Utilisation of stochastic MT inversion results to constrain potential field inversion

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We introduce a methodology for the integration of results from 1D stochastic magnetotelluric (MT) data inversion into deterministic least-square inversions of gravity measurements. The goal of this study is to provide a technique capable of exploiting complementary information between 1D magnetotelluric data and gravity data to reduce the effect of non-uniqueness existing in both methodologies. Complementarity exists in terms of resolution, the 1D MT being mostly sensitive to vertical changes and gravity data sensitive to lateral property variations, but also in terms of the related petrophysics, where the sensitivity to different physical parameters (electrical conductivity and density) allows to distinguish between different contrasts in lithologies. To this end, we perform a three-step workflow. Stochastic 1D MT inversions are performed first. The results are then fused to create 2D model ensembles. Thirdly, these ensembles are utilised as a source of prior information for gravity inversion. This is achieved by extracting geological information from the ensemble of resistivity model realisations honouring MT data (typically, ensemble comprising several thousands of models) to constrain gravity data inversion.

In our investigations, we generate synthetic data using the 3D geological structural framework of the Mansfield area (Victoria, Australia) and subsequently perform stochastic MT inversions using a 1D trans-dimensional Markov chain Monte Carlo sampler. These inversions are designed to account for the uncertainty introduced by the presence of non-1D structures. Following this, the 1D probabilistic ensembles for each site are fused into an ensemble of 2D models which can then be used for further modelling. The fusion method incorporates prior knowledge in terms of spatial lateral continuity and lithological sequencing, to create an image that reflects different scenarios from the ensemble of models from 1D MT inversion. It identifies several domains across the considered area where it is plausible for the different lithologies to occur. This information is then used to constrain gravity inversion using a clustering algorithm by varying the weights assigned to the different lithologies spatially accordingly with the domains defined from MT inversions.

Our results reveal that gravity inversion constrained by MT modelling results in this fashion provide models that present a lower model misfit and are geologically closer to the causative model than without MT-derived prior information. This is particularly true in areas poorly constrained by gravity data such as the basement. Importantly, in this example, the basement is better imaged by the combination of both gravity and MT data than by the separate techniques.
The same applies, to a lesser extent, to dipping geological structures closer to surface. In the case of the Mansfield area, the synthetic modelling investigation we performed shows the potential of the workflow introduced here and that it can be confidently applied to real world data.