Assessing the challenges of inverting IP-affected TEM data

Juan C. Zamora-Luria, Department of Geosciences, Aarhus University, Aarhus, Denmark
Muhammad Rizwan Asif, Department of Electrical and Computer Engineering, Aarhus University, Aarhus Denmark
Denys Grombacher, Department of Geosciences, Aarhus University, Aarhus, Denmark

Abstract

Transient electromagnetics (TEM) is a geophysical method well suited to mapping hydrogeological structures, especially in remote areas where little or no information is available. However, induced polarization (IP) effects across different geological settings have increasingly been observed mainly due to the advancements in the systems used for mapping. Handling IP-affected TEM data presents significant challenges both in the data processing and during the inversion. For example, IP-affected TEM data could be interpreted as noise, thus, it is removed, which impacts the value of the data to extract hydrogeological information. During the inversion, two issues can arise: achieving convergence can be a problem, especially in large datasets and equivalences in the IP-parameters, meaning that many different models can fit the data equally well. In this work, we study both the convergence and model equivalence challenges on the inversion results using field data collected across different countries in the African continent, where no ground truth information is available to validate the inverted results.

Using the maximum phase angle (MPA) Cole-Cole model, a subset of the collected data from each field example was inverted with 1000 starting half-space models using random combination of the four IP parameters ($\rho_0, \varphi_{max}, \tau_\varphi, C$). The results show that convergence rate is 26 % for the best scenario and as low as 2% for the worst scenario, evaluated using an average data residual threshold of 1 and 6, respectively. This means that there is a high dependency on the starting model in IP-affected TEM data. Further, the uncertainty across the models that fit the data calculated as the coefficient of variance (CV, standard deviation divided by the mean) show high uncertainties (CV > 1), especially in the $\varphi_{max}, \tau_\varphi,$ and C parameters. Furthermore, inverted φ_{max} models show a positive correlation with the starting φ_{max} values used during the inversion, meaning that there is a user residual in the inverted profiles. Finally, $\tau_\varphi,$ and C show no sensitivity as the starting models for these parameters remain unchanged throughout the inversion. Our results highlight the challenges of inverting IP-affected TEM using field data. While significant uncertainty was observed in the inverted IP parameters, resistivity demonstrated relatively lower uncertainty and may still be useful for interpretation. Nevertheless, the unavailability of ground-truth data limits the applicability of the TEM method in regions where IP effects are present and no prior geological information is available.