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# Reply to "Comment on 'Magnetotelluric appraisal using simulated annealing'" by S. Constable

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We thank Dr Constable for his comments, and concur with his suggestion that adding simulated noise to synthetic data (rather that simply assuming an uncertainty associated with the responses) does indeed represent the most realistic synthetic test of an inversion or appraisal algorithm. Also, as he points out, failure to do so can bias the results and effectively reduce the apparent resolving power of the appraisal in synthetic examples.

Nonetheless, the results of our present work remain unchanged. The purpose of our paper was to develop a practical simulated annealing algorithm for magnetotelluric (MT) modelling, and to use this algorithm to corroborate the results of the linearized extremal model appraisal developed in Oldenburg (1983) and Dosso & Oldenburg (1989). Test cases involving synthetic and MT field data were considered using both algorithms: the results of these comparisons and the similarity of the constructed extremal models to the analytic solutions predicted by the exact theory of Weidelt (1985) indicate that excellent approximations to the global extremum are achieved. The synthetic MT example we considered did not include noise; however, the test case was treated consistently by both methods, and therefore the comparison is valid.

We wish to emphasize that both the simulated annealing and linearized appraisal algorithms work well when noise is added to the data (see e.g. Dosso 1990). More importantly, the algorithms perform well for MT field data (which certainly contain noise), as illustrated by example in each of our papers. This, of course, is the crucial test for any practical algorithm—synthetic test cases serve only as developmental and illustrative tools.

We believe that as long as the shortcomings are recognized, test cases using accurate synthetic data can be of use in developing and illustrating new methods. An example done with accurate data can easily be duplicated by anyone else who is developing the same algorithm. If violating the assumptions about the noise is of great concern, misfit measures such as the rms relative error

$$E_{\rm rms} = \left[\frac{1}{N}\sum_{j=1}^{N}\left(\frac{\delta R_j}{R_j}\right)^2\right]^{1/2},$$

which make no assumptions about the properties of the noise can be adopted instead of $\chi^2$ or $\chi^1$. A bias towards decreased resolution can be expected; however, in the case of a simple illustration of the method or comparison of algorithms, this may not be a great concern. In order to treat the case of Gaussian noise rigorously and ensure that there is no bias, averages taken over a large number of realizations of the random noise are required, as Constable illustrates for the simple example of finding the slope of a line. However, for more complicated problems such as MT appraisal this may be impractical or, in the case of relatively slow methods such as simulated annealing appraisal, virtually impossible. Of course, to verify that an algorithm is of practical use, it must be demonstrated that the algorithm performs well with noisy synthetic or (preferably) MT field data.

Test cases involving accurate synthetic data with an assumed uncertainty are fairly common in the literature. Constable clearly demonstrates the potential problems associated with this practice; this should prove helpful in future research in extremal model inversion.

## REFERENCES

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