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

Ilya Prutkin (1), Peter Vajda (2), and Gerhard Jentzsch (1)
(1) Institute of Earth Sciences, Jena University, Jena, Germany
(2) Earth Science Institute, Slovak Academy of Sciences, Bratislava, Slovakia

Our approach to 3D interpretation of gravity/magnetic data

- Preliminary separation of sources

  - in depth based on subsequent upward and downward continuation

  - in the lateral direction using approximation with the field of several 3D line segments

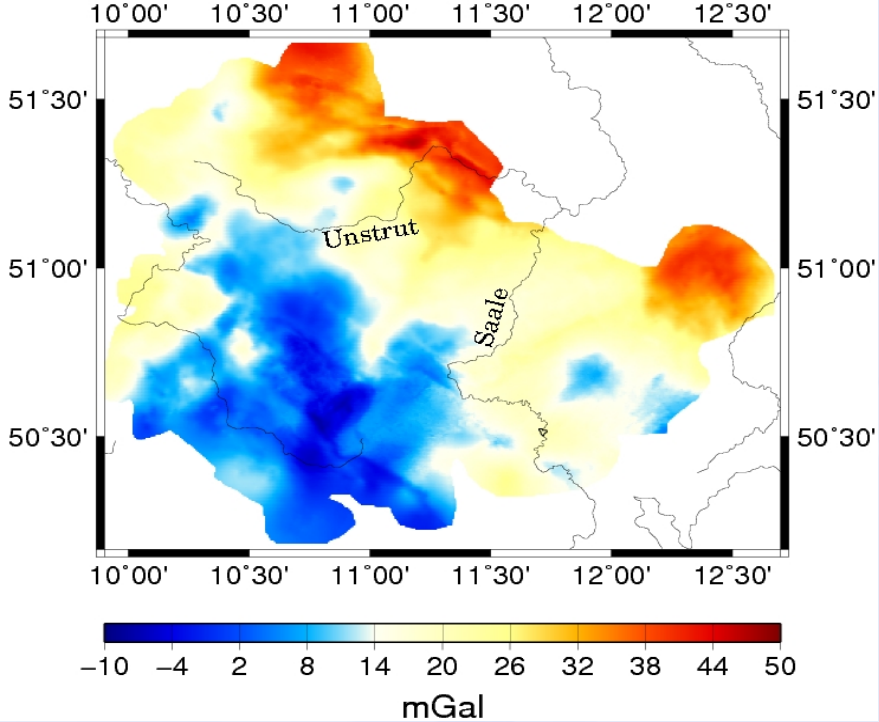
  - according to density and magnetization contrast by calculation of pseudo-gravity

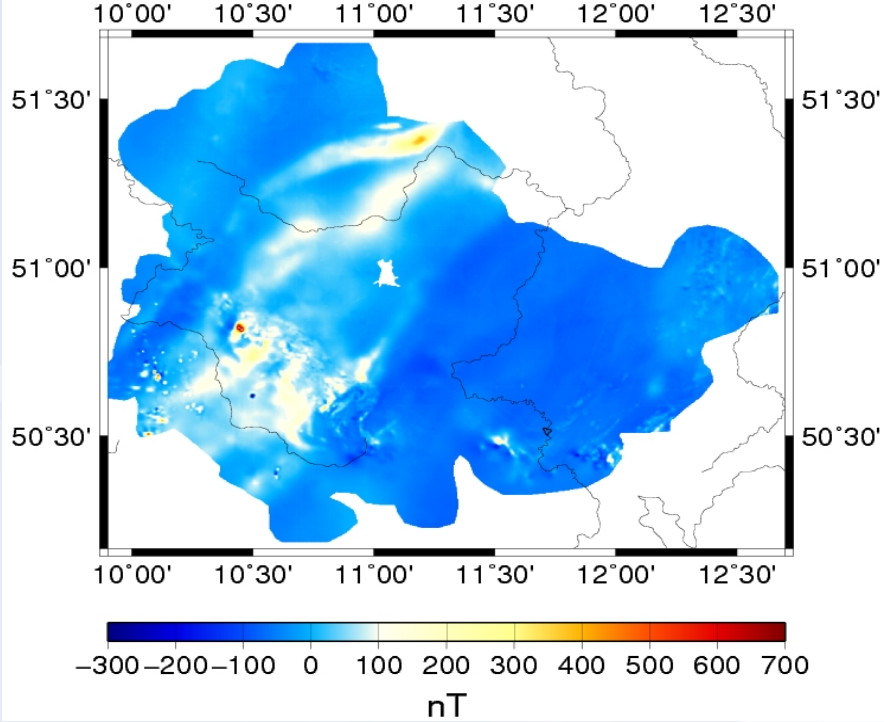
- Original algorithms for 3D gravity and magnetic data inversion

  - for restricted objects of arbitrary shape

  - for 3D topography of contact surfaces

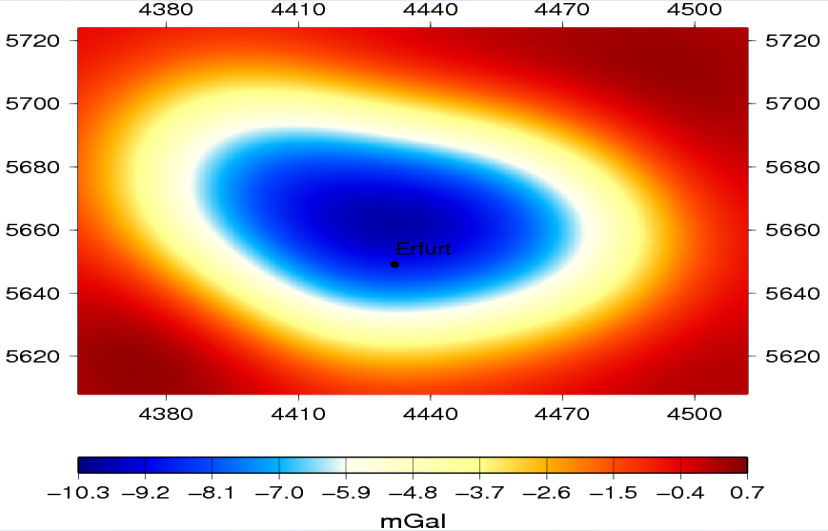
Initial data set (GGD Leipzig)

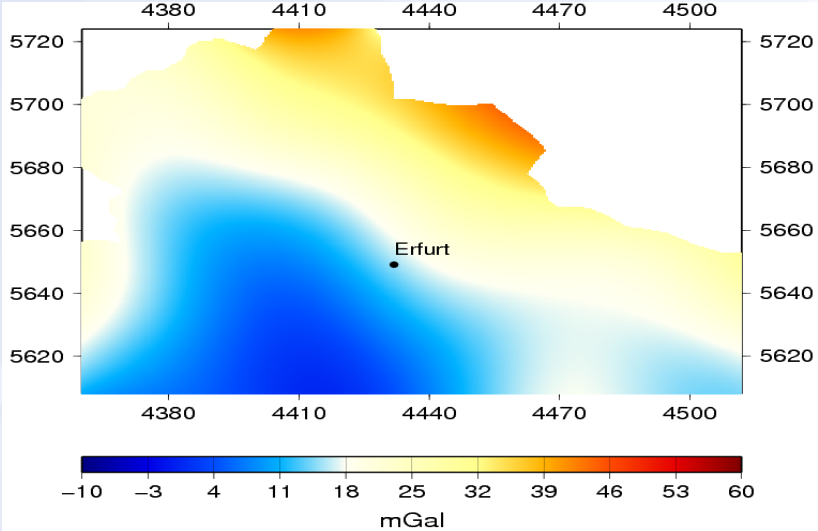




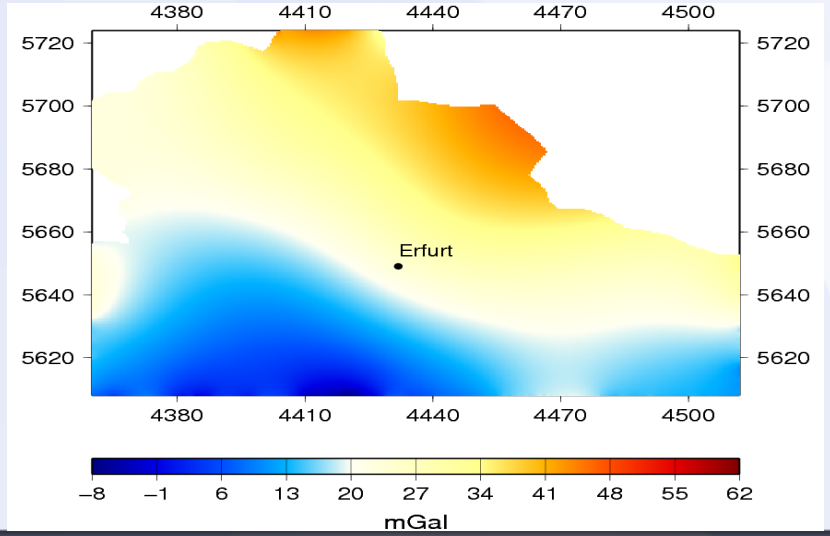
Initial data. Left: gravity (Bouguer anomalies, grid distance 500m). Right: magnetic (total magnetic intensity anomalies, grid distance 250 m)

Long wavelengths

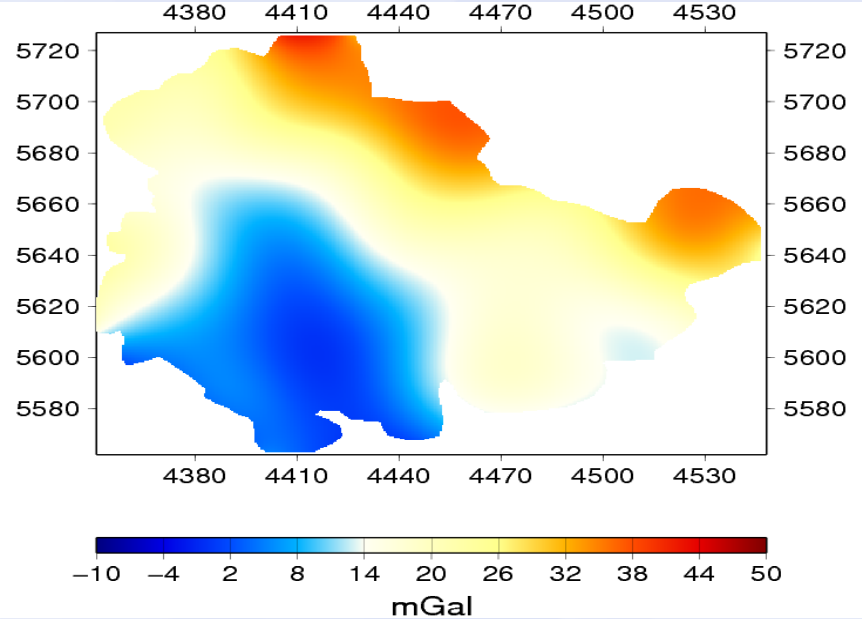


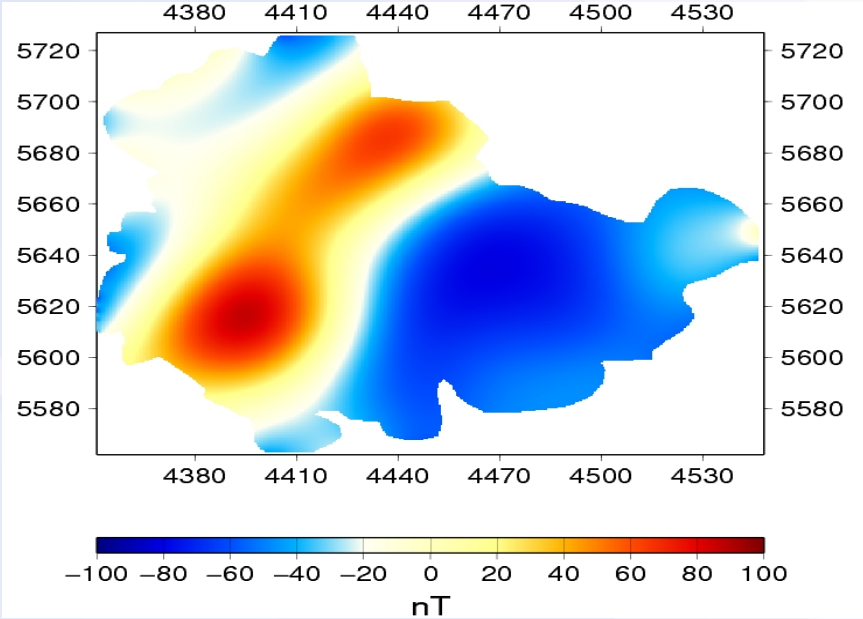


Low-frequency component of the geological model effect (top left), the same for initial data (top right) and for residuals (bottom right), which we attribute to an uplift of Moho



Comparison with magnetic data

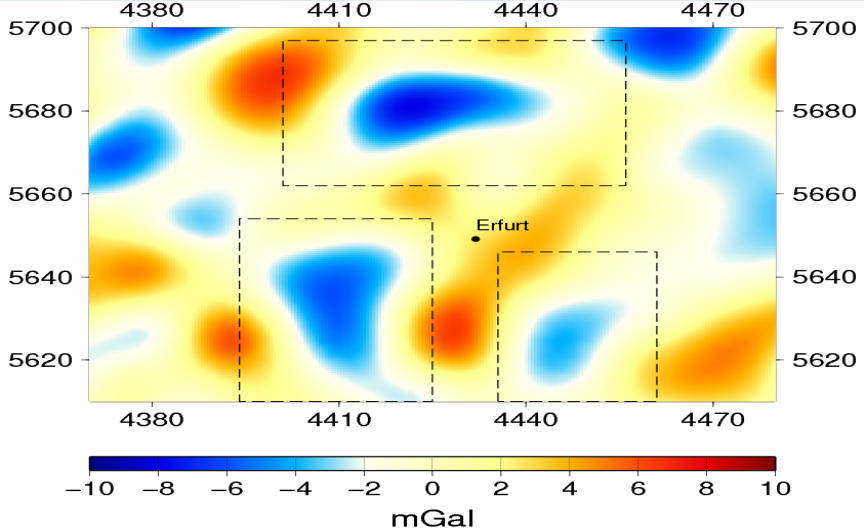


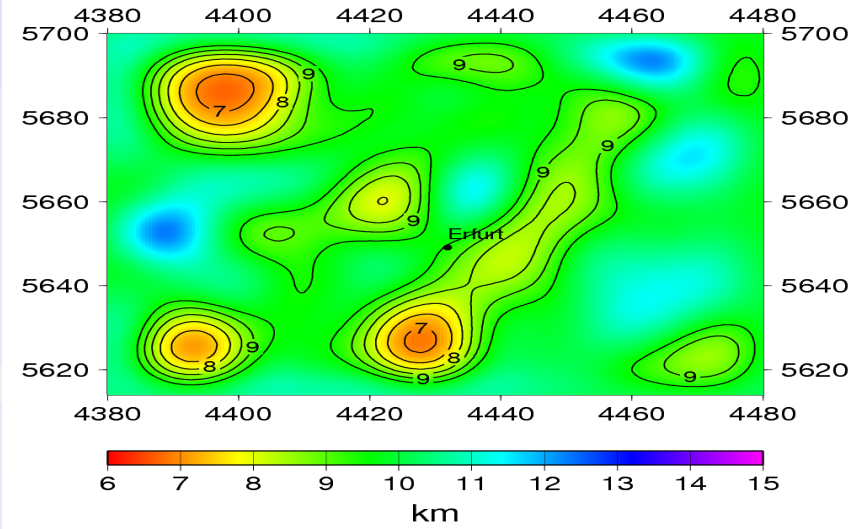


Long wavelengths for gravity (left) and magnetic data (right)

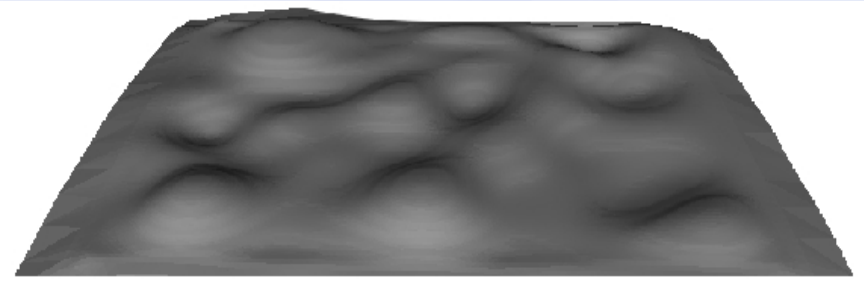
Their comparison reveals that gravitational and magnetic anomalies are caused partly by different objects. The low-frequency component of gravity is caused by the uplift of Moho and the long-wave effect of the basin structure, meanwhile the same component of the magnetic field is generated by the Mid-German Crystalline High

Intermediate wavelengths





ρ = 2.75g/cm3



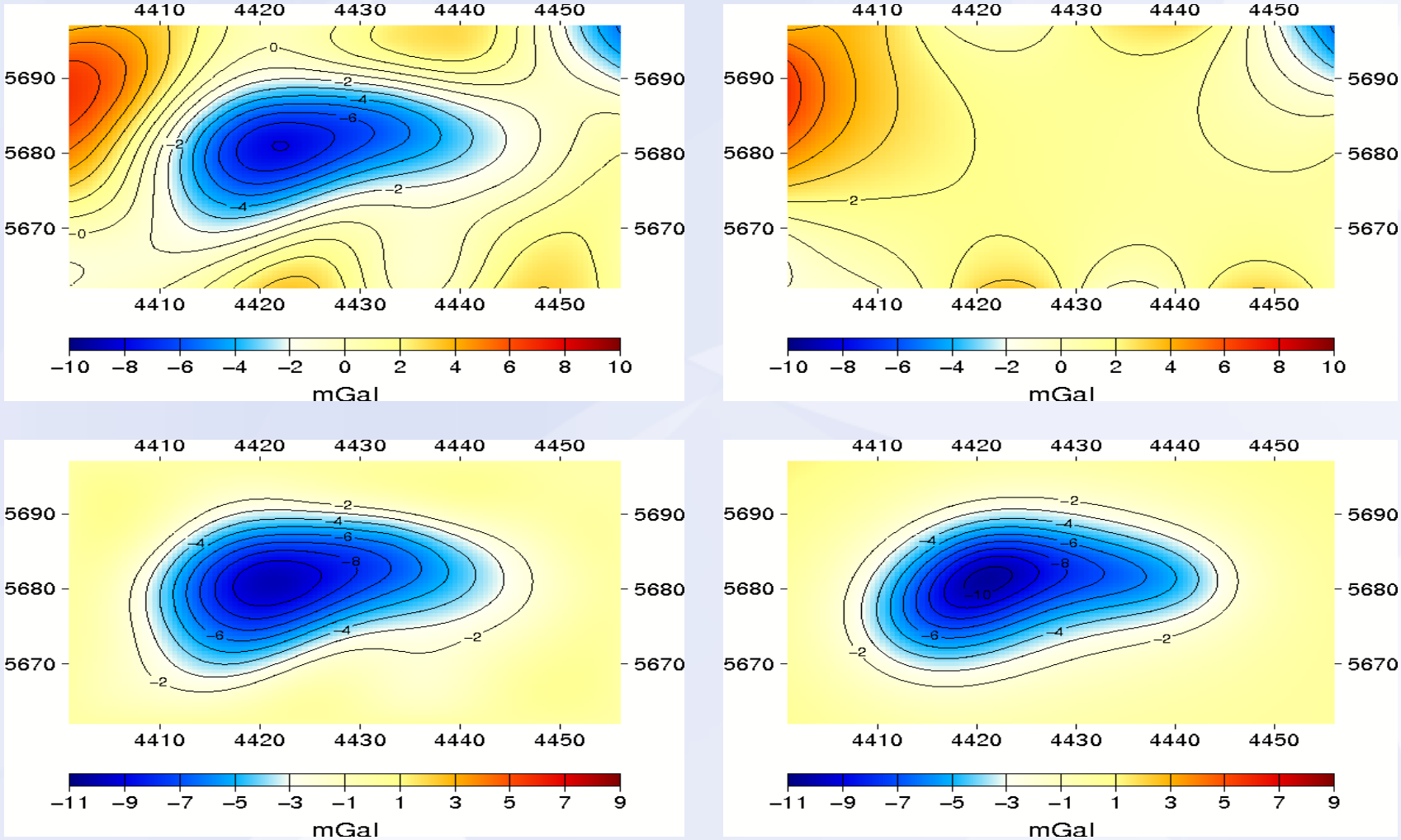
ρ = 2.85g/cm3

z≈10km

Gravity (intermediate wavelengths) (top left) and its inversion after subtracting negative anomalies

Top right: depths to the contact surface, bottom: 3D model of topography

Approximation of a local anomaly



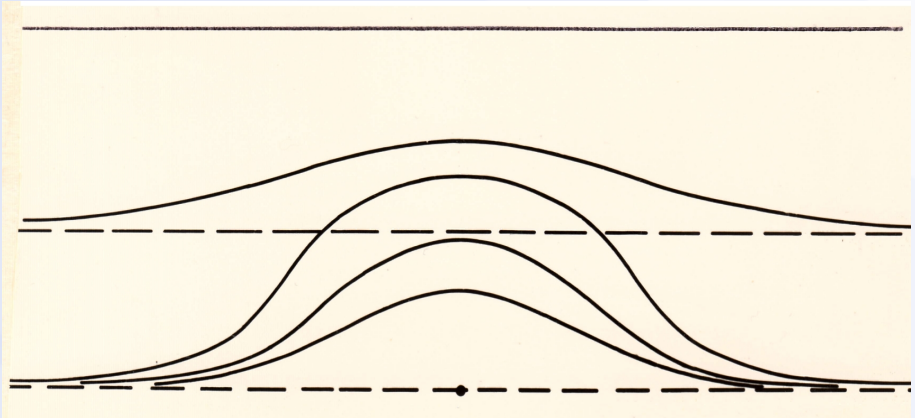
Top: zoomed anomaly (left), regional field model (right). Bottom: residuals (left) and their approximation with 3D line segments (right). RMS=0.41mGal

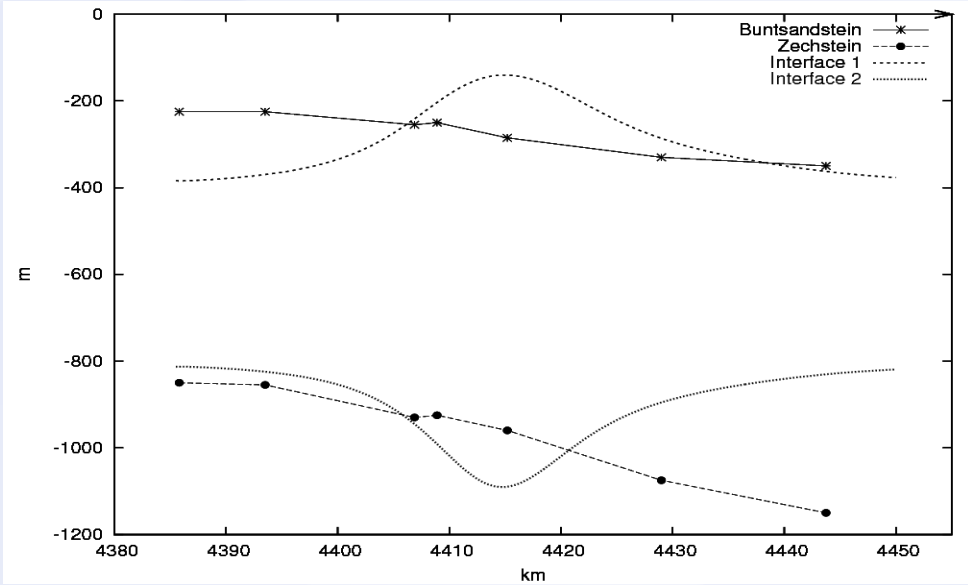
Problem of low frequencies

Deep object => long wavelengths prevail
Equivalently, if the signal contains high frequencies, it is caused by near-surface objects

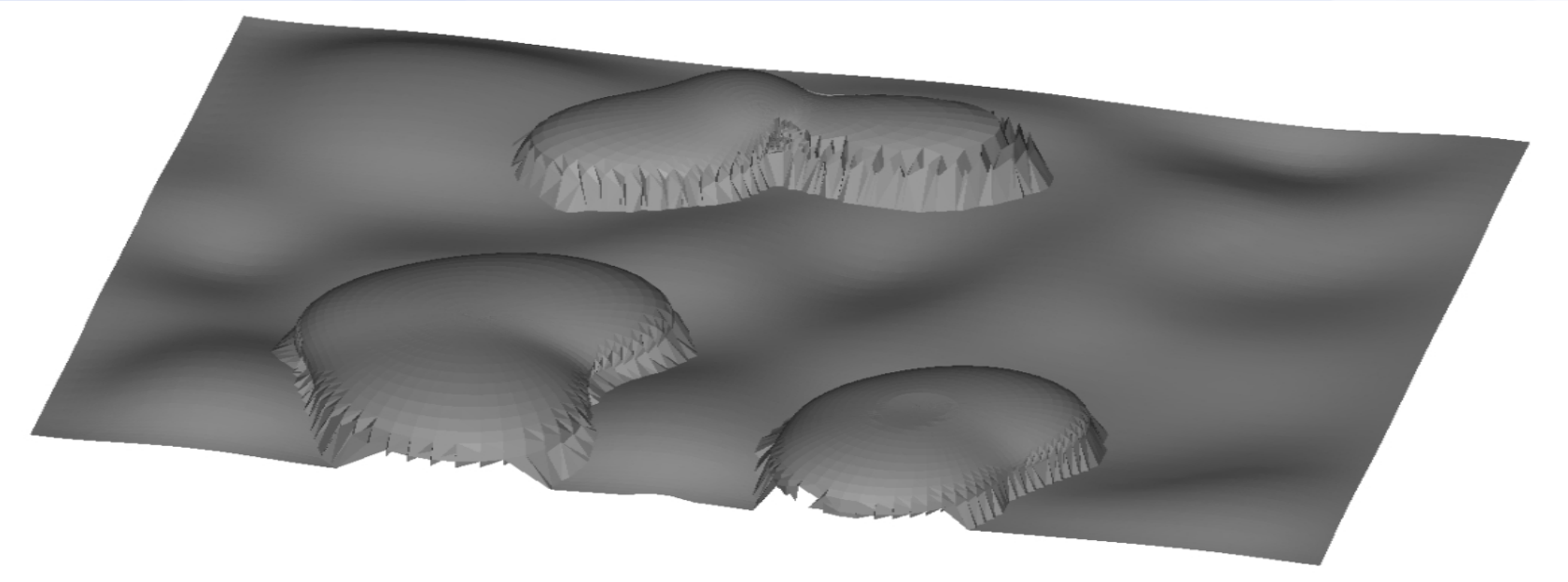
The converse implication is not necessarily true:
the basin structure contributes substantially into low frequencies

Top right: density interfaces with the same field as a point source; bottom right: comparison of inversion results and boreholes data



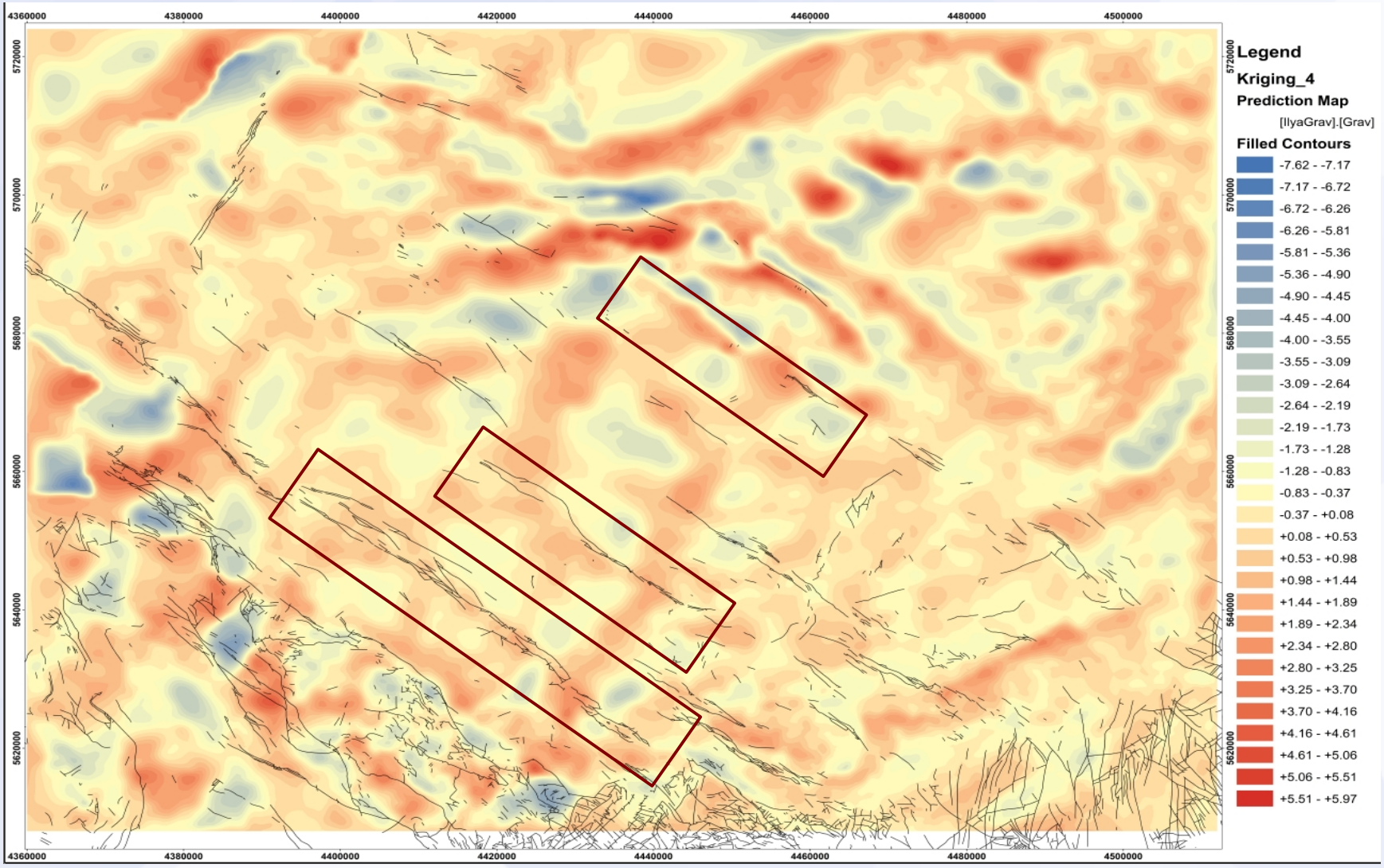


3D model for intermediate wavelengths

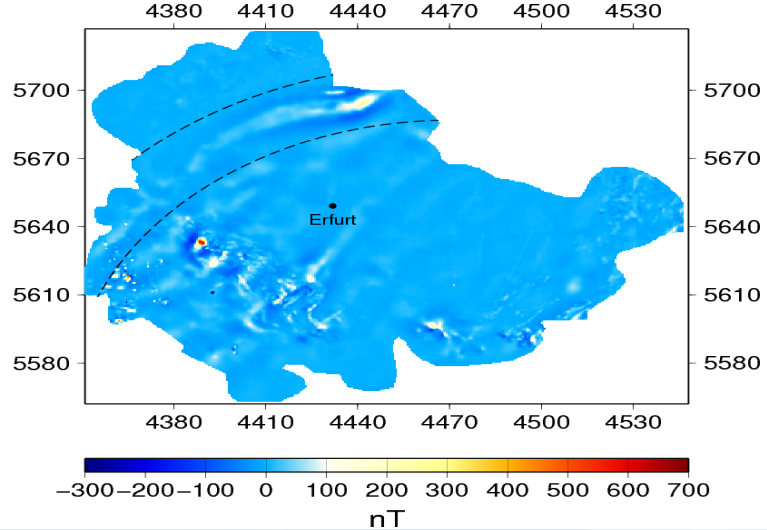


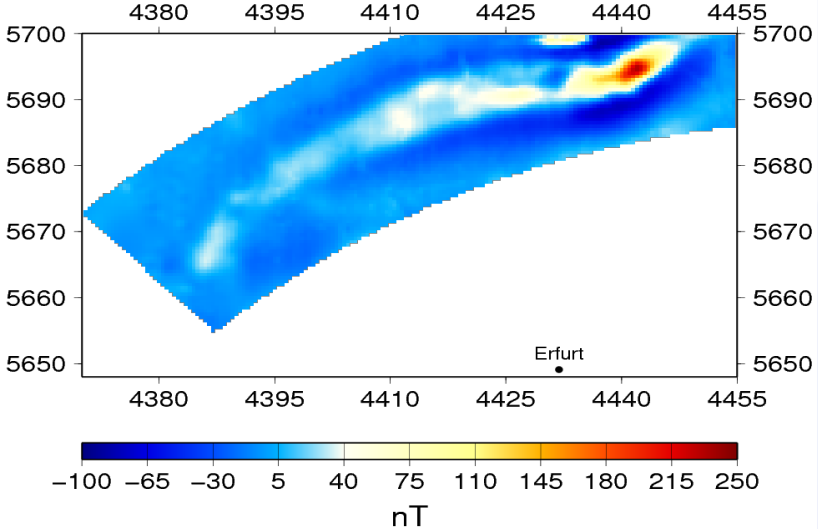
We transform line segments to 3D restricted bodies with the same field and put them back. The obtained model for the the main intermediate sources includes three low-density bodies that we interpret as granitic intrusions, and a density interface with topography below them (~10 km depth)

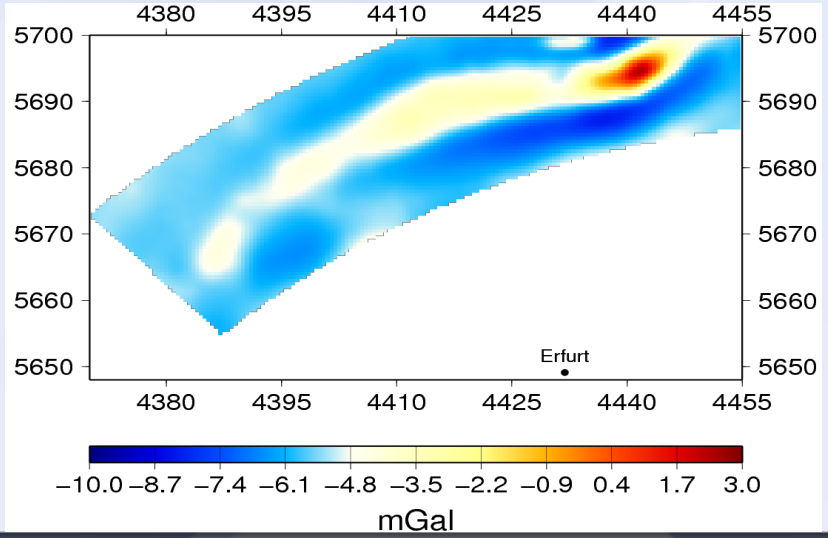
Comparison of gravity anomalies and known faults

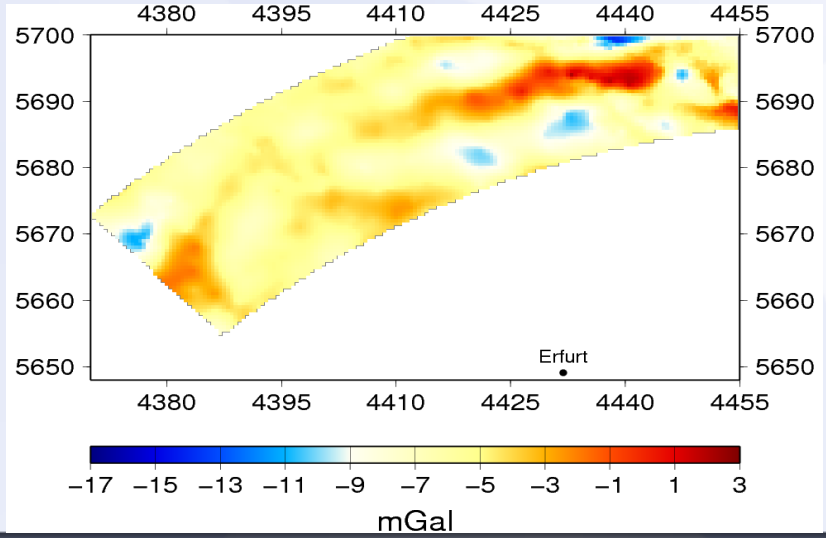


Interpretation of the arc-shaped anomaly



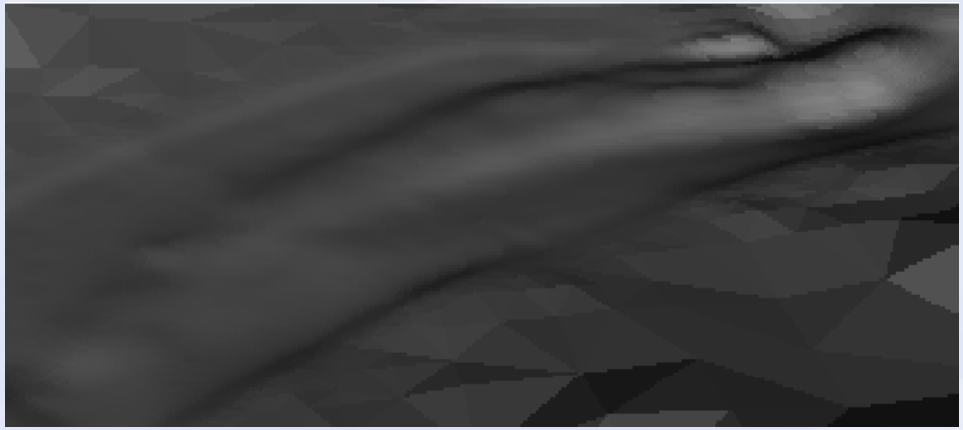






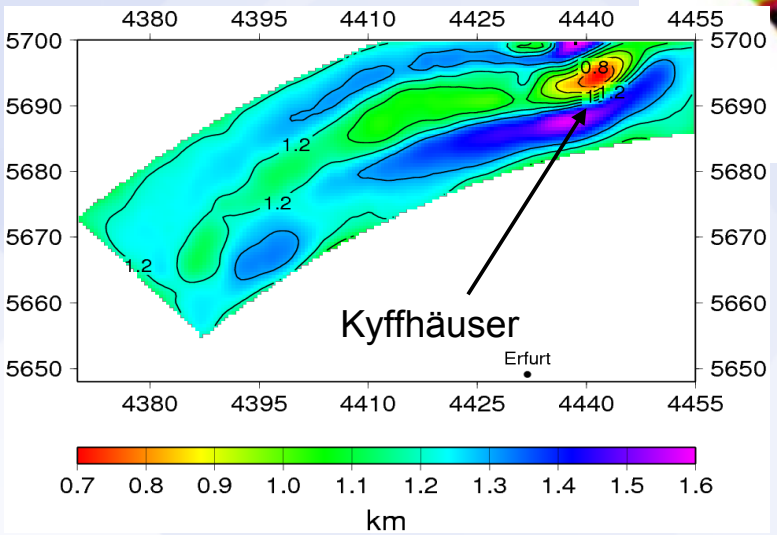
Top: magnetics. Bottom: pseudo-gravity and measured gravity

3D inversion for an uplift of the crystalline basement

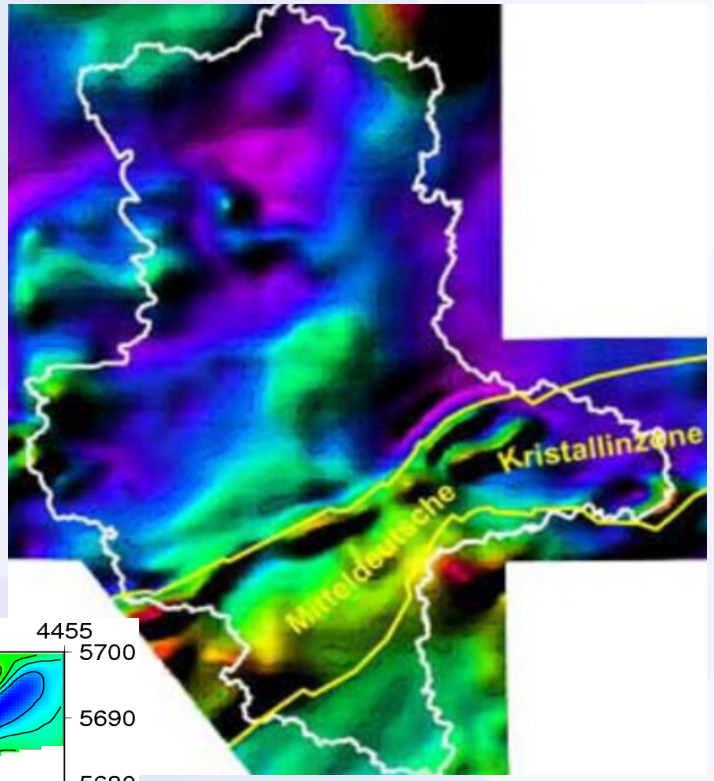


3D model of the topography

Kyffhäuser represents not an isolated hill surrounded by a flat surface (TLUG model), but a top of a prolonged mountain chain. Magnetic anomaly continues farther to Sachsen-Anhalt



Depths to the contact surface



Geomagnetische Karte von Sachsen-Anhalt als Pseudoreliefdarstellung
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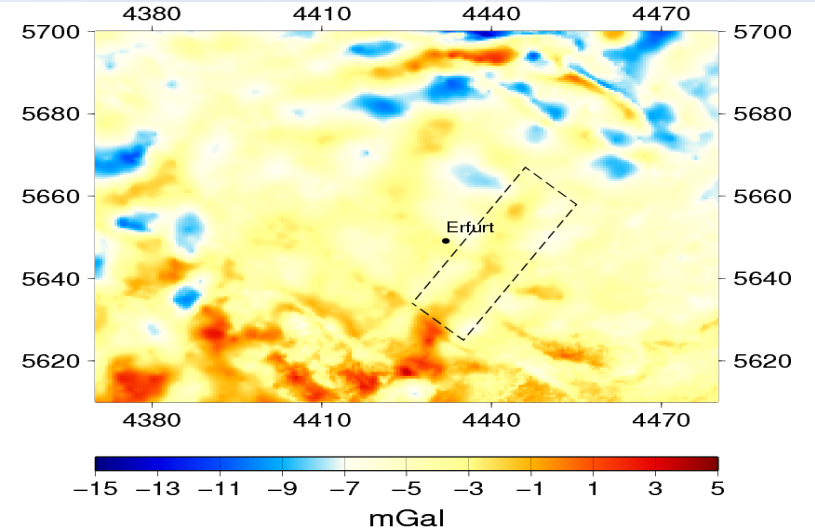
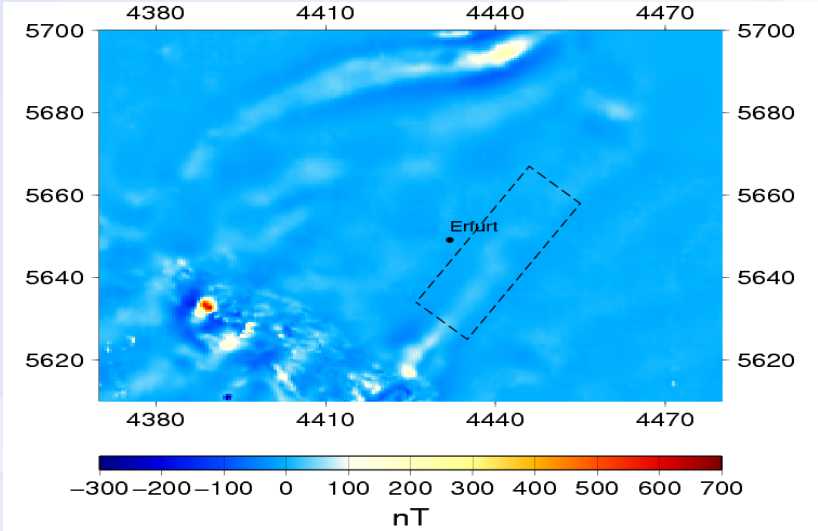
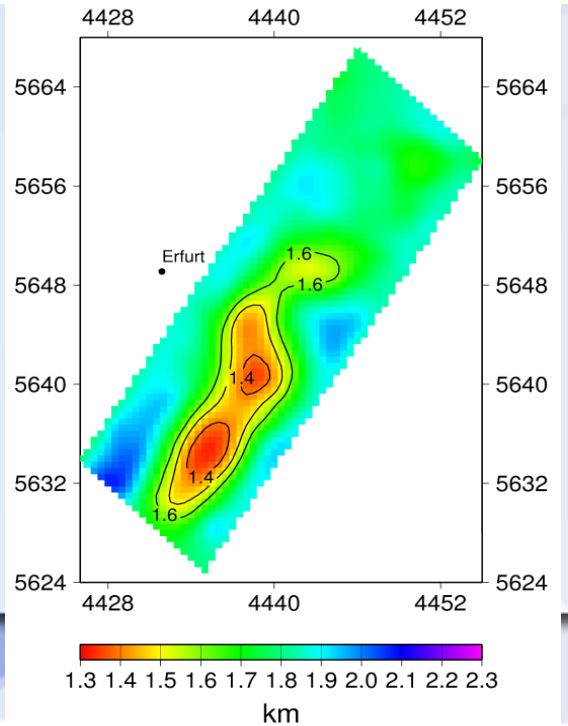
3D inversion for SW-NE anomaly

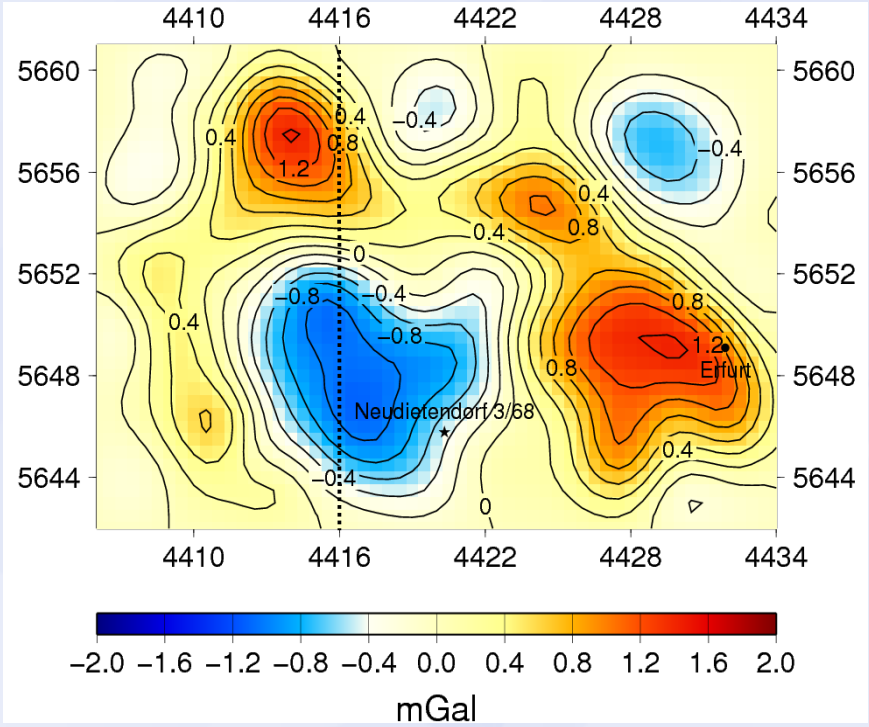




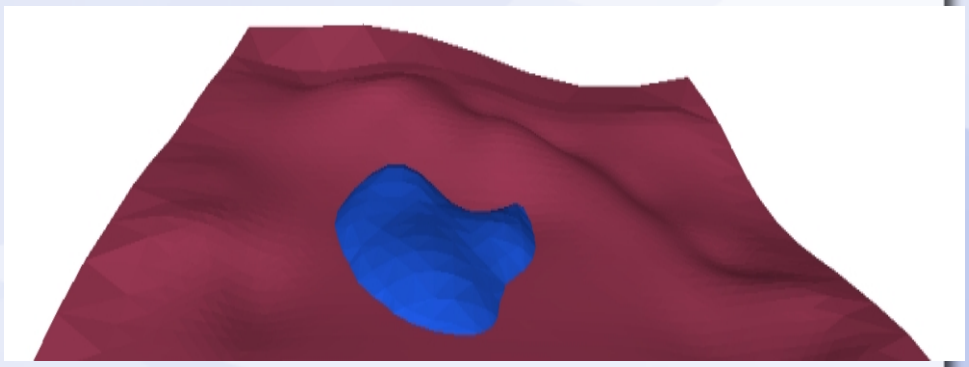


Top: gravity (left) and magnetics (right). Bottom: depths to the contact surface found by our inversion algorithm.
Both anomalies are caused allegedly by the same uplift of the crystalline basement

Fahner Hoehe: residual gravity

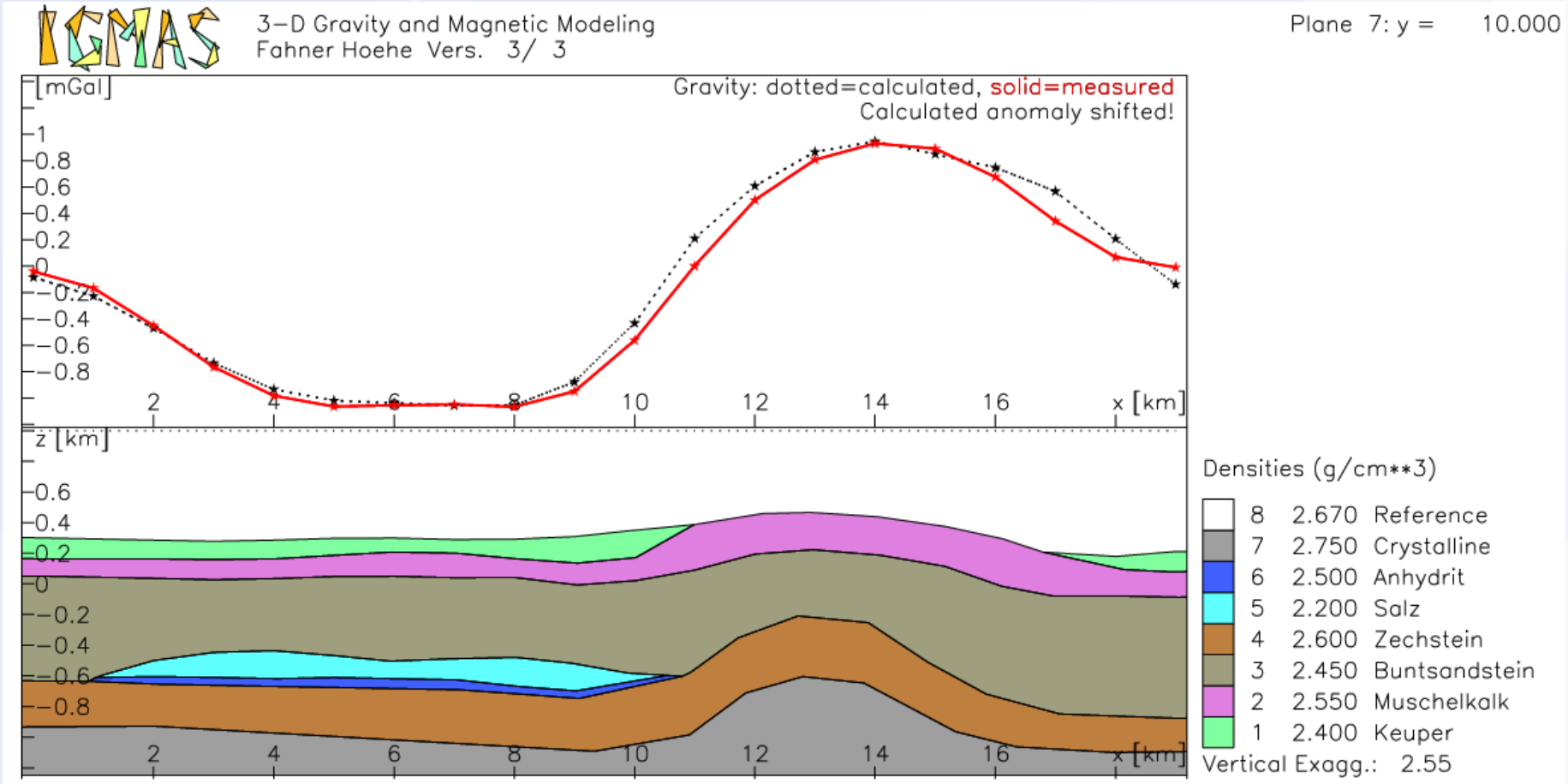


Gravity data. A star – location of the Neudietendorf borehole, dashed line - a south-north profile, the section along it is shown in the next slide



3D inversion for a salt deposit geometry. Red – upper boundary of the Zechstein layer (according to the TLUG geological model), blue – shape of the salt pillow found based on our inversion algorithm

Fahner Hoehe: IGMAS modeling



According to IGMAS modeling, for the area of the Fahner anticline, process of folding affects also the upper boundary of the crystalline layer

Conclusions

- Separating into long, intermediate and short wavelengths provide opportunity to investigate deep structure of the Thuringian Basin: granitic intrusions above density interface
- For a local area, we subtract the model of the regional field (2D harmonic function), approximate the residuals with 3D line segments (quite stable) and transform a chosen set of line segments into a restricted object or a contact surface (in the class of uniqueness)
- 3D inversion of magnetic data allow investigating of fine structure for the crystalline basement (arc-shaped and linear uplifts)
- We study salt tectonics for local areas. With some preliminary assumptions it is possible, to isolate the effect of a salt deposit and to find its unknown geometry