Analysis of the topographic correction in 3D Magnetotelluric data and the relationship with impedance parameters

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1. Introduction

Magnetotelluric exploration is one of the geophysical methods for investigating the Earth's deep interior. In the early day, the responses at receiver were simply considered as one dimension and the impedance was scalar. Nowadays, we have considered three dimensional structure and the impedance is matrix. It is very important to know how these components reflect underground structure or surrounding environment.

We focus on the topographic effects distorting impedance components and the result of correction with three dimensional earth model. Conventional topographic correction assumes that topographic distortions are linearly related to a 2 by 2 distortion tensor and it is enough for simple topographies. However it is not perfect for complex area and there is no parameter indicating the magnitude of the error.

Therefore, in this study we evaluate the effects of topographic correction with simple and complex model. And we analyze the relationship between the error of the correction and two impedance parameters. We use inhomogeneity parameter, N and asymmetry parameter, skew. This relationship will help quantify the error of topographic correction.

2. Theory

1) Impedance-correction method (Nam et al., 2008)

It corrects the topographic distortions using linear relation between distorted (Z^D) and undistorted (Z^U) impedance. Distortion tensor (D^Z) represents the linear relation and it is calculated from the relationship between the impedance at one dimensional medium with surface topography (Z^t) and flat surface (Z^h).

$$Z^D = D^Z \cdot Z^U$$

$$Z^t = D^Z \cdot Z^h \rightarrow D^Z = Z^t \cdot (Z^h)^{-1}$$

2) Impedance parameters, N & Skew (Berdichevsky and Dimitriev, 2002)

N is the inhomogeneity parameter. This parameter characterizes the degree of horizontal inhomogeneity of the medium. In the one dimensional model, N=0. Departure of N from 0 indicates the violation of horizontal homogeneity (2D, 3D).

$$N = \left|\frac{Z_{e1} - Z_{e2}}{Z_{e1} + Z_{e2}}\right| \quad \text{where} \quad Z_{e1} = Z_1 + \sqrt{Z_1^{\,2} - \det(Z)}, \quad Z_{e2} = Z_1 - \sqrt{Z_1^{\,2} - \det(Z)}, \quad Z_1 = \frac{Z_{xy} - Z_{yx}}{2}$$

Skew is a measure of the asymmetry of a medium. In the two dimensional and axially symmetric three dimensional models, skew=0. The deviation of skew from 0 characterizes the presence of asymmetric three dimensional structures.

$$Skew = \left|\frac{Z_{xx} + Z_{yy}}{Z_{xy} - Z_{yx}}\right|$$

3. Numerical Example

- We use the finite element methods using hexahedral and tetrahedral elements to examine the topographic correction method and effect in three dimensional models.
- Model 1, 3D hill model (Nam et al., 2008)

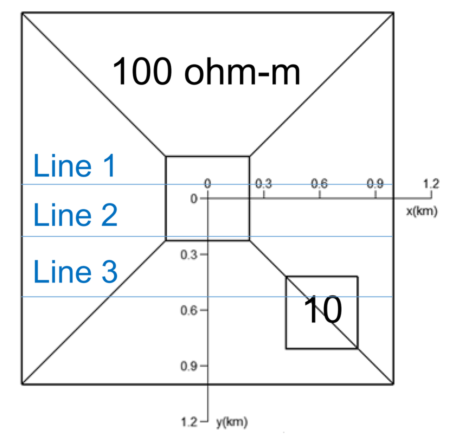

Fig 1. Plan view

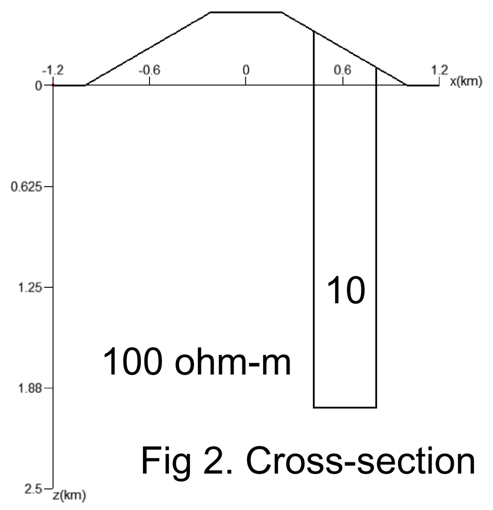

Fig 2. Cross-section

1) The results of topographic correction

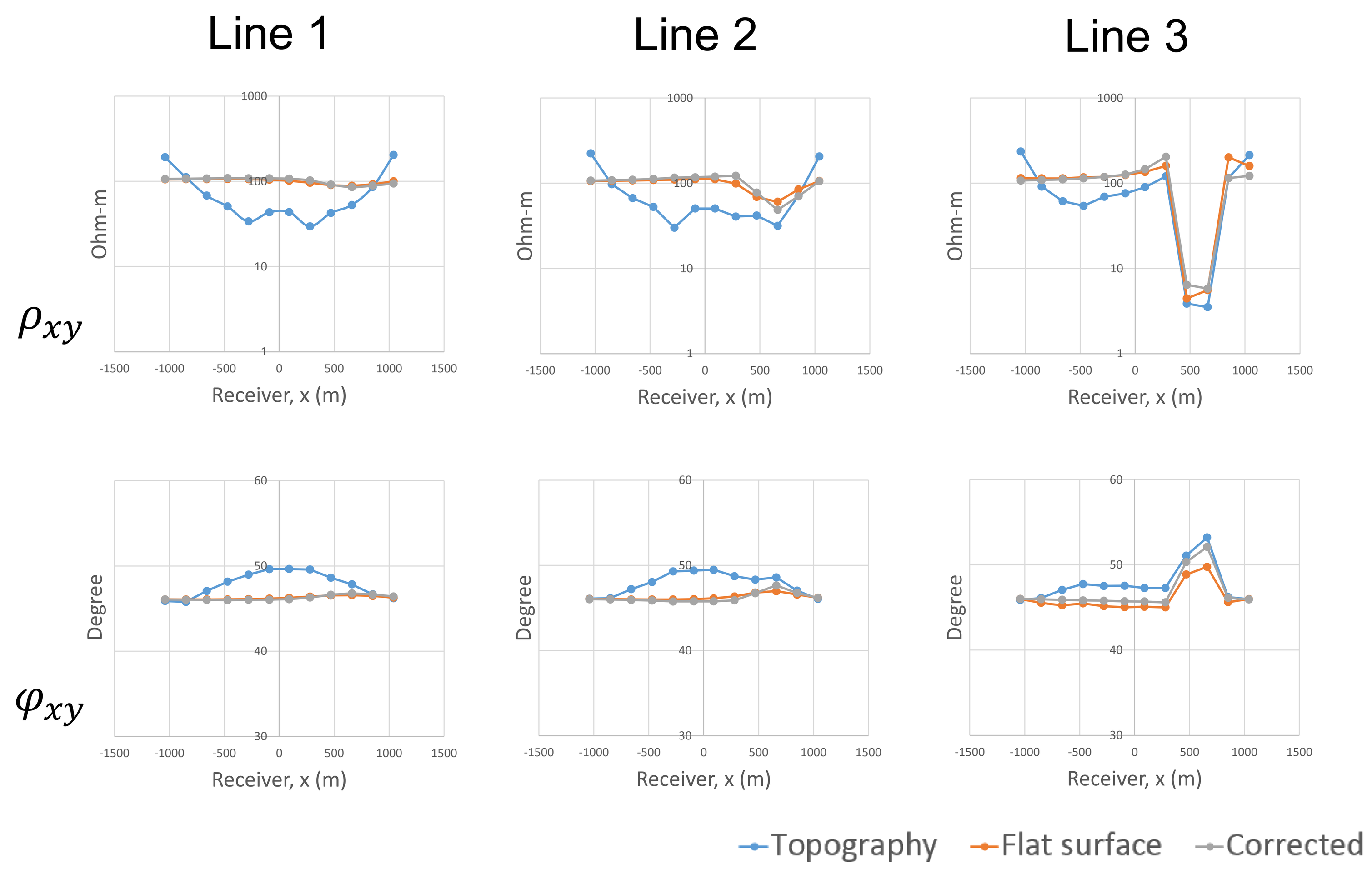

Fig 3. Comparisons of apparent resistivity and phase among topographic model, flat model and corrected result using model 1.

2) The relationship between the error of topographic correction and impedance parameters, N & Skew.

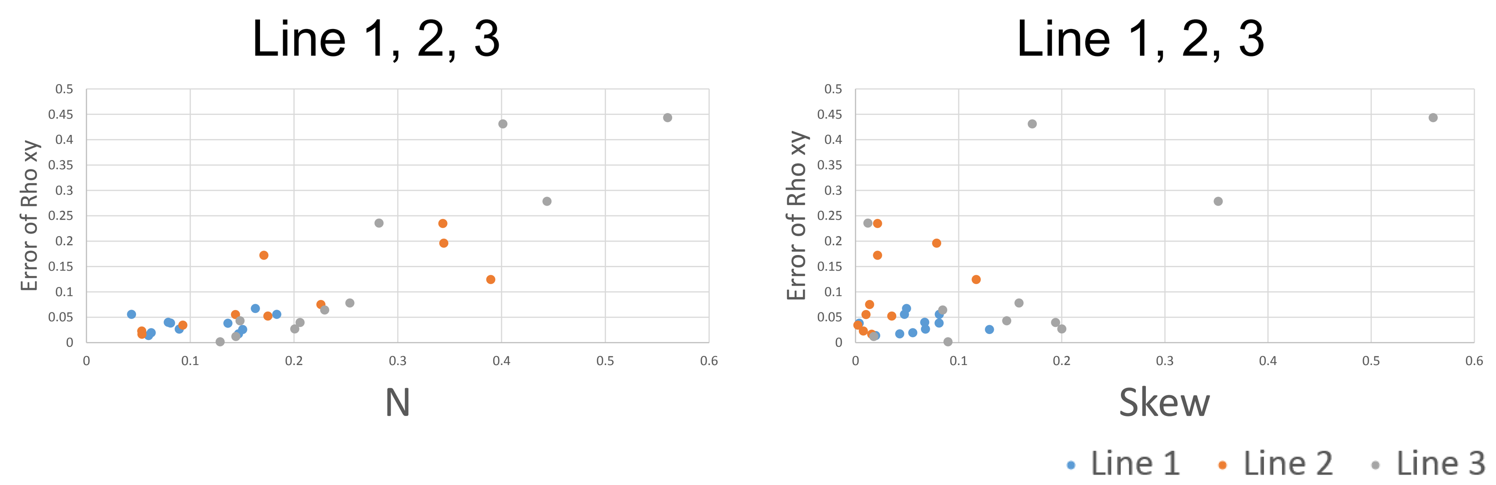

Fig 4. Plot with the error and N (right), the error and Skew (left) using all receivers of Line 1, 2 and 3.

- Model 2, Complex 3D hill model with tilted anomaly

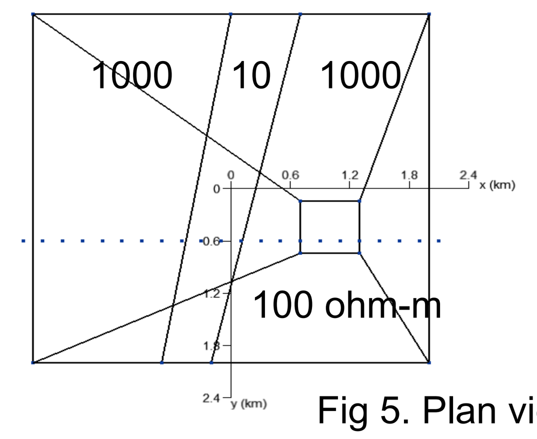

Fig 5. Plan view

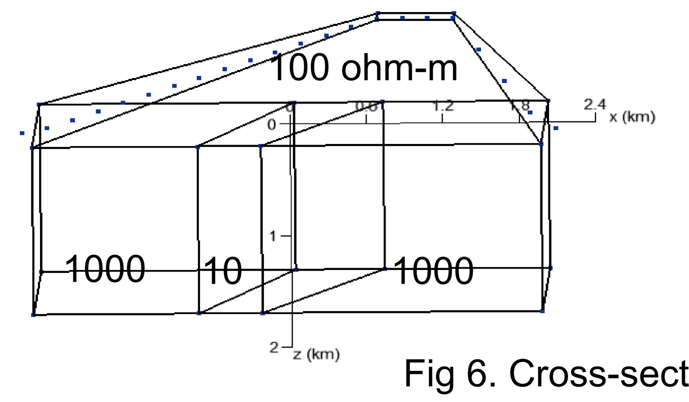

Fig 6. Cross-section

1) The results of topographic correction

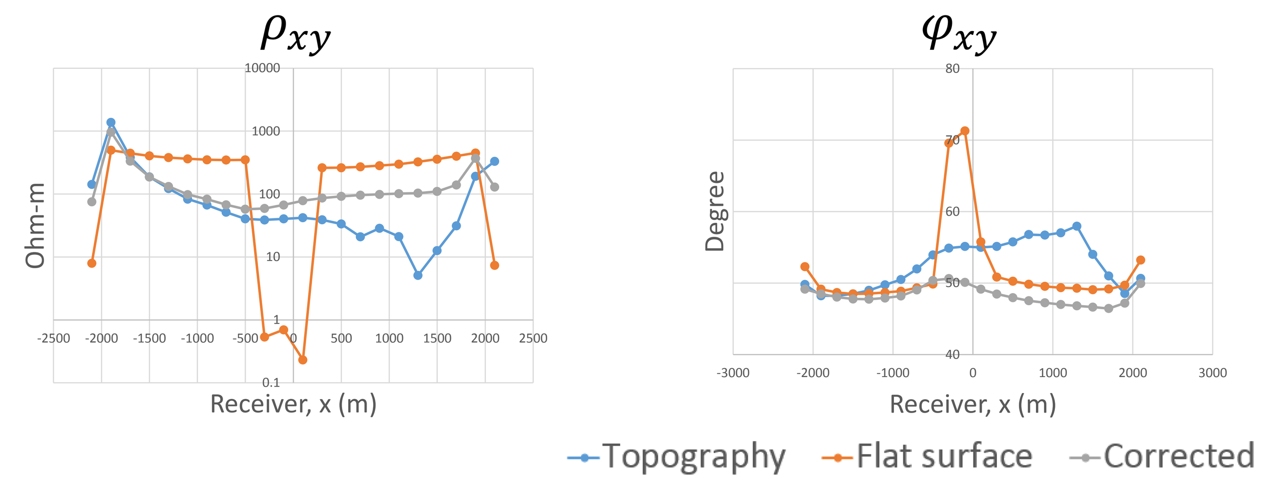

Fig 7. Comparisons of apparent resistivity and phase among topographic model, flat model and corrected result using model 2.

2) The relationship between the error of topographic correction and impedance parameters, N & Skew.

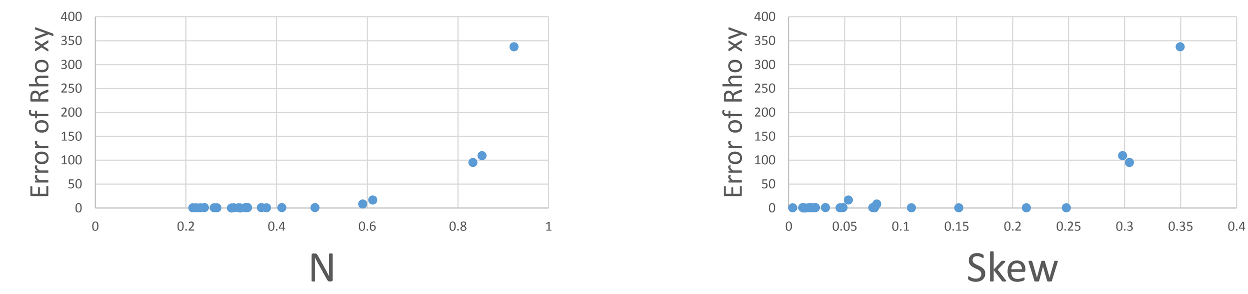

Fig 8. Plot with the error and N (right), the error and Skew (left) using one line.

4. Conclusion

- The relationships between the error and N or Skew
  - The parameter, N and the error show a positive correlation.
  - There is no specific correlation between error and skew.
  - When 0<N<0.3, it shows a linear relationship.
  - When 0.5<N, the error increases more sharply than linear relationship.
- The effect of topographic correction
  - For the case of simple 3D topographic model, the topographic correction works well. However for the case of more complex 3D topographic model, this method does not work well. By using the value of parameter N we can predict the reliability of topographic correction method and even the quantitative value of the error in specific range of N (0<N<0.3).

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- Reference
  - Berdichevsk, M. N., and Dmitriev, V. I., 2002, "Magnetotellurics in the context of the theory of ill-posed problems", Society of Exploration Geophysicists, p. 130-142.
  - Nam, M. J., Kim, H., J., Song, T., Lee, T. J., and Suh, J. H., 2008, "Three-dimensional topography corrections of magnetotelluric data", Geophys. J. Int., 174, p. 464-474