Joint inversion of ground-based and helicopter-borne electromagnetic data

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1. Motivation

Geophysical data inversions often suffer from uncertainties and non-uniqueness. To obtain a unique and meaningful model, inverted models are constrained by using the information from various sources. The constraints are the information from the local geology and lithology, sequential and joint inversion of two or more data sets belonging to the same structure.

The focus of this work is the 1D joint inversion of ground-based and airborne electromagnetic methods. The idea is that the capability to resolve the near surface structures with radiomagnetotelluric (RMT) method is higher, however, deeper electrical conductivity structures can be well resolved by transient electromagnetic method (TEM). On the other hand, helicopter-borne electromagnetic method (HEM) provides better lateral coverage. Therefore, the joint inversion of HEM, TEM and RMT would yield quasi-2D images of the electrical conductivity over a large depth interval (Fig. 1).

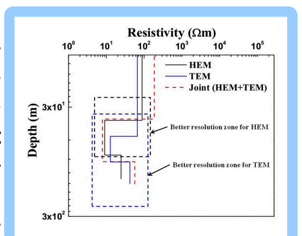

Fig. 1: An schematic example: joint inversion of HEM and TEM.

2. Methods

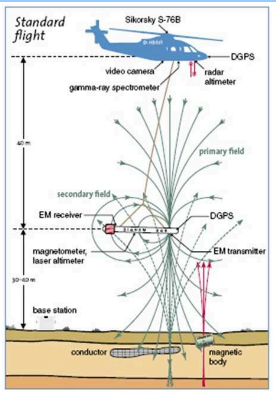

Fig. 2: The frequency-domain helicopter-borne geophysical system operated by BGR (Siemon, 2006).

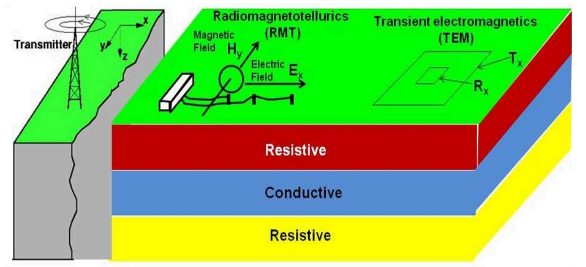

Fig. 3: Ground-based electromagnetic methods: transient electromagnetic (TEM) and radiomagnetotelluric (RMT).

For the verification of the developed 1D joint inversion algorithm with field data, HEM (Fig. 2) and ground-based (TEM and RMT (Fig. 3)) electromagnetic data are used.

3. Results

The 1D numerical inversion codes, which were developed by the Cologne geophysics group as a tool for the interpretation of individual methods (TEM, RMT), are extended to accomplish the 1D single and joint inversion with HEM data.

3.1. 1D joint inversion of synthetic HEM and TEM data

At first, the newly developed joint inversion algorithm is validated on synthetic HEM and TEM data (Fig. 4 and 5).

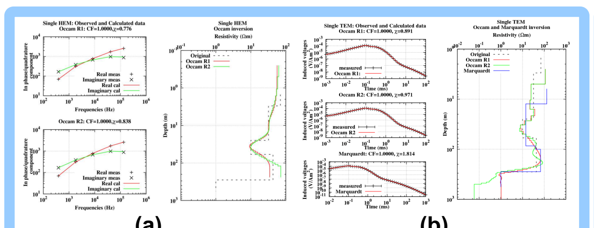

Fig. 4: The synthetic data for a 5 layer model and its fitting for 1D Occam and Marquardt inversions of (a) HEM and (b) TEM.

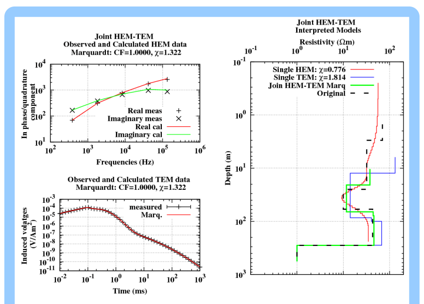

Fig. 5: The 1D Marquardt joint inversion of synthetic HEM and TEM data and their fitting.

Here, 'Occam R1' and 'Occam R2' refer to the first and second order derivatives of smoothness constraints that were used in the Occam inversion. In the zones, in which these two models were consistent and/or approximately the same, the obtained resistivity values were well resolved. The zones, where the two model results (Occam R1 and Occam R2) were not concurrent, were assumed as the unreliable zone. No noise are added on the synthetic data.

The measure of error is defined by misfit criterion; $\chi^2 = \sum_{i=1}^{N}\left[\frac{d_i - f_i}{\sigma_{si}}\right]^2$

where d_i is the measured data; f_i is the computed response; σ_{si} is the standard deviation associated with i^{th} data.

The resolutions of model parameters for the third, fourth and fifth layers are enhanced in joint inversion in comparison with the individual inversion of HEM and TEM data. However, the model parameters corresponding to first layers are not well resolved.

3.2. 1D joint inversion of synthetic HEM, TEM and RMT data

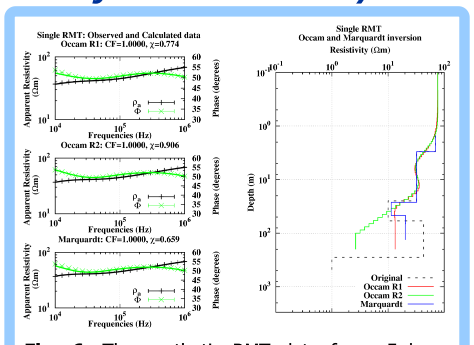

Fig. 6: The synthetic RMT data for a 5 layer model and its fitting for 1D Occam and Marquardt inversions (the fitting for single inversions of synthetic HEM and TEM data is shown in Fig. 4).

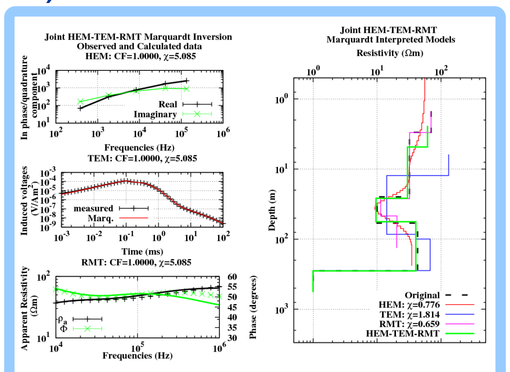

Fig. 7: The 1D Marquardt joint inversion of synthetic HEM, TEM and RMT data and their fitting.

To resolve the very shallow subsurface, the code is extended for the joint inversion of HEM-TEM-RMT (Fig. 6 and 7).

The resolution of the first layer model parameter was enhanced in 1D joint inversion of HEM-TEM-RMT in comparison with HEM-TEM.

However, to improve the fitting of the RMT phase data (Fig. 7), weighting of the parameter sensitivity matrix can be a solution in the joint inversion of HEM-TEM-RMT data.

3.3. 1D joint inversion of field HEM and TEM data

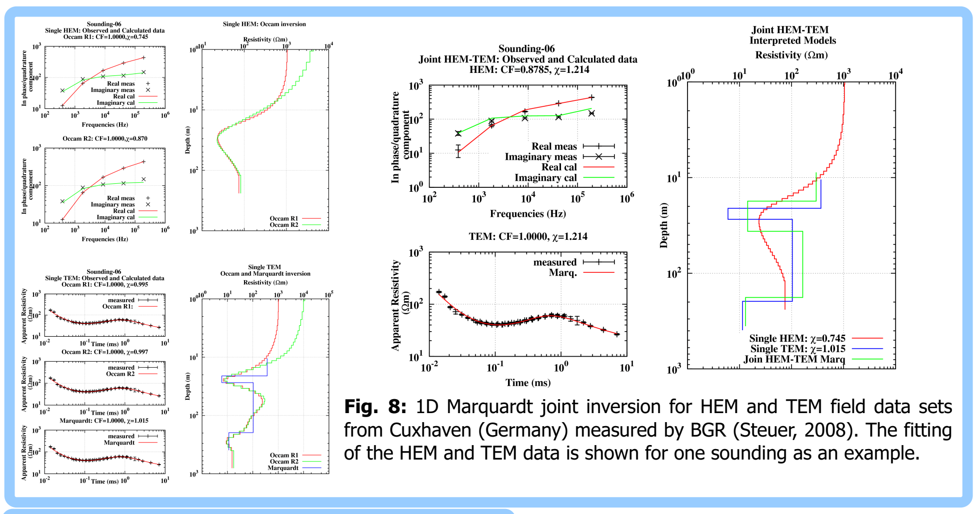

Fig. 8: 1D Marquardt joint inversion for HEM and TEM field data sets from Cuxhaven (Germany) measured by BGR (Steuer, 2008). The fitting of the HEM and TEM data is shown for one sounding as an example.

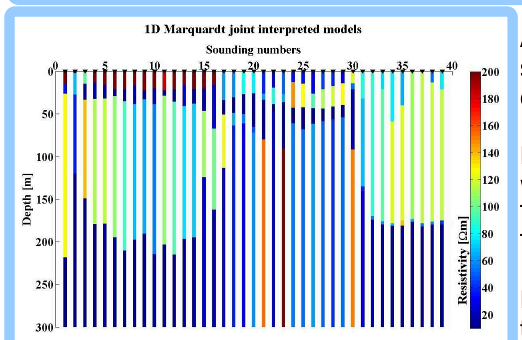

Fig. 9: 1D Marquardt joint inversion for HEM and TEM field data sets from Cuxhaven (Germany).

After the successful validation of joint inversion on synthetic data, it is applied to the field data.

No RMT field data are available from the sites, which were already investigated by HEM and TEM, therefore only the joint inversion of HEM TEM is tested on field data (Fig. 8 and 9).

From the inversion statistics, it is seen that the top 20 m was not resolved by any of the used methods.

4. Conclusions

The 1D numerical inversion codes, which have been used for the interpretation of single methods (TEM and RMT), are extended to perform the single and joint inversion with the HEM data.

The joint inversion is tested for synthetic data and field data (HEM and TEM). The resolution of model parameters is enhanced in joint inversion.

5. Proposed plans

Additional RMT measurements will be carried out on the sites, which were already investigated by HEM and TEM.

Weighting on the parameter sensitivity matrix of RMT, TEM and HEM in joint inversion will be realized.

A spatially constrained joint inversion algorithm for HEM, TEM and RMT data will be developed.

Acknowledgements

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References

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