The CEA has developed the CERES-MITHRA (C-M) application to model the radionuclide atmospheric dispersion in order to evaluate the consequences on human health of radionuclide releases in the environment. This application is used either for crisis management or to perform assessment calculations for regulatory safety documents relative to nuclear facilities. C-M code is a time consuming complex spatio-temporal model based on a Gaussian puff model and depends on many uncertain variables related to radionuclide, release or weather conditions. These variables are of different kind: scalar, functional and qualitative. Given the uncertain parameters, C-M code provides spatial maps of radionuclide concentration for various moments defined by the scenario. The objective is to assess how these uncertainties can affect the C-M forecasts. In order to achieve this objective, a global sensitivity analysis of C-M code and an uncertainty propagation are performed. The sensitivity analysis is used to identify the most influential uncertain parameters, the non-influential ones and the interaction between parameters. We consider here the global sensitivity analysis which often calls for the estimation of variance-based importance measures, called Sobol’ indices.

For simulators that require a reasonable computational time, direct sampling methods (Monte Carlo) can be used to conduct uncertainty propagation studies or sensitivity analysis. In the case of simulators that take several hours or days for a single run, such direct sampling methods are impractical. To deal with these expensive models such as C-M, several metamodel-based methods have been proposed in the past few years. In this paper, we propose a global methodology combining metamodels and several advanced statistical techniques which enable to deal with the various natures of the uncertain inputs and the high dimension of model outputs.

At first, an initial realistic sampling design taking into account the correlation between inputs is generated and the corresponding C-M simulations are performed. Based on this sample, a proper orthogonal decomposition of the spatial output is used and the main decomposition coefficients are modelled with Gaussian process metamodels. The obtained spatial metamodel provides a predictor for any set of uncertain input values. Its accuracy and predictivity are assessed. The predictor is then used to compute spatial maps of Sobol’ indices, yielding the identification of global and local influence of each input variable and the detection of areas with interactions. A global index is proposed to synthesize the influence of each parameter on the whole spatial domain. Its interpretation is compared with the generalized sensitivity index proposed by Lamboni et al. (Reliability Engineering and System Safety, 2011). A propagation of uncertainties is also performed using the spatial metamodel and a comparison is made between two scenarios: one with constant weather conditions and the other with variable weather conditions.