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3D stochastic geophysical inversion for contact surface geometry

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Geologists' interpretations about the Earth typically involve distinct rock units with contacts (interfaces) between them. As such, 3D geological Earth models typically comprise wireframe contact surfaces of tessellated triangles or other polygonal planar facets. In contrast, standard minimum-structure geophysical inversions are performed on meshes of space-filling cells (typically prisms or tetrahedra) and recover smoothly varying physical property distributions that are inconsistent with typical geological interpretations. There are several approaches through which mesh-based geophysical inversion can help recover models with some of the desired characteristics. However, a more effective strategy is to consider a fundamentally different type of inversion that works directly with models that comprise surfaces representing contacts between rock units. We are researching such an approach, our goal being to perform geophysical forward and inverse modelling directly with 3D geological models of any complexity. Geological and geophysical models should be specified using the same parameterization such that they are, in essence, the same Earth model.

We parameterize the wireframe contact surfaces in a 3D model as the coordinates of the nodes (facet vertices). The physical properties of each rock unit in a model remain fixed while the geophysical inversion controls the position of the contact surfaces via the control nodes, perturbing the surfaces as required to fit the geophysical data responses. This is essentially a "geometry inversion", which can be used to recover the unknown geometry of a target body or to investigate the viability of a proposed Earth model. We apply global optimization strategies to solve the inverse problem, including stochastic sampling to obtain statistical information regarding the likelihood of particular features in the model, helping to assess the viability of a proposed model. Jointly inverting multiple types of geophysical data is simple, requiring no additional mathematical coupling measure in the objective function. The use of global optimization methods introduces high computational costs: to provide computationally feasible inversion methods we reduce the dimensionality of the problem by allowing the inversion to control the nodes in a coarse representation of the wireframe model, which is refined before calculating the geophysical responses at each iteration. This strategy also provides a simple and effective way to regularize the inverse problem. We have tested our inversion method on several illustrative synthetics and applied it to a joint inversion of gravity and magnetic survey data collected above an IOCG deposit.