2D Joint Inversion of Radiomagnetotelluric and DC Resistivity Data Incorporating Surface Topography and Sequential Inversion of IP Data

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SUMMARY

In this study, we suggest to use two-dimensional (2D) joint inversion result of Radiomagnetotelluric (RMT) and DC Resistivity (DCR) data in Induced Polarization (IP) data inversion. We developed a new code for this purpose. The code use triangular cells in finite difference technique for both RMT and DCR forward solution. Henceforth, surface topography could be included in joint inversion of RMT and DCR data in the developed code. The suggested methodology tested for synthetic data and a field data collected from a copper mining area.

Keywords: Joint, Inversion, 2D, Radiomagnetotelluric, Resistivity, IP

INTRODUCTION

The geophysical methods are sensitive to different physical parameters of underground structure. In most of the geophysical methods, the inverted data are interpreted. Electric and electromagnetic (EM) methods are sensitive to subsurface electrical resistivity structures. Nowadays, to obtain more reliable resistivity model, different electric and EM data sets are collected and inverted jointly. The first, Vozoff and Jupp (1975) introduced the 1D joint inversion algorithm for magnetotelluric and DCR data. After this pioneering study, many studies have been done about 1D (e.g. Raiche et al. 1985; Meju 1996) and 2D (Sasaki 1989) joint inversion of electric and EM data. Harinarayana (1999) provided an overview reviewing the combined inversion of electric and EM measurements. Joint inversion can improve the resolution of subtle features, reduce the influence of noise and limit the range of acceptable models (Candansayar and Tezkan, 2008).

Candansayar and Tezkan (2008) developed 2D joint inversion algorithm for DCR and RMT data sets. Based on this study, here we suggested using joint inversion result of DCR and RMT data sets in IP data inversion. The previously developed algorithm was modified to use triangular grid in modeling part of joint inversion code to incorporate surface topography into inverse solution. The time domain IP data inversion also added in the modified code. In the inverse solution, one can use DCR and RMT data individual and joint inversion result in IP data inversion.

We tested suggested idea by using synthetic data and the field data collected in a copper mining area. These inversion results showed that the suggested IP data inversion approach gives better chargeability model than the IP data inversion by using the resistivity model obtained from only inversion of DCR data.

2D INVERSION OF RMT, DCR and IP DATA

Candansayar and Tezkan (2008) combined previously developed magnetotelluric (Candansayar, 2002;2008) and DCR inversion (Candansayar 2008) algorithms to develop joint inversion algorithm for RMT and DCR data. The modeling part of 2D joint inversion algorithm, finite difference technique is used both for RMT and DCR forward solution. Aprea et al.(1997) and Demirci et al. (2012) suggested to use finite difference forward solution with triangular grid to incorporate topography into the inverse solution of magnetotelluric and DCR data, respectively. In this study, we modified the forward solution algorithms for RMT and DCR methods to be use triangular grid to incorporate surface topography into inverse solution. The joint inversion algorithm is uses smoothness constrained regularized inversion approach (Tikhonov et al. 1995).

We also added IP inversion into joint inversion algorithms. Linear approach was used for time domain IP data inversion suggested by Oldenburg and Li (1994). In this approach the following linear matrix equation is solved;

$$\mathbf{A}\boldsymbol{\eta} = \boldsymbol{\eta}_a \tag{1}$$

A is jacobian (or sensitivity) matrix that is calculated for inverted resistivity model, $\boldsymbol{\eta}$ is vector consisting of unknown chargeability of each blocks in the model mesh and $\boldsymbol{\eta}_a$ is a vector containing measured apparent chargeability values. In general, the first DCR data are inverted and the resulted resistivity model and the Jacobian matrix are used to solve equation (1). Therefore, chargeability model solution is strongly dependent on inverted resistivity model. It is shown that joint inversion of RMT and DCR data sets is resolving resistivity structure better than the individual inversion of them. Different from previous studies, we suggest using resistivity model from joint inversion of RMT and DCR data in IP data inversion.

SYNTHETIC DATA INVERSION

The 2D resistivity model is shown in Figure 1a.This model has valley type surface topography with 18^o slope which is the similar surface topography of the copper mining area where field data are collected. In the model, there is three conductive bodies that are simulates copper ore bodies with 10 ohm-m resistivity in the 50 ohm-m homogenous medium. The bodies' depth from the surface is 5 meters. The chargeability model for the same structure boundaries are given in Figure 2a. The chargeability of three buried bodies are 200 mV/V and surrounding medium chargeability is equal to zero.

The DCR and IP data were calculated as same setting used in field survey. The distance between consecutive electrodes taken as 10 and 20 meters and the apparent resistivity data calculated for n=1, 2, 3, …, 7 levels for pole-dipole array. RMT data (TE- and TM-mode apparent resistivity and phase) were calculated for 7 frequencies (f=1000, 500, 200, 100, 50, 20, 10 kHz) on 31 stations with 10 meter interval. Two percent Gaussian noise added to data and it is used as field data to test the algorithm.

DCR and RMT data inversion results are shown in Figure 1b and 1c, respectively. The joint inversions of these two data sets are also given in Figure 1.d. The joint inversion gives better result than individual inversion of DCR and RMT data if one compares inversion results with the real model. Different from our previous study (Candansayar and Tezkan), here we also incorporate surface topography in inversion algorithm. To show importance to include surface topography to the inversion solution, we also did joint inversion assuming surface topography is flat (Figure 1.e). It is seen that if surface topography is not included in inversion process, the model cannot be recovered.

We also compared IP data inversion solution for different initial resistivity models. The first, as classical approach, we used the resistivity model obtained from DCR data inversion (Fig. 1b) in IP data inversion (Figure 2b). Then, we use joint inversion result (Fig. 1d) in IP data inversion (Figure 2c). The best solution is obtained by using joint inversion result in IP data inversion, if one compare all of IP inversion results with the real chargeability model. It is also showed that, If we do not consider surface topography in DCR and RMT data inversion, we could not resolve only resistivity model but also the chargability model (Figure 2d). The RMS error values between inverted and the calculated data are given on the top of each inverted models, in Figure 1 and 2.

CONCLUSION

In IP data inversion, resistivity model should be known. In general, this resistivity model obtained from DCR data inversion. In this study, it is suggested to use the resistivity model recovered from joint inversion of RMT and DCR data in IP data inversion. It is showed with synthetic data that suggested IP data inversion approach resolved chargeability model better than the classical IP data inversion approach if one compare the inversion results with the real model. The suggested approach also tested with field data (not presented here) collected from a copper mining area. In this study we also showed importance of surface topography

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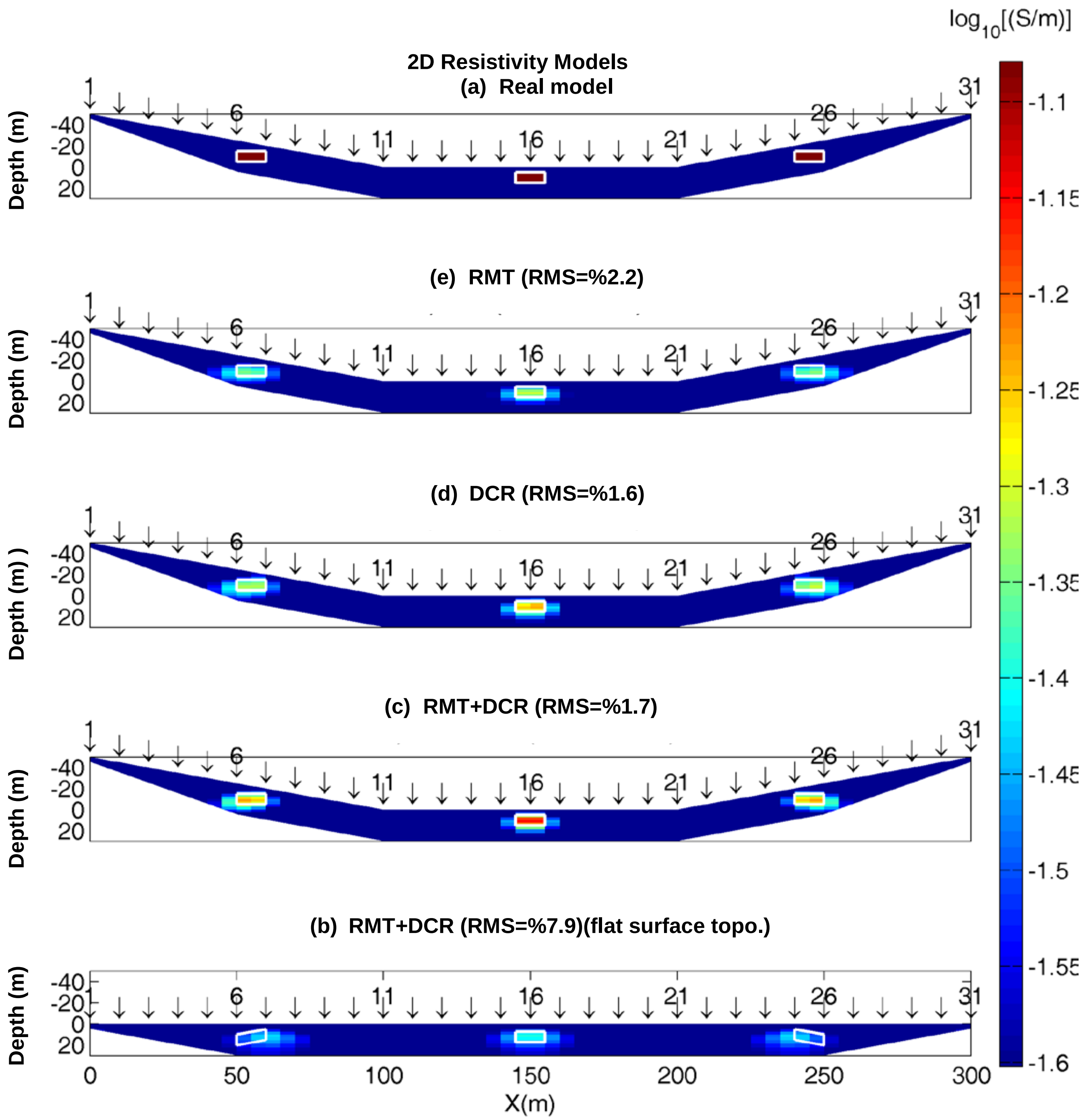

Figure 1. (a) 2D resistivity model (slope is 26^{o}). Inversion results of different data: (b) RMT data inversion result, (c) DCR data inversion result, (d) Joint inversion result of RMT and DCR data, (e) Joint inversion result of RMT and DCR data assuming flat surface topography.

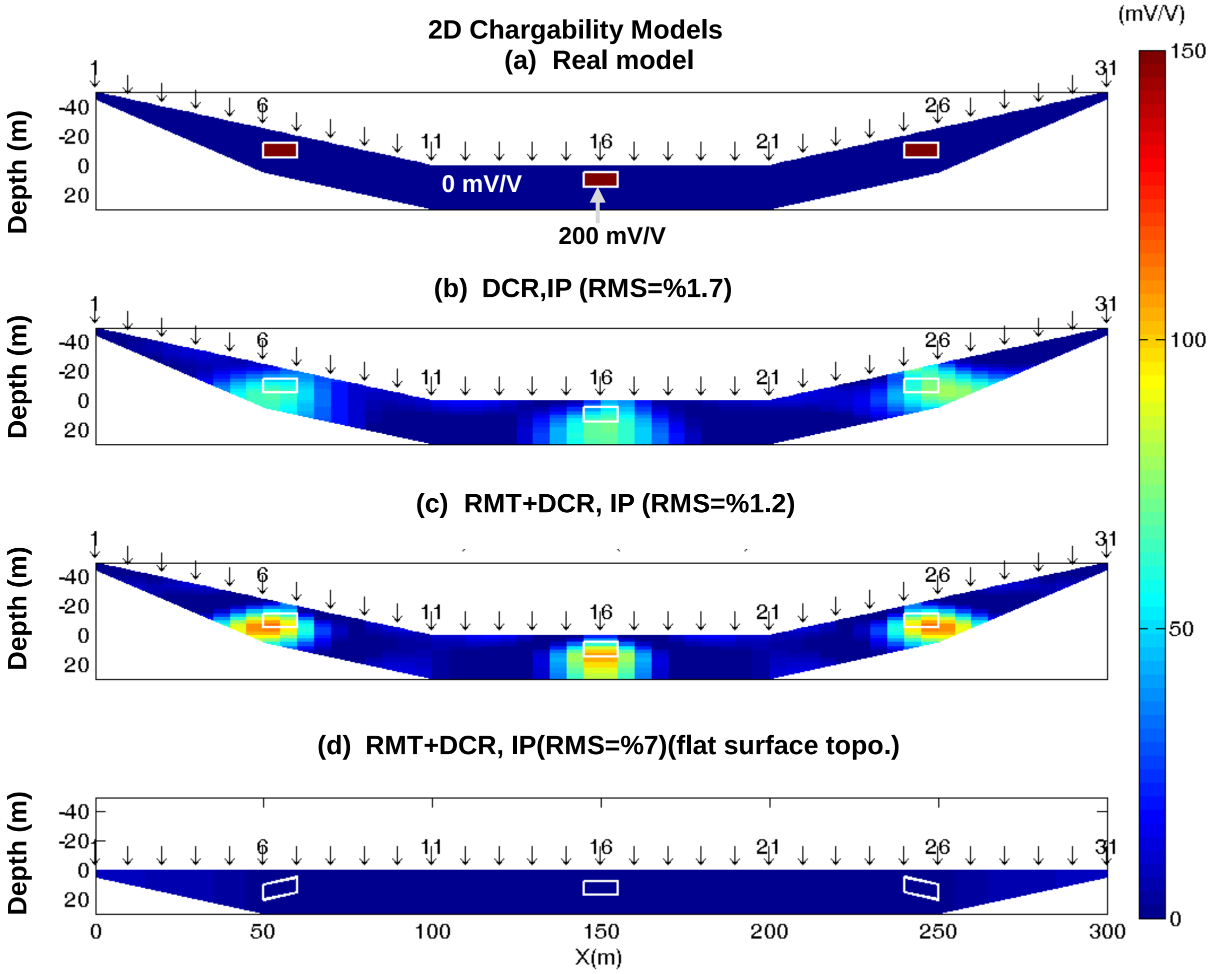

Figure 2. (a) 2D chargeability model (slope is 26°). Inversion results of apparent chargeability data: (b) inversion with the resistivity model in Fig.1c (c) inversion with the resistivity model in Fig.1d, (e) (b) inversion with the resistivity model in Fig.1e