Analytical Investigations of the Magnetotelluric Directionality Responses in 1-D Anisotropic Media

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Electrical anisotropy is discussed in the interpretation of electrical structures of the earth in magnetotelluric observations. It is then of fundamental interest to infer the properties of anisotropy at a site from data, so as to select an appropriate method for modeling or inversion. As for isotropic media, dimensionality tools are established which estimate geoelectric structures such as dimensionality (1D, 2D or 3D) and directionality (strike directions for a 2D case) from the impedance tensor. Although satisfactory criteria including anisotropic media have been unavailable yet, several studies were performed trying to extend the criteria to distinguish anisotropic media. Among them, Marti et al. (2010) examined using numerical code the responses of anisotropic media in the dimensionality analysis based on a set of rotational invariants (WAL invariants) established by Weaver et al. (2000), and proposed an extended criteria including anisotropic media. They dealt with synthetic models of anisotropic 1D and 2D media, and confirm their results in half-space using analytical expressions. In this talk, we present the results of analytical investigation of the strike estimation of the WAL method for 1D anisotropic layered media for which only numerical results were shown in Marti et al. (2010), with a generalization to arbitrary number of layers.
We first show that if anisotropy axes are identical in all anisotropic layers, the strike direction generally coincides with the axis. The exception is an indeterminate value, which in practice corresponds to unstable behavior. We reveal the condition of it for two types of strike estimations. One always has a definite value as long as anisotropy exists, while the other is indeterminate if conductivity contrast is absent as half-space because it relies only on phases.
We then deal with general anisotropic layers to evaluate the impedance tensor at long periods. The method is expansion of the impedance tensor with respect to (the square root of) frequency at the first order. It gives an analytical formula of the strike direction at the long period limit. This shows that the strike points to the azimuth where the conductance integrated along depth takes a maximum value. We further examine behavior of the phase tensor (Caldwell et al. 2004). At the long period limit, it reduces to the unit tensor corresponding to half-space as expected. The leading part in frequency consists of two parts. One changes the radius of the tensor circle as ordinary phase responses by vertical conductivity contrast. The other distorts the tensor ellipse reflecting anisotropy in total. The major axis points to the maximum conductance direction as the strike does.
We finally compare our analytical results with the results of numerical researches. Applying the obtained formula to the models treated in Marti et al. (2010), we found that the strike angles are different by about 3 degrees. This seems to be because the numerical calculations are evaluated at finite periods. Then electromagnetic fields damp in depth, so the impedance would capture the structure of upper layers more than that of lower layers. The numerical results are more close to the anisotropy axis of the upper layer than the theoretical ones, which supports this expectation.
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