Assimilation of spatio-temporal distribution of radionuclides in early phase of radiation accident

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Exploitation of the data assimilation methodology in the field of radiation protection is studied. When radioactive pollutants are released into the atmosphere, a radioactive plume is passing over the terrain. The released radioactive material causes pathway-specific irradiation which has detrimental effects on population health. In order to ensure efficiency of introduced countermeasures, it is necessary to predict spatial and temporal distribution of the aerial pollution and material already deposited on the ground. The predictions are made by the means of a numerical dispersion model with many inputs. Output of such a model is a prediction of radiation situation given in terms of radiological quantities. Exact values of the inputs are uncertain due to the stochastic nature of the dispersion, lack of accurate information, etc. Typically, the choice of values of these inputs is subject to an expert opinion. Their subjective choice can introduce significant errors into the predictions and thus decrease the positive impact of the countermeasures. To avoid this, we apply Bayesian approach and treat the parameters as random quantities. We employ data assimilation to improve reliability of model predictions on basis of available radiological measurements.

Data assimilation is the optimal way how to exploit information from both the measured data and expert-selected prior knowledge to obtain reliable estimates of the input parameters. Early identification of the parameters is essential for reduction of uncertainty of the radiation situation predictions. In this paper, sampling-importance-resampling algorithm (particle filter) is used to evaluate posterior distribution of estimated parameters and improve their estimates on-line as the plume is passing over the stationary measuring sites.

In our experiments we assume that the radiological quantity of interest is the activity concentration in air. The concentration itself is a difficult quantity to measure, therefore the measuring devices are assumed to measure the gamma dose rate. Nonlinear observation operator converting the activity concentration in air in Bq/m^3 to the gamma dose rate in Gy is constructed. It is evaluated by the means of Gaussian quadrature method of numerical integration.

A group of the most significant input parameters affecting the dispersion process was selected using available sensitivity and uncertainty studies performed on dispersion models. The algorithm is tested on a simulated scenario with an instantaneous release of ^{41}Ar. For propagation of the radioactive plume is used basic statistical approximation of the advection-diffusion equation, the Gaussian puff model. Experiment is conducted as a twin experiment when the measurements are simulated via model and perturbed.

The method gives us a joint estimation of spatio-temporal distribution of activity and parameters of the dispersion model. Thus, we obtain improved estimate of the radiation situation on the terrain and a way how to easily extend this estimates to predictions on an arbitrary horizon.

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