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Bayesian source term determination with unknown covariance of measurements

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Determination of a source term of release of a hazardous material into the atmosphere is a very important task for emergency response. We are concerned with the problem of estimation of the source term in the conventional linear inverse problem, $y = Mx$, where the relationship between the vector of observations y is described using the source-receptor-sensitivity (SRS) matrix M and the unknown source term x. Since the system is typically ill-conditioned, the problem is recast as an optimization problem $\min_{R,B}(y - Mx)^T R^{-1}(y - Mx) + x^T B^{-1} x$. The first term minimizes the error of the measurements with covariance matrix R, and the second term is a regularization of the source term. There are different types of regularization arising for different choices of matrices R and B, for example, Tikhonov regularization assumes covariance matrix B as the identity matrix multiplied by scalar parameter.

In this contribution, we adopt a Bayesian approach to make inference on the unknown source term x as well as unknown R and B. We assume prior on x to be a Gaussian with zero mean and unknown diagonal covariance matrix B. The covariance matrix of the likelihood R is also unknown. We consider two potential choices of the structure of the matrix R. First is the diagonal matrix and the second is a locally correlated structure using information on topology of the measuring network.

Since the inference of the model is intractable, iterative variational Bayes algorithm is used for simultaneous estimation of all model parameters. The practical usefulness of our contribution is demonstrated on an application of the resulting algorithm to real data from the European Tracer Experiment (ETEX).

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