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Improved source term estimation using blind outlier detection

Marta Martinez-Camara (1), Benjamin Bejar Haro (1), Martin Vetterli (1), and Andreas Stohl (2)

(1) School of Computer and Communication Sciences, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland (marta.martinez-camara@epfl.ch), (2) Norwegian Institute for Air Research (NILU), Norway

Emissions of substances into the atmosphere are produced in situations such as volcano eruptions, nuclear accidents or pollutant releases. It is necessary to know the source term – how the magnitude of these emissions changes with time – in order to predict the consequences of the emissions, such as high radioactivity levels in a populated area or high concentration of volcanic ash in an aircraft flight corridor. However, in general, we know neither how much material was released in total, nor the relative variation of emission strength with time. Hence, estimating the source term is a crucial task.

Estimating the source term generally involves solving an ill-posed linear inverse problem using datasets of sensor measurements. Several so-called inversion methods have been developed for this task. Unfortunately, objective quantitative evaluation of the performance of inversion methods is difficult due to the fact that the ground truth is unknown for practically all the available measurement datasets.

In this work we use the European Tracer Experiment (ETEX) – a rare example of an experiment where the ground truth is available – to develop and to test new source estimation algorithms. Knowledge of the ground truth grants us access to the additive error term. We show that the distribution of this error is heavy-tailed, which means that some measurements are outliers. We also show that precisely these outliers severely degrade the performance of traditional inversion methods.

Therefore, we develop blind outlier detection algorithms specifically suited to the source estimation problem. Then, we propose new inversion methods that combine traditional regularization techniques with blind outlier detection. Such hybrid methods reduce the error of reconstruction of the source term up to 45% with respect to previously proposed methods.