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RESEARCH NOTE

Improving Bahr's invariant parameters using the WAL approach

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SUMMARY

In the magnetotelluric technique, several methods exist to perform dimensionality analysis of the measured data using rotational invariants of the impedance tensor. Among these methods there is some dilemma on the different criteria established, which sometimes lead to non-equivalent interpretations. The aim of this work is to compare the Bahr and Weaver *et al.* (WAL hereafter) methods, and to propose a new method that makes both dimensionality methods consistent. This new method complements the parameters used in Bahr method with WAL invariant Q, and redefines their threshold values. To accomplish this, we used the analytical relations between both sets of parameters and re-analyse and compare the threshold values of each method. Both the Bahr and WAL methods use sets of rotational invariant parameters of the magnetotelluric tensor [$\underline{\boldsymbol{M}}\,(\mathrm{m\,s^{-1}})$; $\vec{E} = \underline{\boldsymbol{M}} \cdot \vec{B}$] and establish a classification of their values to determine the kind of dimensionality associated to the measured data.

Key words: geoelectric dimensionality, magnetotelluric tensor, rotational invariants, threshold values.

1 BAHR METHOD

Bahr (1991) (with modifications of Szarka 1999) was the first author who presented a classification of the types of distortion that affect the regional structures by quantifying the values of four rotational invariant parameters: κ (swift skew), μ, η, (regional skew of phase sensitive skew) and Σ. Bahr parameters are dimensionless; μ and η are normalized to unity whereas κ and Σ can have values greater than 1 in the presence of galvanic distortion. κ is related to one-dimensionality. μ is a measure of the phase difference in the magnetotelluric tensor. η indicates if the magnetotelluric tensor can be described by a superimposition model (a real distortion matrix that represents a 3-D small heterogeneity producing galvanic distortion multiplying the regional 1-D or 2-D magnetotelluric tensor: 3-D/1-D or 3-D/2-D) and is also a measure of three-dimensionality. Σ is related to two-dimensionality. The information given by these parameters, and the recommended threshold values according to Bahr (1991), are summarized in Table 1.

One of the main limitations of the Bahr method is that, except for κ and η (Simpson & Bahr 2005), the threshold values do not have a justified physical or mathematical meaning, or are set in a statistical framework. As we will show below, the use of only these four parameters is insufficient to characterize completely the dimensionality (Ledo *et al.* 2002).

2 WAL METHOD

Weaver *et al.* (2000), following and extending the work of Szarka & Menvielle (1997), defined a set of seven independent (I_1–I_7) rotational invariant parameters. An eight invariant, dependent on the other ones, Q, is also defined, which controls the value of I_7. As Q approaches zero, that is, for error-free and distortion free data from a 1-D or 2-D Earth, then I_7 approaches infinity and its value is undetermined.

Invariants I_1 and I_2 provide information about the 1-D magnitude and phase of the geoelectrical resistivity. The other invariants characterize the dimensionality according to whether their values are null of not (Table 1). Cases 3 and 4 are related to different types of galvanic distortion. Case 3a (3-D/2-Dtwist) corresponds to a local distortion caused by a twist of the electric field (Groom & Bailey 1989).

Case 3b corresponds to a regional 1-D or 2-D with equal phases for both *xy* and *yx* polarizations, affected by small-scale distortion (3-D/2-D1-D). In this case there is an ambiguity in the recovery of the regional tensor (Weaver *et al.* 2000). Case 4 corresponds to a regional 2-D tensor affected by galvanic distortion described by a general distortion tensor (3-D/2-D) (Groom & Bailey 1989).

For real data, it is necessary to use a threshold value to evaluate whether an invariant is null or not.

3 COMPARISON BETWEEN BOTH METHODS

The number of WAL invariants used for determining dimensionality criteria is six (I_3–I_7 and Q), which can be reduced to five since I_3 and I_4 are used together in the dimensionality classification.

