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SHORT ABSTRACT

Abstract title: Near-range source term estimation and uncertainty quantification informed by an early warning network around a nuclear facility

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Abstract text

In the context of airborne releases in nuclear or radiological settings, there is a continuing need for suitable inverse atmospheric dispersion modelling (ADM) techniques for source localisation and estimation. On the near range, the required observations can be provided by gamma dose rate (GDR) detector networks that are routinely set up in the vicinity of nuclear facilities as early warning networks. Both observations and modelling results are generally uncertain, though. Using the GDR exacerbates these uncertainties – particularly when dealing with smaller releases – because the GDR induced by the radiological plume comes on top of the background GDR. Isolating the plume-induced GDR from the background is non-trivial, because the latter is a function of a large number of natural radioactive processes that vary in space and time. These uncertainties need to be addressed during GDR-informed inverse modelling lest they influence the source term estimate.

In this work, we present a Bayesian inference framework for source term estimation and uncertainty quantification that was specifically tailored to the direct vicinity around a nuclear reactor, taking into account the uncertainties arising from the ADM, observations and background GDR. We parametrised the different uncertainties and constructed physics-based likelihoods, identifying a series of nuisance parameters in the process. The ADM of choice was ADDER, an in-house code that combines an extended bi-gaussian plume model with a GDR model. While Gaussian type models are strongly simplified, they are also very fast. That makes them ideal for use in combination with Markov Chain Monte Carlo algorithms, which are required to keep Bayesian inference problems tractable. The Bayesian backbone of this work was provided by PyMC, a general-purpose Bayesian modelling tool. Our framework allows for the joint estimation of source term and nuisance parameters. Using data from Telerad, the Belgian radiological surveillance and early warning network, we estimated the source term and nuisance parameters for the BR1 research reactor in Mol (which emits small but measurable amounts of argon-41 during routine operation) to good effect. In the future, our algorithm might also be used for the calibration of model parameters besides the source term – e.g., the dispersion coefficients in a plume model.