3D tipper response of Controlled-Source Audio-frequency Magnetotellurics

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SUMMARY

Tipper data of magnetotelluric sounding method is sensitive to the underground geological body boundary. Controlled-Source Audio-frequency Magnetotellurics (CSAMT) is developed from magnetotelluric sounding method. Traditional CSAMT has only one source, and few research focuses on its scalar tipper response. This paper firstly shows a results of high and low frequencies tipper response with two different scalar line sources. Then two slant sources are adopted to further research. The tipper calculation method refers to 2D magnetotelluric TE mode. Finally, 3D magnetotelluric tipper calculation method is adopted to compute the tipper response of tensor CSAMT through combining two slant sources. Our research shows that the tipper data of CSAMT can provide an extra and important information to identify the boundary.

Keywords: tipper data, Magnetotellurics, CSAMT, tensor CSAMT

INTRODUCTION

Controlled-Source Audio-frequency Magnetotellurics (CSAMT) is developed from Magnetotelluric sounding method. It has been widely used in many fields. However, there is few research to focus on its tipper response. In the early papers, Li and Pedersen (1991) preliminarily put forward tipper data in 1D tensor CSAMT. Wang et al. (2014) adopted two line sources to construct a 'L' shape and discussed the characteristic of observed tipper data. This paper will use 3D staggered-grid finite difference method as forward modeling method and five kinds of configurations to show and analyze their tipper data.

TIPPER AND SOURCES

We adopt 5 kinds of sources. The first two sources are shown in Figure 1.

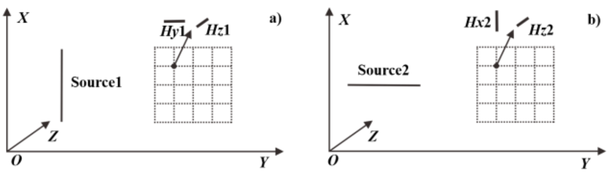


Figure 1. two single sources.

Source 1 and 2 are along X axis and Y axis, respectively. The configuration shown in Figure 1 (a) is the tradition scalar CSAMT. To some extent, Figure 1 (a) can be regarded as 2D magnetotelluric TE mode if we assume X axis is the strike direction. So we can refer to tipper calculation method of TE mode for the configuration shown in Figure 1 (a) as below:

$$T_{y1} = \frac{H_{z1}}{H_{y1}} \tag{1}$$

For source 2, we can use a similar way in equation 2 to calculate its tipper data due to the source direction.

$$T_{x1} = \frac{H_{z2}}{H_{x2}} \tag{2}$$

From equation 1 and 2, we can see the configurations shown in Figure 1 can only produce one directional tipper. So we rotate source 1 and 2 45° and 135° respectively in Figure 2.

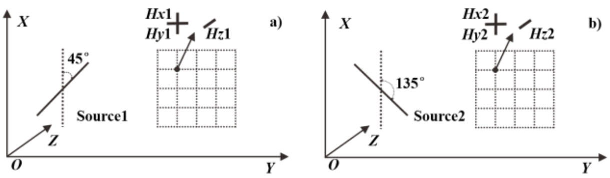


Figure 2. two slant sources.

After rotating, both slant sources in Figure 2 can calculate two orthogonal tippers because to some extent, their own $\boldsymbol{H_x}$ and $\boldsymbol{H_y}$ have equal magnitude. With this situation, for source 1 and 2, their tipper data can be computed as below:

$$T_{x1} = \frac{H_{z1}}{H_{x1}} \qquad T_{y1} = \frac{H_{z1}}{H_{y1}}$$
$$T_{x2} = \frac{H_{z2}}{H_{x2}} \qquad T_{y2} = \frac{H_{z2}}{H_{y2}} \tag{3}$$

At last, we combine the sources in Figure 2 to construct a tensor CSAMT source. Then we can use 3D magnetotelluric tipper calculation method as below to compute a more complex tipper response.

$$T_x = \frac{H_{z1}H_{y2} - H_{z2}H_{y1}}{H_{x1}H_{y2} - H_{x2}H_{y1}}$$
$$T_y = \frac{H_{z2}H_{x1} - H_{z1}H_{x2}}{H_{x1}H_{y2} - H_{x2}H_{y1}} \quad (4)$$

In equation 4, the subscript 1 and 2 represent the magnetic component from source 1 and 2, respectively. Equation 1~4 are referred to magnetotelluric method. However, magnetotelluric method is based on the assumption of plane wave which means the tipper response of CSAMT will be different with that of magnetotelluric method. We will preliminarily discuss them in the next section.

Tipper modeling of CSAMT

In this section, we build a 3D model shown in Figure 3.

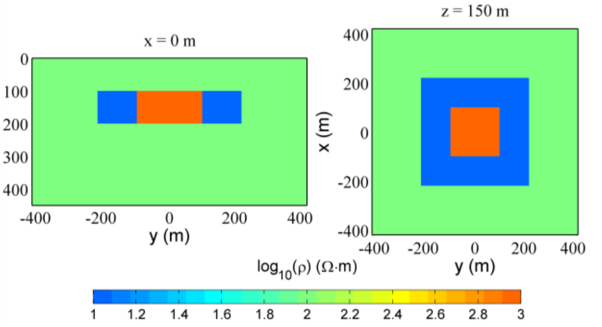
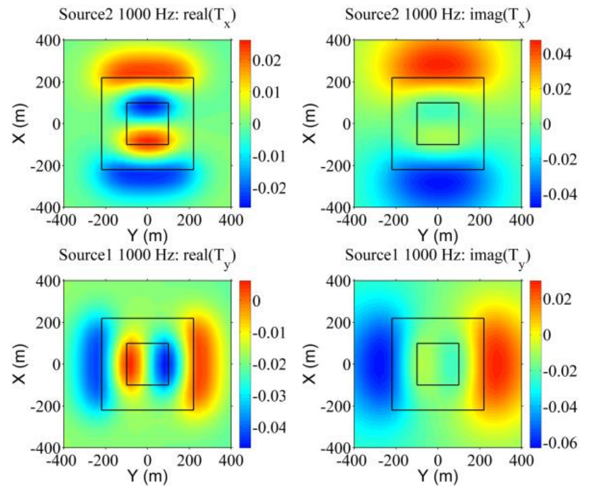


Figure 3. A simple 3D model. The low and high resistivity body is 10 Ω·m and 1000 Ω·m, respectively. The background resistivity is 100 Ω·m.

Firstly, we use the sources shown in Figure 1 to calculate their own tipper data. We set the lengths of both line sources to be 500 m and both of their center are at Y = -6175 m. Here we only use 1000 Hz and 10 Hz. The results are shown in Figure 4.



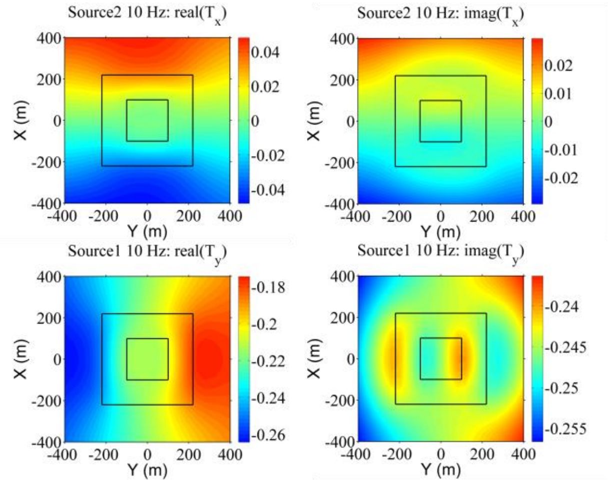
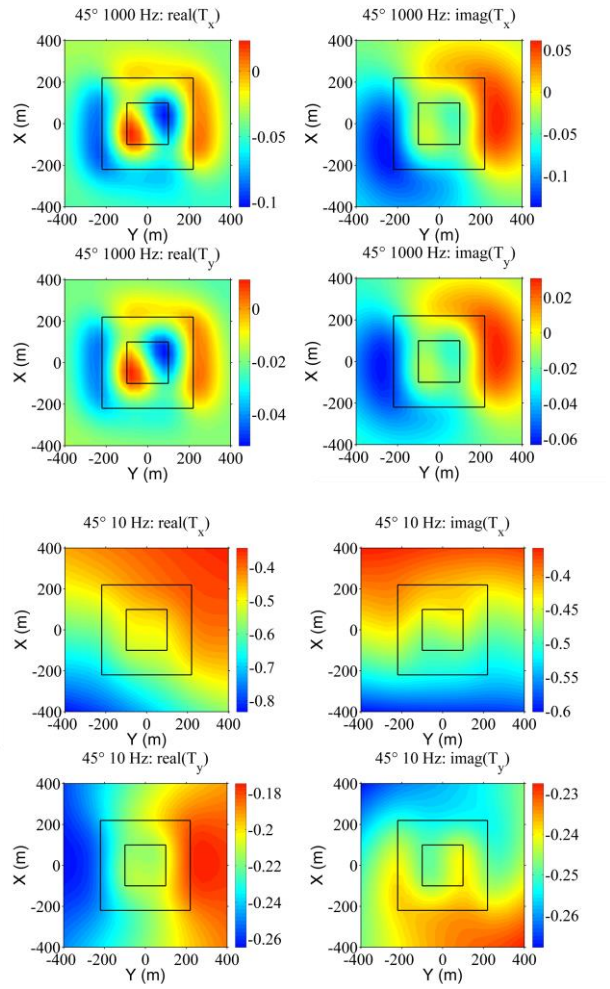


Figure 4. T_x and T_y responses. The sources configurations in Figure 1 are adopted.

Secondly, the sources shown in Figure 2 are adopted to further research. We also set the lengths of both line sources to be 500 m and both of their center is at Y = -6175 m. 1000 Hz and 10 Hz are used. The results are shown in Figure 5.



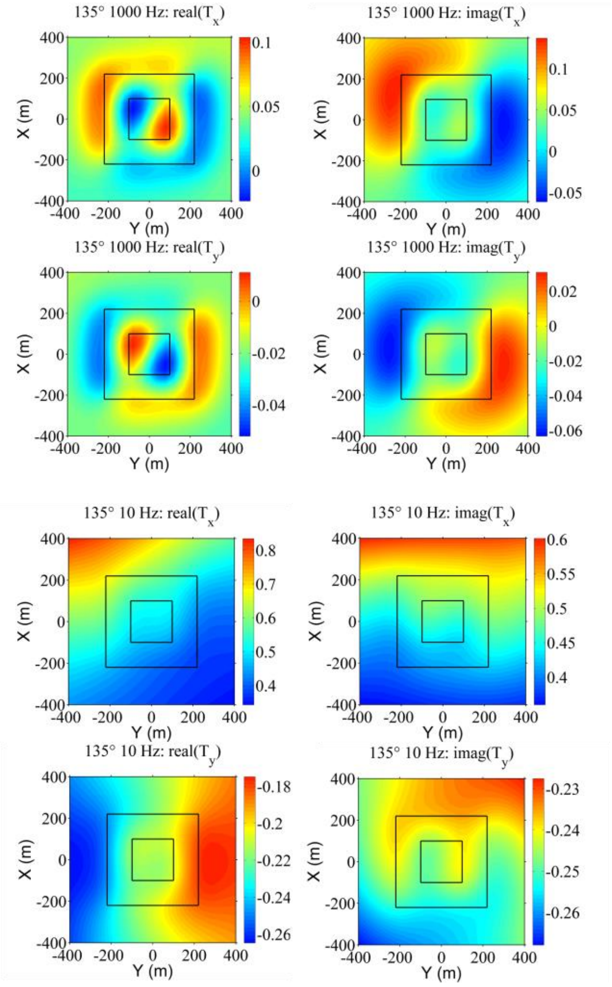
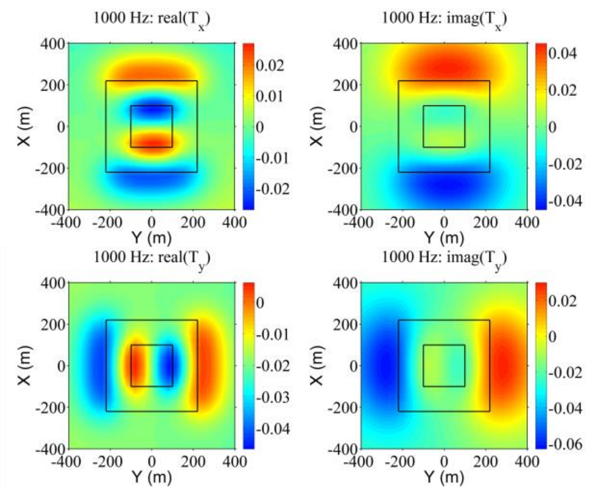


Figure 5. T_x and T_y response. The sources configurations in Figure 2 are adopted.

Thirdly, we combine the magnetic field data of source 1 and source 2 shown in Figure 2 to calculate a more complex tipper as in equation 4. The results are shown in Figure 6.



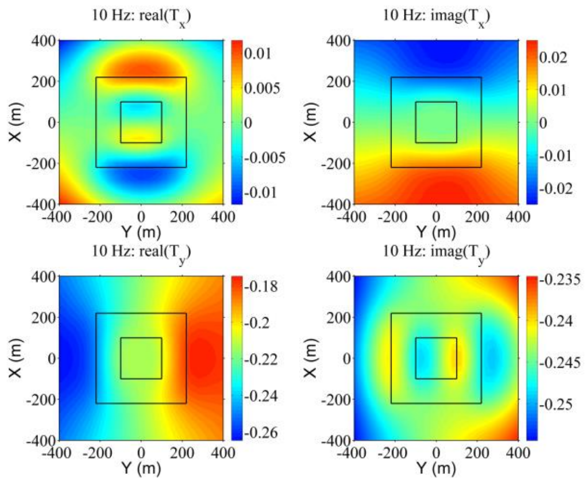


Figure 6. T_x and T_y response. The source is a tensor CSAMT configuration through combining two slant sources shown in Figure 2.

From Figure 4, we can see that the boundary can be clearly showed in the tipper data at the high frequency. For the low frequency, although nonplanar wave is strong, we can still intuitively see some boundary influences. So tipper data can provide an extra and important information to identify the boundary.

The configuration shown in Figure 1 can only provide single tipper data. So we rotate the sources and calculate two directional tipper responses shown in Figure 5. From Figure 5, we can see that the boundary information can be directly shown at high frequency but confusing at low frequency. Besides, the tipper response distribution, to some extend, is parallel to its source direction. So the results in Figure 5 may at least mislead an initial qualitative explanation.

Finally, we combine the sources in Figure 2 to construct a tensor CSAMT source and adopt equation 4 to calculate tipper data. The results shown in Figure 6 are similar to those in Figure 4. But the ability of low frequency to show the boundary in Figure 6 is a little stronger. The results suggest that tensor CSAMT is more suitable if we want to use tipper data of CSAMT.

CONLUSION

This paper preliminarily discusses the tipper response data of CSAMT. Five kinds of source configurations are used in our research. The final results suggest that tensor CSAMT is an ideal method to produce two directional tippers. In the future, we will further research the tipper data characteristic of CSAMT and add them into 3D CSAMT inversion to check whether they can promote the inversion results.

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REFERENCES

Li X., and Pedersen L.B., 1991, Controlled source tensor magnetotellurics, *Geophysics*, **56**, 1456-1461.

Wang X. X., Di Q. Y., and Xu C., 2014, Characteristics of multiple sources and tensor measurement in CSAMT, *Chinese J. Geophys. (in Chinese)*, **57**, 651-661.