Structurally constrained inversion in Geochron space

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The inherent non-uniqueness of geophysical inverse problems requires that constraints are placed on the model space to exclude solutions that are not geologically reasonable. Minimum structure is the most commonly applied constraint, resulting in the so called 'Occam-style' inversion, where spatial fluctuations in the modelled physical properties are penalized, resulting in the smoothest possible model that explains the data to an acceptable level of misfit. While Occam-style inversions can be successful in generating models approximating the Earth's structure, geological processes such as faulting and folding can result in abrupt lateral changes in physical properties in Cartesian space which are difficult to recover and interpret in smooth models. By applying a mathematical transformation, a deformed geological model in Cartesian space can be restored into its undeformed configuration at the time of deposition, called Geo-Chronological (Geochron) space. In Geochron space, the model consists of two horizontal spatial dimensions, and a third vertical dimension that obeys the laws of stratigraphy, younging upwards. Geological units within this space are continuous in the horizontal dimensions and distinct in the vertical dimension. We propose a new constrained inversion scheme in which the model smoothing takes place not in present day Cartesian coordinates, but rather in Geochron space. We have modified the Occam2D inversion codes for magnetotelluric data to work in Geochron space. A mapping is generated based on a geological model that transforms the model from Cartesian to Geochron space. At each inversion step, the mapping is applied and penalties on model roughness are calculated. We apply this methodology on: 1) a simple test case of a layered Earth with two reverse faults; and 2) real data collected in the Amundsen sedimentary basin in northern Canada, and the results are compared to those of a standard Occam inversion. While the standard Occam approach produces models that adequately fit the observed data, they are difficult to interpret in the context of known geological units. Models generated using Geochron inversion, in addition to fitting the observed data to a similar level of misfit, respect interpreted layer boundaries and fault locations, as well as the continuity of geological units across these boundaries. The results of the tests indicate that Geochron inversion provides a method to test and improve upon current geological interpretations. Further improvements to this technique should provide a new framework to incorporate stratigraphic and structural data directly into the inversion process.