta g_{ij}^{SB} + \delta g_{ij}^{BP} \quad (5)$$

which is based on complete Bouguer reduction:

$$\Delta g_{ij}^{FA} = \Delta g_{ij}^{CB} + \delta g_{ij}^{BP} + \delta g_{ij}^{TC} \quad (6)$$

These grids are then used as input to the KTH method in order to compute gravimetric geoid models

3. MATERIALS

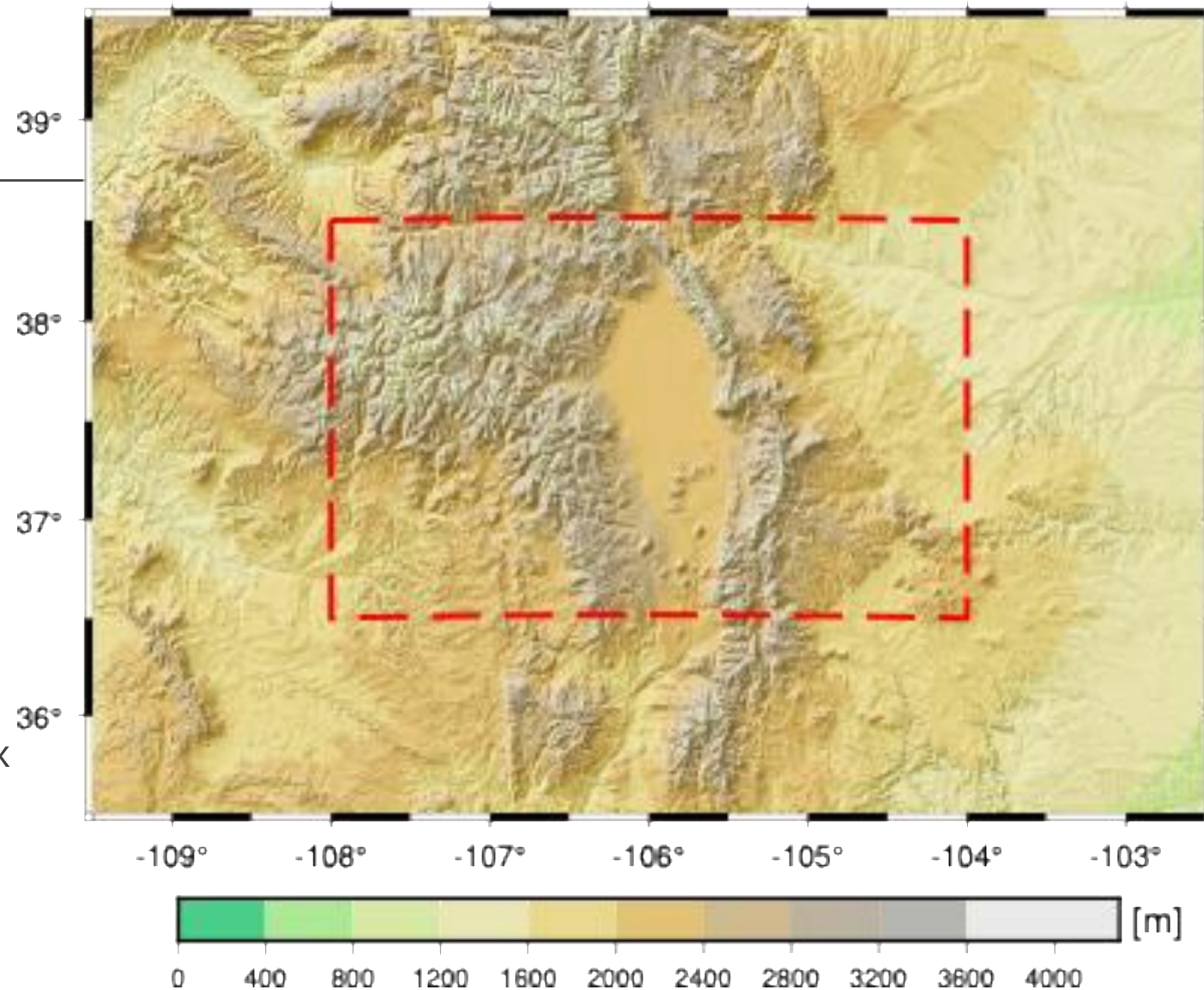
3.1 Study Area

*The Colorado test area is selected which is limited by 104° – 108° W and 36.5° – 38.5° N,

*covering approximately 80,000 km².

*The topographic heights range from 1000 m to 4400 m, with a mean value of about 2000 m.

*the region is one of the most complex areas worldwide in terms of topographic and geoidal variability.



3. MATERIALS

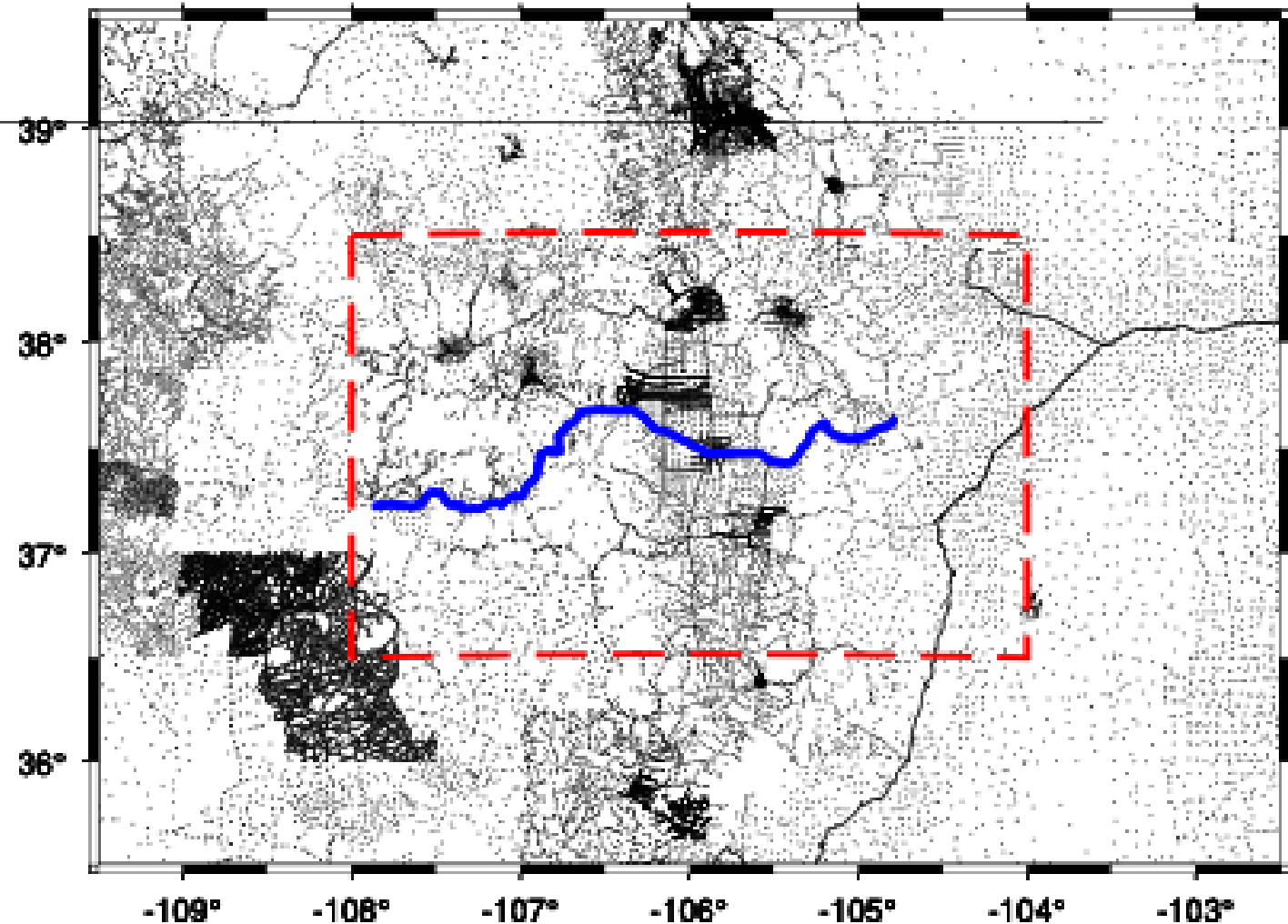
3.2 Terrestrial gravity data

*The total number of gravity observations in the study area is 59,303, provided by NGS

*Each record contains latitude, longitude, orthometric height, and observed gravity value of point P .

*The observation density corresponds to approximately one point per 7 km²

*the data accuracy is better than 1 mGal.



3. MATERIALS

3.3 Control Benchmarks

- *The computed geoid models are compared with GNSS-levelling data, since these are the only independent observations available for validating gravimetric geoid models.
- *A total of 223 GNSS-levelling benchmarks is available within the study area.
- *The spatial distribution of these benchmarks follows an east-west profile across the study region
- *The horizontal accuracy of the points is at the millimetre level, while the vertical accuracy is approximately 1 and 2 cm for ellipsoidal and orthometric heights, respectively.
- *This indicates that GNSS-levelling data provide highly accurate geometric geoid information for final point-wise validation of the computed geoid models.

4. NUMERICAL APPLICATIONS

Comparison of Free-Air Gravity Anomalies

*Two different smoothing strategies were applied to generate free-air gravity anomaly grids.

*The first gridding approach can be summarized as follows: randomly distributed free-air gravity anomalies on the Earth's surface were first converted into simple Bouguer anomalies Δg^{SB} using orthometric heights H_{P_i} of gravity points P_i .

*Subsequently, the simple Bouguer anomalies were interpolated onto grid nodes using the nearest-neighbour method.

*After interpolation, the Bouguer plate effect was restored using the mean elevation of each grid cell.

4. NUMERICAL APPLICATIONS

Comparison of Free-Air Gravity Anomalies

- *As the second gridding strategy, simple Bouguer anomalies at observation points are first converted into complete Bouguer (CB) anomalies Δg^{CB} by subtracting terrain corrections at the gravity stations.
- *The same interpolation scheme is then applied to transfer the CB anomalies onto a regular grid.
- *After interpolation, the complete Bouguer anomalies at grid centres are converted back to free-air gravity anomalies by adding the Bouguer plate effect based on the mean grid elevation and restoring the mean terrain correction.
- *As a result, a free-air gravity anomaly grid based on the CB formulation is obtained.

4. NUMERICAL APPLICATIONS

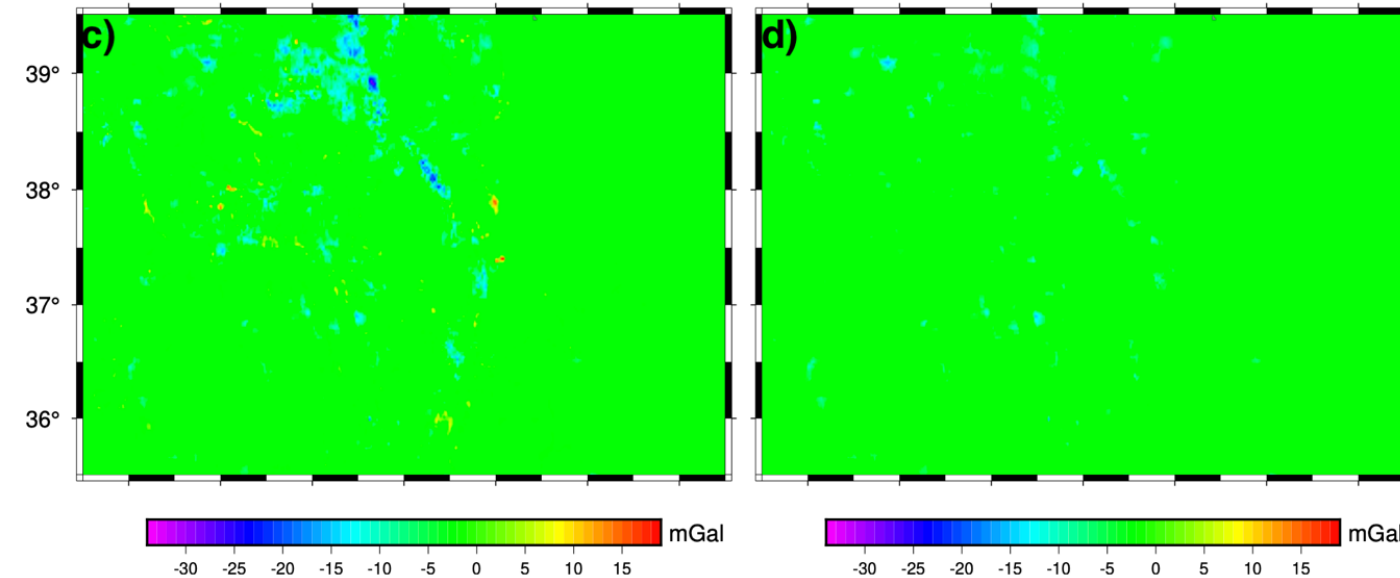
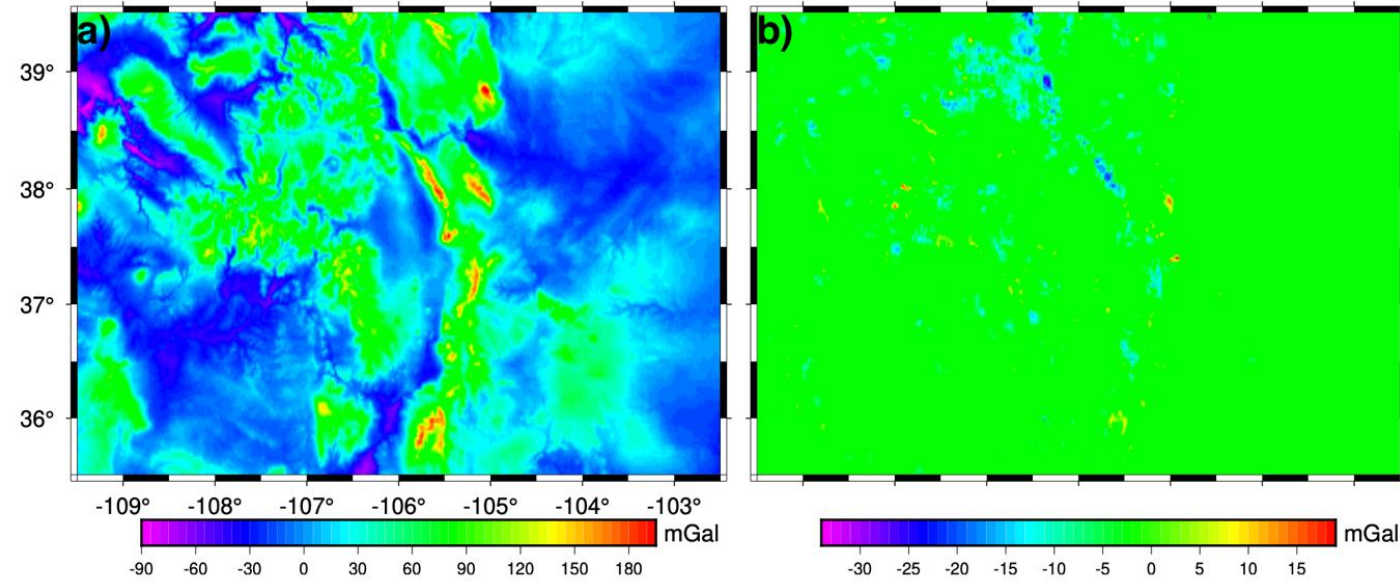
Comparison of mean free-air gravity anomalies with respect to Complete Bouguer anomalies via tesseroïdal TC. Statistics are in mGal.

Comparison type	Reference	Min	Max	Mean	STD
SPB	CTB	-35.042	19.815	-1.396	2.416
SCB	CTB	-35.105	19.312	-1.403	2.383
CPB	CTB	-33.081	1.687	-1.230	1.427

SPB: Simple Planar Bouguer
SCB: Simple Cap Bouguer

CPB: Complete Bouguer via Planar TC
CTB: Complete Bouguer via Tesseroidal TC

Comparison of Free-Air Gravity Anomalies



4. NUMERICAL APPLICATIONS

Comparison of Geoid Models

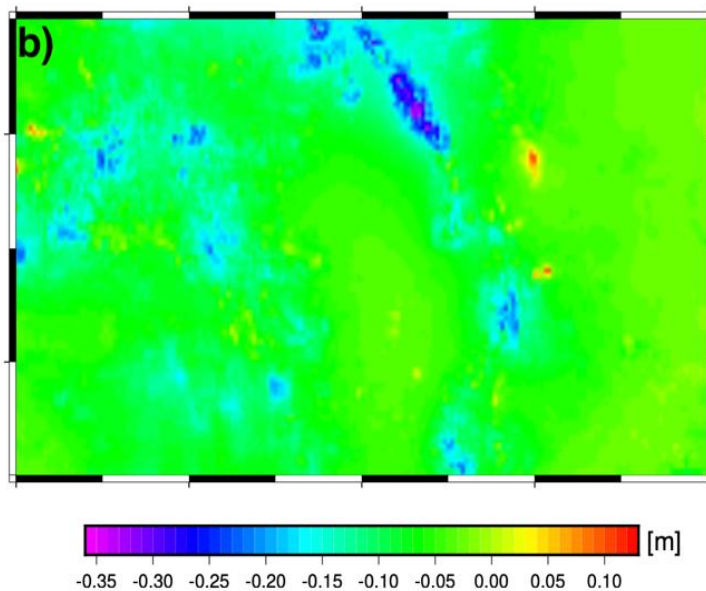
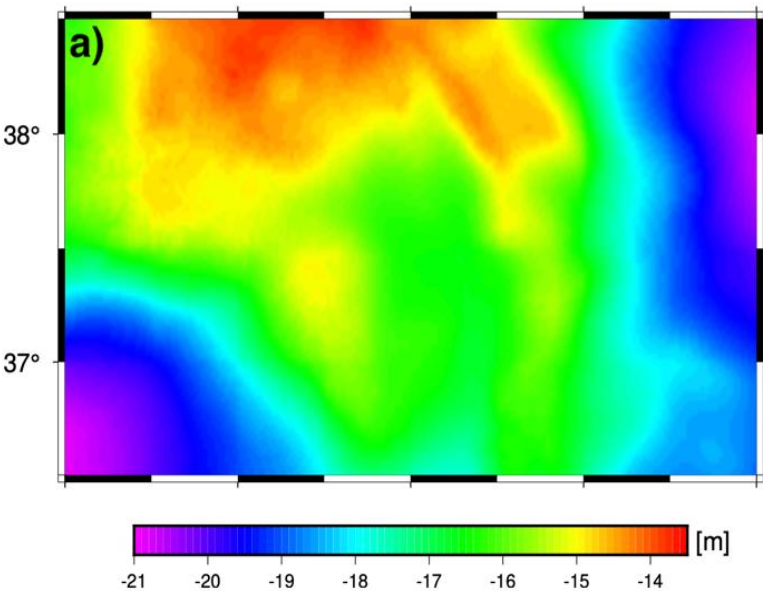
*Four geoid models, referred to as Colorado Geoid models based on SB and CB were computed separately using the boundary data.

*In the geoid computations, the LSMSSOFT developed by Abbak and Ustun (2015) was used.

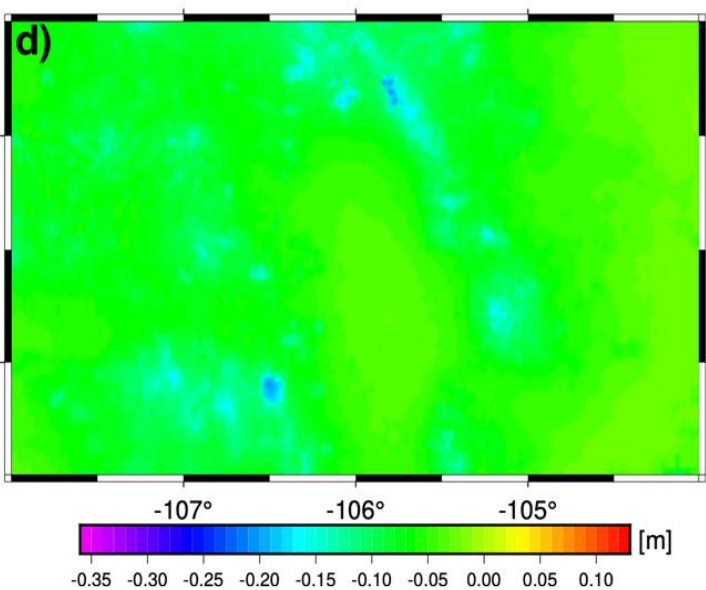
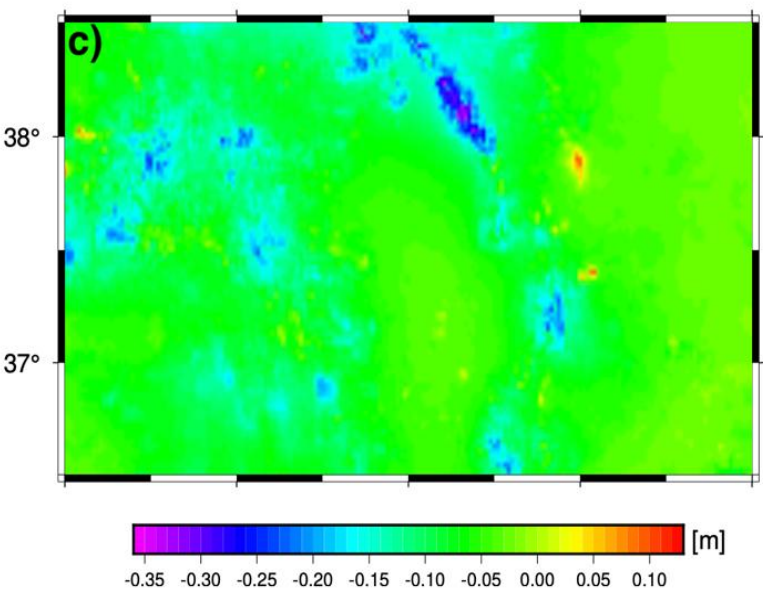
*Once the optimal parameters are identified, all input datasets and parameters are fixed, except for the free-air gravity anomaly grid used in each geoid computation.

Absolute and relative assessment of geoid models using GNSS-levelling data. RMS denotes Root Mean Square Error. Absolute values are in cm, and relative values are in ppm.

Geoid model	Min (abs)	Max (abs)	Mean (abs)	RMS (cm)	Min (rel)	Max (rel)	Mean (rel)
SB planar approx. (before fit)	-129.25	-100.00	-121.25	4.22	0.00	53.38	1.15
SB planar approx. (after fit)	-8.33	9.88	0.00	3.47	0.00	53.96	1.10
SB spherical approx. (before fit)	-129.18	-100.00	-121.08	4.26	0.00	53.38	1.15
SB spherical approx. (after fit)	-8.26	9.72	0.00	3.46	0.00	53.88	1.10
CB via planar TC (before fit)	-130.50	-100.00	-122.21	3.23	0.00	52.23	0.97
CB via planar TC (after fit)	-6.19	10.16	0.00	3.01	0.00	52.61	0.94
CB via tesseroidal TC (before fit)	-140.23	-100.00	-128.94	3.11	0.00	54.76	0.88
CB via tesseroidal TC (after fit)	-5.42	11.28	0.00	2.93	0.00	54.67	0.84



a) geoid model obtained from CTB.
b) geoid differences: SPB-CTB.



c) geoid differences: SCB-CTB.
d) geoid differences: CPB-CTB.

5. CONCLUSIONS

*According to our numerical investigations, the maximum difference between the computed geoid models reaches up to ~ 0.40 m, and is highly correlated with elevation, particularly along the northern part of the study area.

*Comparisons with GNSS-levelling data indicates that there are slight differences between the computed geoid models when terrain corrections are applied.

*It can be inferred that the complete Bouguer gravity anomalies (with tesseroidal terrain corrections) should be used in gridding gravity anomalies, particularly in mountainous areas.

Thank you for your attention...

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Effect of the Generation of Bouguer Anomalies on the Geoid Determination: A Case Study in a High-Mountainous Area

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Abstract

Different types of gravity anomalies are engaged in geophysical and geodetic tasks. Whether they are used for regional or global applications, they require efficient calculations. All variants are based on the so-called free-air gravity anomalies. Mean free-air grav-