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How to select a prior subsurface covariance model from indirect geophysical data observations

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Least squares type inversion is applied to infer information about the subsurface for many types of near surface geophysical data (e.g. electric, electromagnetic, gravity data). Such inverse problems are typically under-determined inverse problems, and therefore additional information needs to be provided. For least squares type inversion problems, such information is given in form of a covariance model (C_M) describing the prior assumptions of the variability between sets of points in the model parameter space. In recent years, stochastic least squares inversion methods have been used for more wide spread applications. Here the solution to the inverse problem is not just one smooth model, but a set of realisations consistent with data observations and the prior C_M. For such methods the choice of prior C_M plays a very important role. Sometimes one may have knowledge about the subsurface covariance model from for example reflection georadar/seismic profiles, and well logs, from which one can try to infer an appropriate prior C_M. In other cases such additional data are not available, and it can be difficult to choose a prior C_M. We have recently proposed a method to identify the prior C_M most consistent with data observations for least squares types of problems. We present the methodology and an analysis of the method for inferring properties of the subsurface covariance from indirect geophysical measurements. We illustrate that for a synthetic cross-borehole georadar tomography example we are able to infer the properties of the subsurface with an accuracy comparable to a traditional semivariogram analysis of the actual subsurface model (which in a real case is unknown). We also illustrate the effect such a choice of prior C_M has on both stochastic realisations and the least squares mean estimate.