Supplementary Material to the Article:

Electrical Resistivity Structure at the North-Central Turkey Inferred from Three-dimensional Magnetotellurics

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1 Introduction

Here, we present supplementary information to the paper called "Electrical Resistivity Structure at the North-Central Turkey Inferred from Three-dimensional Magnetotellurics." It consists of additional data and figures that was important during interpretation but was not found necessary for the presentation.

2 Instrumentation and Field Procedure

In MT surveys, two components of the natural electric field and three components of the magnetic field are recorded simultaneously by a computer system. The instruments of the system are synchronized with the Global Positioning System (GPS). In this study two Phoenix Geophysics (MTU-5A) recording sets were used. Two horizontal components of electric field ($E_x$ and $E_y$) were received with four non-polarizing $Pb - PbCl_2$ electrodes. By using a sensitive compass, one dipole set of electrodes were placed to align along the geomagnetic north to gather information about N-S component of electric field ($E_x$), while the other dipole set was placed orthogonally to record E-W component of the electric field ($E_y$). The spacing between the electrodes for wide-band measurements taken in values between 50 m to 100 m and determined accordingly depending on the circumstances in the survey area.

Magnetic measurements are deployed by the magnetic coils (MTC-50) placed in three directions. In classical MT analysis, vertical component of the geomagnetic field is not a necessary measure. Nevertheless, vertical component of the magnetic field can be used to generate tipper data. Three coils were placed delicately with the assistance of compasses and water gauges to form accurate geomagnetic references.

3 MT Data

In total, 26 MT stations were deployed as a profile to depict the crustal structure in the area. Eighteen to forty-two hours of electric and magnetic field recordings were performed at every station. The recorded time window allowed
the possibility to obtain data from the wide-band frequency range 320 Hz - 0.00055 Hz (1818 s). One of the collected stations were found to be highly affected by noise (CPon 02), thus the processing and modeling steps were carried out only through data of 25 stations. The last two frequencies were excluded from all data, because it showed consistent outliers within different stations. Remote reference method (Gamble et al., 1979) was also applied on some of the simultaneously recorded data to remove unwanted effects.

Tipper data can be used as a parameter to investigate the lateral conductivity variations and can be included in the inversion algorithms. For the first set of modeling trials, tipper data drastically enhanced the total RMS values. Due to their noisy state at some stations, the tipper data were excluded in the inversion of the final models.

4 Pseudo Section

![Figure 1: Observed apparent resistivity and phase pseudo-sections for xy- and yx-components.](image)

Figure 1: Observed apparent resistivity and phase pseudo-sections for $xy$- and $yx$-components.
5 Ellipticity of the Phase Tensors

Figure 2: Phase tensor ellipticity variations at several frequencies of every recorded station for (a) Çankırı Region, (b) NAF Zone, (c) Pontic Terrane. (d) Pseudo-section of phase tensor ellipses filled with ellipticity values at every station.
Alignment of maximum phase value indicates the geo-electrical strike direction and its intensity grows strong when the difference between maximum and minimum phases increase. Hereby, any deviation from a perfect circle is considered as moving away from the ideal 1-D environment. Ellipticity of the phase tensor is a measure to determine the amount of the two-dimensionality in a specific region. Basically, it is equal to normalized difference between maximum and minimum phases \( \frac{\phi_{\text{max}} - \phi_{\text{min}}}{\phi_{\text{max}} + \phi_{\text{min}}} \). Its value gets closer to 1.0 when the environment is 2-D.
6 Geological Evolution of the Area

Figure 3: Evolutionary tectonic sketch of the area. Redrawn after Okay et al. (2013) and AygÂijl et al. (2015).
7 More Information on Models

7.1 Regional Model

The nodes of the mesh were selected accordingly to prevent any overlap of stations on the mesh elements. At the core of the mesh, both northing and easting cell sizes were selected as 2.5 km. From every boundary, eight horizontal layers outside the core increasing in size with a factor of 1.5 were structured to prevent reverberation effects. Mesh had 42 cells in the vertical direction increasing in size with a factor of 1.2. The thickness of the first layer was selected as 0.1 km, which was accurate enough to solve the corresponding frequencies at shallower layers. The total number of cells in X-Y-Z directions were 87 x 36 x 42, respectively; resulting in a total cell number of 131544. Resistivity of the initial model was selected as 100 $\Omega m$. Northern end of the model was fixed to values of 0.3 $\Omega m$ to a certain depth, to mimic the coast effect of Black Sea. Fifteen frequencies in the range 320 Hz - 0.001 Hz were selected for this purpose.
Inversion was carried out by using different parameters. To take control of the regularization scheme, different lagrange multipliers have been used to find an accurate model that have lower RMS values. Figure 5 depicts the three modeling trials with different initial regularization parameters ($\tau$).
Figure 5: Inversion schemes carried out by different $\tau$ values.

The NAF Model

The mesh was built with evenly spaced 0.75 x 0.75 km nodes at the core of the mesh. Eight padding stations are placed increasing by a factor of 1.5. 35 vertical layers were selected with 1.2 increasing factor starting with initial layer thickness of 0.05 km. Every cell are selected as constant value of 100 $\Omega m$ for starting model. The total number of cells in X-Y-Z directions were 89 x 41 x 35, respectively; resulting in a total cell number of 127715. The attained initial model for these parameters can be seen in Figure 4. Fifteen frequencies in the range 320 Hz - 0.035 Hz were selected for this purpose.
Figure 6: Initial model of the 3-D modeling scheme for the NAF model. Black triangles indicate the stations. Logarithmic scale was used for the colorbar.
8 Residual Maps

Figure 7: Apparent resistivity residuals of the four components of the impedances for the final regional model.
9 Sensitivity Tests

Sensitivity tests were carried out to check the validity of certain anomalies seen on the models. They were carried out by injecting resistive anomalies over the conductive questionable features in resultant models. Then the forward run for the altered models were performed.

9.1 Sensitivity Test for the Conductive Anomaly C

First test was made to investigate the deep conductor placed beneath stations 4 to 6. This anomaly was masked with 300 Ωm values starting at the bottom of the model reaching to three different upper boundaries: 6 km, 11 km and 16.3 km for three different sensitivity experiments. The results of these experiments can be seen in Figure 9.

Difference between data and sensitivity responses get lower when the upper bound of the injected structure gets deeper. RMS values also gradually decreased from 3.89 to 3.52, while injecting a deeper anomaly in the region. According to the forward model tests, data turned out to be sensitive to this anomaly at all tested depths.
Figure 9: Sensitivity tests for conductive anomaly placed between the stations 4 and 5. Maps indicate the injection methodology and the graphs represents the responses of $xy$- and $yx$-components for the three sensitivity experiments.
9.2 Sensitivity Tests for the Base of the Tosya Basin

Another sensitivity test was conducted for determining the base of the Tosya Basin to validate the shadow effect of conductive feature. For this purpose, conductive feature representing the Tosya Basin was injected with anomalies representing the surrounding region for depths: 1.9, 2.4, 2.9 and 3.6 km. Interpretation of this test was carried out by checking the RMS values of the forward responses. RMS values gradually decrease from 2.12 to 2.0363, while the top of the injected anomaly reaches at 3.6 km (Figure 10). This result indicates that the base of the Tosya Basin is in proximity of a value between 3.6 and 4.3 km and shadow effect is present for deeper structure.

Figure 10: RMS values of the forward responses produced with sensitivity tests made to determine the validity of the conductive anomalies around Tosya Basin. Graph demonstrates the upper position of the injected anomaly versus RMS rates that were observed.
10 Fitting Curves

10.1 Regional Model

Figure 11: Fitting curves of station 1 for the final resistivity model.
Figure 12: Fitting curves of station 3 for the final resistivity model.

Figure 13: Fitting curves of station 4 for the final resistivity model.
Figure 14: Fitting curves of station 5 for the final resistivity model.

Figure 15: Fitting curves of station 6 for the final resistivity model.
Figure 16: Fitting curves of station 7 for the final resistivity model.

Figure 17: Fitting curves of station 8 for the final resistivity model.
Figure 18: Fitting curves of station 9 for the final resistivity model.

Figure 19: Fitting curves of station 10 for the final resistivity model.
Figure 20: Fitting curves of station 11 for the final resistivity model.

Figure 21: Fitting curves of station 12 for the final resistivity model.
Figure 22: Fitting curves of station 13 for the final resistivity model.

Figure 23: Fitting curves of station 14 for the final resistivity model.
Figure 24: Fitting curves of station 15 for the final resistivity model.

Figure 25: Fitting curves of station 16 for the final resistivity model.
Figure 26: Fitting curves of station 17 for the final resistivity model.

Figure 27: Fitting curves of station 18 for the final resistivity model.
Figure 28: Fitting curves of station 19 for the final resistivity model.

Figure 29: Fitting curves of station 20 for the final resistivity model.
Figure 30: Fitting curves of station 21 for the final resistivity model.

Figure 31: Fitting curves of station 22 for the final resistivity model.
Figure 32: Fitting curves of station 23 for the final resistivity model.

Figure 33: Fitting curves of station 24 for the final resistivity model.
Figure 34: Fitting curves of station 25 for the final resistivity model.

Figure 35: Fitting curves of station 26 for the final resistivity model.
10.2 NAF Model

Figure 36: Fitting curves of station 9 for the NAF model.

Figure 37: Fitting curves of station 10 for the NAF model.
Figure 38: Fitting curves of station 11 for the NAF model.

Figure 39: Fitting curves of station 12 for the NAF model.
Figure 40: Fitting curves of station 13 for the NAF model.

Figure 41: Fitting curves of station 14 for the NAF model.
Figure 42: Fitting curves of station 15 for the NAF model.

Figure 43: Fitting curves of station 16 for the NAF model.
Figure 44: Fitting curves of station 17 for the NAF model.

Figure 45: Fitting curves of station 18 for the NAF model.
Figure 46: Fitting curves of station 19 for the NAF model.