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Minimum entropy constrained cooperative inversion with application to electrical resistivity, seismic and magnetic field and synthetic data

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Interpreting independent geophysical data sets can be challenging due to ambiguity and non-uniqueness. To address this, joint inversion techniques have been developed to produce less ambiguous multi-physical subsurface images. Recently, a novel cooperative inversion approach that uses minimum entropy constraints has been proposed. The major feature of this approach is that it can produce sharper boundaries inside the model domain. We implemented this approach in an open-source software framework and systematically investigated its capabilities and applicability on electrical resistivity tomography (ERT), seismic refraction tomography (SRT), and magnetic data.

First, we conducted a synthetic 2D ERT and SRT data study to demonstrate the approach and investigate the influence of the equations' parameters that must be calibrated as well as to justify extensions of the method. The results show that the use of the joint minimum entropy (JME) stabilizer outclasses separate, conventional smoothness-constrained inversions and provides improved images.

Next, we used the method to analyze 3D ERT and magnetic field data from Rockeskyller Kopf, Germany. Independent inversion of the magnetic field data already suggested a subsurface volcanic diatreme structure, but the joint inversion using JME not only confirmed the expected structure, but also provided improved details in the subsurface image. The multi-physical images of both methods are consistent in many regions of the model as they produce similar boundaries. Due to the sensitivity of the ERT measurements to hydrogeological conditions in the subsurface, some structures are only visible in the ERT data. These features seem not to be enforced on the magnetic susceptibility model, which highlights another advantage and the flexibility of the approach.

However, the results of both the synthetic and field data use cases suggest that careful parameter tests are required prior to cooperative inversion to obtain a suitable hyperparameters and reference model. Our work implies that minimum entropy constrained cooperative inversion is a promising tool for geophysical imaging provided that proper settings are chosen while it also identifies some objectives for future research to improve the approach.