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Compensation of inaccurate meteorological data in source term determination problem using Bayesian methods

Ondřej Tichý (1), Václav Šmídl (1), Miroslav Hýža (2), Kateřina Šindelářová (3), Lukáš Ulrych (1), and Alkomiet Belal (1)

(1) The Czech Academy of Sciences, Institute of Information Theory and Automation, Prague, Czech Republic (otichy@utia.cas.cz), (2) National Radiation Protection Institute, Prague, Czech Republic, (3) Faculty of Mathematics and Physics, Charles University in Prague, Czech Republic

A common formulation of the source term determination problem is based on linear inverse problem $\mathbf{y} = M\mathbf{x} + \mathbf{e}$, where $\mathbf{y}$ is the the vector of observations, M is the source-receptor-sensitivity (SRS) matrix, $\mathbf{x}$ is the unknown source term, and $\mathbf{e}$ is the model residue. The matrix M is computed using a selected atmospheric transport model fed by a selected meteorological data. The inverse problem is typically ill-conditioned which requires the use of regularization terms. However, the matrix M is typically assumed to be known exactly. The mismatch between the true underlying SRS matrix and that from the numerical model is hard to assess. It is assumed that the residue is a combination of the observation error and the SRS error. Distinction between these errors is typically made explicitly as in methods based on outlier detection, or implicitly in methods based on estimation of the residue covariance matrix.

In this contribution, we propose two probabilistic models of the residue statistics. The first model is based on the assumption of non-Gaussian statistics of the residue. In particular, we choose Student-t model of the residues and design a Variational Bayesian estimation procedure for the source term. The second model is based on Gaussian model of the residues with non-diagonal covariance matrix. Since estimation of the full covariance matrix is not possible due to limited data, we propose several variants of the covariance parametrization using restricted parametrization. We estimate the parameters of the residue model jointly with the source term.

The proposed models will be tested on two data sets: the ETEX experiment for which a ground truth source term is known, and the data from recent detection of ruthenium over Europe and Siberia in late September and early October 2017. We will show that the proposed models improve estimation of the source term for the ETEX dataset. Since the origin of the Ruthenium release is still unclear, we will show the effect of the proposed models on estimated maps of the source location. The source location maps are also computed using Bayesian model selection approach.