



Correlation-based regularization and gradient operators for (joint) inversion on unstructured meshes

Claudio Jordi (1), Joseph Doetsch (1), Thomas Günther (2), Cedric Schmelzbach (1), and Johan Robertsson (1)
(1) ETH Zürich, Geophysics, Earth Sciences, Zürich, Switzerland (claudio.jordi@erdw.ethz.ch), (2) Leibniz Institute for Applied Geophysics, Hannover, Germany

When working with unstructured meshes for geophysical inversions, special attention should be paid to the design of the operators that are used for regularizing the inverse problem and coupling of different property models in joint inversions. Regularization constraints for inversions on unstructured meshes are often defined in a rather ad-hoc manner and usually only involve the cell to which the operator is applied and its direct neighbours. Similarly, most structural coupling operators for joint inversion, such as the popular cross-gradients operator, are only defined in the direct neighbourhood of a cell. As a result, the regularization and coupling length scales and strength of these operators depend on the discretization as well as cell sizes and shape. Especially for unstructured meshes, where the cell sizes vary throughout the model domain, the dependency of the operator on the discretization may lead to artefacts.

Designing operators that are based on a spatial correlation model allows to define correlation length scales over which an operator acts (called footprint), reducing the dependency on the discretization and the effects of variable cell sizes. Moreover, correlation-based operators can accommodate for expected anisotropy by using different length scales in horizontal and vertical directions.

Correlation-based regularization operators also known as stochastic regularization operators have already been successfully applied to inversions on regular grids. Here, we formulate stochastic operators for unstructured meshes and apply them in 2D surface and 3D cross-well electrical resistivity tomography data inversion examples of layered media. Especially for the synthetic cross-well example, improved inversion results are achieved when stochastic regularization is used instead of a classical smoothness constraint.

For the case of cross-gradients operators for joint inversion, the correlation model is used to define the footprint of the operator and weigh the contributions of the property values that are used to calculate the cross-gradients. In a first series of synthetic-data tests, we examined the mesh dependency of the cross-gradients operators. Compared to operators that are only defined in the direct neighbourhood of a cell, the dependency on the cell size of the cross-gradients calculation is markedly reduced when using operators with larger footprints. A second test with synthetic models focussed on the effect of small-scale variabilities of the parameter value on the cross-gradients calculation. Small-scale variabilities that are superimposed on a global trend of the property value can potentially degrade the cross-gradients calculation and destabilize joint inversion. We observe that the cross-gradients from operators with footprints larger than the length scale of the variabilities are less affected compared to operators with a small footprint. In joint inversions on unstructured meshes, we thus expect the correlation-based coupling operators to ensure robust coupling on a physically meaningful scale.