Three-Dimensional Inversion of Magnetotelluric Data from the Tarawera Dome Complex, New Zealand

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SUMMARY

We have merged our long-term numerical software developments at TU Bergakademie Freiberg and TU Chemnitz into a finite element toolbox that now provides blueprints for the implementation of forward operators and inversion routines for arbitrary geophysical EM problems.
Here we present an application of this toolbox to the magnetotelluric method by inverting both synthetic and real MT field data sets to study the behaviour of the implemented numerical solutions and prove the applicability to large field data sets. The MT data were acquired by GNS Science at 68 sites over an area of 25 x 30 km^2 at the Tarawera Dome Complex, New Zealand, from 2006 to 2017. For the 3D inversion, we have used 16 periods between 0.013 s and 341.297 s and placed particular emphasis on an appropriate representation of the rugged topography. In a first attempt, we adapted the level of detailedness of the topography using an inverse distance weighting scheme, which for the time being sufficiently resolves the features of the topography that are important for this particular survey setup. We explicitly show that parts of the data are strongly affected by the topography at sites that are less than 2 km away from steep slopes and that these topographic features have to be resolved with sufficient accuracy. The free software programs gmsh and MUMPS are used to discretize the model domain and solve the forward problem.
For the synthetic case, we have used the targeted field dataset as a guide. A simplified model of the Tarawera Dome Complex has thus been created to generate a synthetic data set. The model is based on the knowledge of the regional geology and an analysis of the raw data. It consists of four main layers and two conductive plume-like structures. In addition, the lakes in the study area and the Pacific Ocean have been included using rough geometric approximations of their true shape. We can clearly see that the lakes cause static shifts at nearby sites and that the ocean affects the longest periods at all sites.
For the inversion of the synthetic data, we have restricted ourselves to the impedances which leads to the resolution of the stratigraphy in terms of layer thicknesses and resistivities. However, the plume-like structures were not resolved, which is probably due to their low significance within the synthetic data.
The 3D inversion of the impedances of the real data set yields very similar results to the ones obtained in previous studies. Two conductive plume-like structures, which seem to rise from a larger conductive zone at depth, are well resolved. These have been previously interpreted to be either high temperature fluids or partial melt rising from a partial melt body at depth.
Both studies give us positive feedback regarding the practical inversion of extensive MT field datasets with our toolbox.

Keywords: Magnetotellurics, Taupo Volcanic Zone, Inversion, Topography, Finite Elements, Unstructured Grids