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Contents

1 Introduction

In case of a radiation accident, the risk evaluation and the decision-making process focused on protecting the public have the highest priority. The task of the decision support is to provide reliable and up-to-date information on the radiation situation, prognosis of its future evolution and possible consequences. Knowledge of spatio-temporal distribution of radionuclides is essential for planning of effective countermeasures. Historically, accidents in nuclear facilities have revealed unsatisfactory level of preparedness and lack of adequate modeling tools. Great attention has been paid to this topic since the Chernobyl disaster (Onishi et al., 2007). Nowadays, decision makers dispose of complex computer systems intended to provide assistance to them throughout various phases of the accident, e.g., (Päsler-Sauer, 2000; Pecha et al., 2007; Thykier-Nielsen et al., 1999).

During the last decades, a great progress has been made in our understanding the atmospheric dispersion and related natural phenomena. Despite all the effort, the stochastic nature of involved physical processes, the deficiencies in their mathematical conceptualization and particularly ignorance of the initial conditions prevent obtaining of accurate results. The only way how to attain satisfactory accuracy of the model forecasts is exploitation of observational data, which represents the only connection with the physical reality. Observations are often sparse in both time and space and it is not possible to get a complete picture of radiological situation based on monitoring data alone, especially during the first hours after the accident.

Data assimilation provides a framework for optimal combination of numerical model predictions and the available observational data (Kalnay, 2003). It makes possible to consistently account for uncertainties in the model, its inputs and observations, and produces probabilistic answers which are more informative than those deterministic. Data assimilation is a compromise between the pure modeling approach on one hand and the data mining approach on the other hand. Nowadays, data assimilation arises in many scientific areas. The main fields of its application are meteorology, oceanography and hydrology (Park and Xu, 2009; Wang et al., 2000). This work addresses the problem of exploitation of advanced data assimilation methods in the field of radiation protection.

1.1 Data assimilation in radiation protection

We are concerned with application of data assimilation in case of a severe radiation accident, when a release of radionuclides into the environment occurred and it is likely to require at least partial implementation of countermeasures. The main objective of data assimilation is to estimate the true scale of the accident and predict its consequences in order to improve reliability of the decision support through the different phases of the accident.

The time tract of an off-site accidental release of radionuclides can be formally split into two consecutive phases:

Early phase begins when the radionuclides are released into the environment. We focus on atmospheric releases, when the effluent forms a radioactive plume advected by the wind field and dispersed by turbulent processes. The plume causes external irradiation from cloudshine and internal irradiation due to inhalation. Duration of this phase is from a few hours up to several days and it formally ends when the plume leaves the area of interest. The main objectives of data assimilation in the early phase are (i) estimation of radiation situation and its evolution and (ii) estimation of committed population doses.

Late phase covers latter stages of the accident and immediately follows after the early phase. After the plume passage, there is no more irradiation due to cloudshine, however, on the ground remains deposited radioactive material. It causes external irradiation from groundshine and internal irradiation from inhalation due to resuspension and ingestion. This phase ends when the radiation levels resume to background values. The main objectives of data assimilation in the late phase are (i) identification of contaminated areas and (ii) estimation of radiation levels and the speed of the radionuclides removal for purposes of long-term forecasting. The estimates enter subsequent models of radionuclides propagation through the different compartments of the environment.

Data assimilation is potentially applicable in both phases, however, different physical processes, time scales etc., determine specific requirements on inputs and target fields of predictions.

1.2 State of the art

1.2.1 Data assimilation in the early phase

Particular data assimilation algorithm for the early phase must be constructed for a given class of atmospheric dispersion models (ADMs). In this work we focus on the ADMs parametrized by a set of control variables. The term *control variables* refers to a selected subset of inputs to the model and parameters influencing its result. The set is selected using the uncertainty and sensitivity studies performed with the dispersion models (Eleveld et al., 2007; Rao, 2005; Twenhöfel et al., 2007). Given some particular values of the control variables, concentration in air is evaluated simply by the model as a deterministic function of the variables. Data assimilation is then formulated as an optimization of the control variables in order to reach the best correspondence of the model forecast with available observations. These estimates may in turn re-enter atmospheric dispersion models, resulting in a greatly improved dose rate assessment.

The most simple methods for optimization of control variables are not probabilistic and minimize just a loss function measuring the pointwise distance between the model and the observations. Eleveld et al. (2007) presented a simple assimilation scheme for tuning of the effective release height and the wind direction of a Gaussian plume model. This idea is more developed in (Pecha and Hofman, 2008), where a segmented version of the Gaussian plume model (Hofman et al., 2008) is used and the set of optimized control variables is extended to address their time variability. The advantage of this method is its simplicity and the potential for extension of the set of optimized control variables.

The disadvantage is the fact, that the method does not consider error statistics of the model and the observations, contrary to the variational methods, where the difference between the model forecast and the observations is weighted with appropriate error statistics. Assimilation schemes based on variational approach are described in (Jeong et al., 2005; Kovalets et al., 2009; Quelo et al., 2005). Here, all the optimized control variables are treated as time invariant.

More advanced methods are based on sequential data assimilation. Drews et al. (2005) described extended Kalman filtering of the Gaussian plume. Here, the set of optimized control variables is restricted to the ratio of the release rate and the wind speed, the wind direction and the plume height. Similar assimilation scheme is proposed by Astrup et al. (2004). It is based on Kalman filtering of the RIMPUFF model (Thykier-Nielsen et al., 1999) and it is implemented in the Real-time On-line Decision Support System for Nuclear Emergency Management (RODOS) (Palma et al., 2003).

1.2.2 Data assimilation in the late phase

The basic aspects of modeling and data assimilation in the late phase are formulated in (Gering et al., 2004). Modeling in the late phase covers a broad range of disciplines focusing on different problems, e.g., contamination of arable soil and urban areas, contamination of water resources, propagation of radionuclides in the food chain, etc. In (Yuschenko et al., 2005), the method *iterations to optimal solution* is applied for assimilation of an aquatic model with observations of the Black Sea contamination after the Chernobyl accident. The details regarding this simple empirical interpolation method can be found in (Daley, 1993).

In (Palma, 2005), the ensemble Kalman filtering (EnKF) based method for assimilation of the groundshine measurements with a radioecological model is described. The system is a part of the RODOS. EnKF introduced by Evensen (1994) is proposed here as the most promising approach for data assimilation in the late phase.

1.3 Aims of the thesis

The main goals of the thesis are:

- To develop a suitable data assimilation methodology for the early phase of a radiation accident based on sequential Monte Carlo methods for on-line estimation of the most significant control variables of a parametrized dispersion model using the time integrated gamma dose rate measurements.
- To develop a suitable data assimilation methodology for the late phase of a radiation accident based on sequential Monte Carlo methods for estimation of contaminated areas and determination of radiation levels mitigation due to the environmental removal processes.
- To implement the developed data assimilation algorithms into a software tool.

2 Methods of Solution

In this work, the task of data assimilation is interpreted as a problem of inference of a discrete-time stochastic process:

$$\mathbf{x}_t \sim \quad p(\mathbf{x}_t|\mathbf{x}_{t-1}), \quad \mathbf{y}_t \sim p(\mathbf{y}_t|\mathbf{x}_t).$$

Here, $\mathbf{x}_t$ is a vector known as the state variable, $\mathbf{y}_t$ is a vector of observations, t is the time index, and $p(\cdot|\cdot)$ denotes the conditional probability density function (pdf) of the variable. The state evolution model given by the *state transition pdf* $p(\mathbf{x}_t|\mathbf{x}_{t-1})$ describes the evolution of $\mathbf{x}_t$ over time, whereas the measurement model given by the *likelihood function* $p(\mathbf{y}_t|\mathbf{x}_t)$ explains how the measurements $\mathbf{y}_t$ relate to the state variable.

Formally, the prior pdf $p(\mathbf{x}_0)$ representing uncertainty of the forecast in time $t = 0$ is transformed into the posterior pdf $p(\mathbf{x}_t|\mathbf{y}_{1:t})$ using measurements $\mathbf{y}_{1:t} = (\mathbf{y}_1, \ldots, \mathbf{y}_t)$ by recursive application of the data update and the time update:

1. Data update:

$$p(\mathbf{x}_t|\mathbf{y}_{1:t}) = \frac{p(\mathbf{y}_t|\mathbf{x}_t)p(\mathbf{x}_t|\mathbf{y}_{1:t-1})}{\int p(\mathbf{y}_t|\mathbf{x}_t)p(\mathbf{x}_t|\mathbf{y}_{1:t-1})d\mathbf{x}_t}, \tag{1}$$

2. Time update:

$$p(\mathbf{x}_{t+1}|\mathbf{y}_{1:t}) = \int p(\mathbf{x}_{t+1}|\mathbf{x}_t)p(\mathbf{x}_t|\mathbf{y}_{1:t})d\mathbf{x}_t. \tag{2}$$

Given the prior pdf $p(\mathbf{x}_t|\mathbf{y}_{1:t-1})$ representing uncertainty in the forecast in time t, we use the Bayes formula (1) and evaluate the posterior pdf $p\left(\mathbf{x}_t|\mathbf{y}_{1:t}\right)$ representing uncertainty in the analysis in time t. In recursive Bayesian filtering we exploit the fact that if the prior pdf is properly chosen from a class *conjugate* to the likelihood function $p(\mathbf{y}_t|\mathbf{x}_t)$, the formula (1) yields a posterior pdf of the same type.

Chapman–Kolmogorov equation (2) (Jazwinski, 1970) advances the the posterior $p\left(\mathbf{x}_t|\mathbf{y}_{1:t}\right)$ in time and produces the forecast in time $t+1$ represented by the new prior pdf $p(\mathbf{x}_{t+1}|\mathbf{y}_{1:t})$.

Using the posterior $p\left(\mathbf{x}_t|\mathbf{y}_{1:t}\right)$ we can evaluate the expected value of a function $f(\cdot)$ of $\mathbf{x}_t$ integrable with respect to $p(\mathbf{x}_t|\mathbf{y}_{1:t})$, (Doucet et al., 2001):

$$\mathbb{E}[f(\mathbf{x}_t)|\mathbf{y}_{1:t}] = \int f(\mathbf{x}_t)p(\mathbf{x}_t|\mathbf{y}_{1:t})d\mathbf{x}_t.$$

Data assimilation methodologies for the early and the late phase developed in the dissertation are based on Bayesian approach. The probabilistic aspect of the solution optimally combines a likely answer with uncertainties of available data. We focus on sequential Monte Carlo methods, specifically particle filtering and marginalized particle filtering.

3 Data Assimilation in the Early Phase

We propose a new data assimilation methodology based on particle filtering for reduction of uncertainty in atmospheric dispersion modeling during the early phase of a radiation accident. We focus on the parametrized ADMs, where the selected control variables are treated as random and we attempt to select their most plausible values in consecutive time steps using available measurements. The corrected parameters may in turn be used as input to long- and short-range atmospheric dispersion models, resulting in greatly improved dose rate assessment.

3.1 Data assimilation methodology

Parametrized ADMs can be understood as deterministic functions of control variables aggregated in a vector $\mathbf{x}$. It means, that all the uncertainty is assumed to be in the values of $\mathbf{x}$, not in the parametrization itself. The trajectory $\mathbf{x}_{1:t}$ represents values of control variables of the model up to time t and fully determines its propagation. Vector $\mathbf{x}_t$ aggregates the values of control variables used for model propagation between the time instances t and $t+1$. Physics behind the dispersion modeling motivates us to distinguish between two types of control variables, where each type must be treated differently:

Mutable control variables: Values of mutable control variables can—and are expected to—change in respective time steps. Typically, control variables describing meteorological conditions must be treated as mutable in order to correctly simulate stochastic fluctuations in the wind field and other atmospheric phenomena.

Immutable control variables: Values of immutable control variables must be the same along the whole state trajectory. Typical representative is the magnitude of release in the case of an instantaneous releases. As the initial magnitude of the release affects the doses and other radiological quantities along the trajectory of the plume, its change during the model propagation would violate the law of activity conservation. Neglecting the radioactive decay, the integral of activity over time and space must be equal to the initial value in all time steps. In context of the classical estimation theory, the immutable control variables denote the stationary parameters.

We exploit sequential Monte Carlo methods, specifically particle filtering, where the posterior pdf $p(\mathbf{x}_{1:t}|\mathbf{y}_{1:t})$ of control variables is approximated using samples $\{\mathbf{x}_t^{(i)}\}_{i=1}^N$ from a *proposal density* $q(\mathbf{x}_{1:t}|\mathbf{y}_{1:t})$ and corresponding weights $\{w_t^{(i)}\}_{i=1}^N$:

$$p(\mathbf{x}_{1:t}|\mathbf{y}_{1:t}) \approx \sum_{i=1}^{N} w_t^{(i)} \delta\left(\mathbf{x}_{1:t} - \mathbf{x}_{1:t}^{(i)}\right), \tag{3}$$

$$w_t^{(i)} \propto \frac{p(\mathbf{x}_{1:t}^{(i)}|\mathbf{y}_{1:t})}{q(\mathbf{x}_{1:t}^{(i)}|\mathbf{y}_{1:t})}. \tag{4}$$

Here, $\delta(\mathbf{x}_{1:t} - \mathbf{x}_{1:t}^{(i)})$ denotes the delta-Dirac mass located at $\mathbf{x}_{1:t}^{(i)}$. The advantage of the chosen filtering methodology over more traditional approaches based on Kalman filtering is its generality, where an arbitrary pdf can be approximated via an empirical distribution.

Selection of the proposal density $q(\mathbf{x}_{1:t}|\mathbf{y}_{1:t})$ is a crucial part of the particle filter designing and it affects the efficiency of the filter. If the proposal is badly chosen, the performance of the filter will be rather poor. Setting the proposal with the state transition density $p(\mathbf{x}_t|\mathbf{x}_{t-1})$ (Ristic et al., 2004) is the most straightforward choice. However, it resulted in a poor performance of the filter. The filter was computationally ineffective since the computational resources were wasted on propagation of particles with small weights. Enormous number of particles would be needed to achieve a good performance with this choice.

Significant improvements were achieved by application of the adaptive proposal selection methodology, where the proposal density is re-estimated in respective time steps (Andrieu et al., 2010). We assume a parametrized form of the proposal and estimate its parameters using weights $w_t^{(i)}$. From the re-estimated proposal we can generate new population of trajectories $\mathbf{x}_{1:t}^{(i)}$ and recompute the model and the weights from the beginning up to time t. This adaptive procedure guarantees that the trajectories with low weights are discarded and a new population of trajectories is sampled from the regions of the state-space determined by particles with high weights. In other words, the sequential update of the proposal effectively suppresses the effect of particle impoverishment.

3.2 Numerical experiment

The methodology was demonstrated on a simulated instantaneous release from the nuclear power plant Temelín. The activity concentration in air was modeled using the Gaussian puff model propagated for three hours and it was assimilated with the gamma dose rate measurements from a radiation monitoring network. Experiment was performed as a twin experiment, where the measurements were simulated by the model initialized with a random set of parameters and perturbed with noise. Convergence of the assimilated results can be then easily assessed. The set of estimated control variables comprised of the total magnitude of release, the wind direction and the wind speed. In the numerical experiment we assumed an instantaneous release of the radionuclide ^{41}Ar. The algorithm performed well in a meandering wind field, which is particularly important under a low-wind conditions. The extension of the algorithm to account for different physical effects is straightforward, however, we have to consider computational demands regarding intensive sampling during the particle filtering assimilation procedure. Since the uncertainty is accounted for, the physical parameters of the model are the best parameters possible, not in the sense of an exact match, but because they lead to the best representation of the true system, given the assumptions that were used to build the model.

4 Data Assimilation in the Late Phase

For data assimilation in the late phase we propose a new general method for joint estimation of a spatially distributed quantity and a set of parameters influencing its temporal and/or spatial evolution.

4.1 Data assimilation methodology

The main advantage of importance sampling is its generality. Particle filters are capable of approximating an arbitrary density via empirical density at the price of high computational cost, which is prohibitive in high-dimensional problems. This obstacle can be overcome in cases, where the structure of the model allows analytical marginalization over a subset, $\mathbf{x}_t^c$, of the full state vector

$$\mathbf{x}_t = \begin{bmatrix} \mathbf{x}_t^c \\ \mathbf{x}_t^p \end{bmatrix}. \tag{5}$$

Using the chain rule and the factorization (5), posterior $p(\mathbf{x}_{1:t}|\mathbf{y}_{1:t})$ has the form

$$p\left(\mathbf{x}_{1:t}|\mathbf{y}_{1:t}\right) = \underbrace{p\left(\mathbf{x}_{1:t}^c|\mathbf{x}_{1:t}^p, \mathbf{y}_{1:t}\right)}_{\text{analytical filter}} \underbrace{p\left(\mathbf{x}_{1:t}^p|\mathbf{y}_{1:t}\right)}_{\text{PF}}, \tag{6}$$

where $p\left(\mathbf{x}_{1:t}^c|\mathbf{x}_{1:t}^p, \mathbf{y}_{1:t}\right)$ is analytically tractable, while $p\left(\mathbf{x}_{1:t}^p|\mathbf{y}_{1:t}\right)$ is not (Doucet et al., 2001; Schön et al., 2005), and we use particle filter for its approximation. This technique is referred as Rao-Blackwellization (Doucet et al., 2001). We replace the term $p\left(\mathbf{x}_{1:t}^p|\mathbf{y}_{1:t}\right)$ in (6) by a weighted empirical distribution, in analogy to (3)–(4), yielding a weighted mixture

$$p\left(\mathbf{x}_{1:t}|\mathbf{y}_{1:t}\right) \approx \sum_{i=1}^{N} w_t^{(i)} p\left(\mathbf{x}_{1:t}^c|\mathbf{x}_{1:t}^{p,(i)}, \mathbf{y}_{1:t}\right) \delta\left(\mathbf{x}_{1:t}^p - \mathbf{x}_{1:t}^{p,(i)}\right).$$

Since the optimal Kalman filter is not suitable for large scale and non-linear problems, it would be advantageous to substitute it with an approximate filter within the marginalized filter. We propose to relax the requirement of exact marginalization and replace it by an approximation. What results is an algorithm equivalent to the marginalized particle filter where the analytical Kalman filters are replaced by approximate conditional filters, e.g. ensemble filters.

4.2 Numerical experiment

Firstly, the methodology was demonstrated on a small-scale problem given by the 40-variable Lorenz-96 model. We compared the developed technique with other techniques for tuning of model error, inflation factor and localization length-scale parameter in an ensemble filter.

Secondly, the method was applied on a large-scale problem regarding data assimilation of the deposition on terrain with the groundshine dose measurements and estimation of the speed of radionuclides removal due to environmental processes. The speed of radionuclides removal was estimated using the particle filter and the conditional distribution of deposition on terrain was estimated using the ensemble square root filter with sequential processing of observations.

5 Conclusion

The contributions of this dissertation are presented in three separate parts. The first part concerns development of the marginalized particle filtering framework for analytically intractable filters. The second part is devoted to application of particle filtering for assimilation in the early phase of a radiation accident. The last part applies the developed marginalized particle filtering framework for data assimilation in the late phase of a radiation accident. Specific goals of the respective parts are discussed below.

The main contributions of the first part presented in Chapter 4 are as follows:

- The extension of marginalized particle filtering on analytically intractable approximate filters and formulation of a framework for on-line tuning of ensemble filters resulting in a hybrid data assimilation method.
- The comparison of the new adaptive method with the "best tuned" ensemble filters on data assimilation scenarios with 40-variable Lorenz 96 model.

The main contributions of the second part presented in Chapter 5 are as follows:

- The formulation of a new data assimilation methodology for estimation of selected control variables of a parametrized atmospheric dispersion model in the Bayesian framework using particle filtering.

- The implementation of the Gaussian puff model and the nonlinear observation operator transforming the activity concentration in air into the time integrated gamma dose rate.

- The demonstration of the assimilation algorithm resulting from the proposed methodology on estimation of the source term, the wind speed, and the wind direction in the Gaussian puff model using the time integrated gamma dose rate measurements.

The main contributions of the third part presented in Chapter 6 are as follows:

- The formulation of a new data assimilation methodology for the late phase exploiting the extension of marginalized particle filtering presented in Chapter 4.

- The implementation of the groundshine dose evolution model and the observation operator for the spatial interpolation of deposition fields.

- The demonstration of the developed assimilation algorithm on an assimilation scenario, where the initial distribution of the deposition is estimated together with the speed of radionuclides removal.

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6 Author's Publications

6.1 Publications related to PhD thesis

1. Šmídl Václav, Hofman Radek: Marginalized particle filtering framework for Tuning of Ensemble filters, Accepted for publication in Monthly Weather Review

2. Hofman Radek, Pecha Petr: Application of regional environmental code HARP for off-site consequence assessment, Proc. of Topical Meeting on Probability Safety Assessment PSA2011, (Wilmington NC, USA, 13.3.2011-17.3.2011)

3. Hofman Radek, Šmídl Václav: Assimilation of spatio-temporal distribution of radionuclides in early phase of radiation accident, Bezpečnost jaderné energie, vol. 18, p. 226-228 (2010)

4. Pecha Petr, Hofman Radek: Comprehensive Modelling and Simulation System for Decision Support in the Field of Radiation Potection, ERCIM News, vol. 81, p. 17-18 (2010)

5. Pecha Petr, Hofman Radek, Kuča P., Zemánková K.: Development of software tools for consequence assessment of aerial radioactive discharges, Bezpečnost jaderné energie, vol. 7/8, p. 147-157 (2010)

6. Hofman Radek, Dedecius Kamil: A Hybrid Filtering Methodology for Nonlinear Estimation, Proc. of 6th International Workshop on Data-Algorithms-Decision Making, (Jindřichův Hradec, CZ, 02.12.2010-04.12.2010)

7. Hofman Radek, Šmídl Václav: EnKF within the Marginalized Particle Filter and Its Application for Adaptive Estimation of Inflation Factor, Proc of. The Meeting of the Americas 2010, (Foz do Iguaçu, BR, 08.08.2010-12.08.2010)

8. Hofman Radek, Kuča P., Pecha Petr: Problémy s predikcí šíření radioaktivního znečistění při specifických meteorologických pod-

mínkách, Sborník konference XXXII. Dny radiační ochrany, (Třeboň, CZ, 08.11.2010-12.11.2010)

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6.3 Software products related to PhD thesis

- Co-author of the decision support system HARP (HAzardous Radioactivity Propagation)

7 Summary

The task of the decision support in the case of a radiation accident is to provide up-to-date information on the radiation situation, prognosis of its future evolution and possible consequences. The reliability of predictions can be significantly improved using data assimilation, which refers to a group of mathematical methods allowing an efficient combination of observed data with a numerical model. The dissertation concerns application of the advanced data assimilation methods in the field of radiation protection. We focus on assessment of off-site consequences in the case of a radiation accident.

The main contribution of this thesis is the development of sequential data assimilation methods for the early and the late phase of a radiation accident. Data assimilation is understood here as a particular case of recursive Bayesian estimation. Instead of using traditional estimation methods for state-space models based on Kalman filtering, we focused on sequential Monte Carlo methods, specifically particle filtering and marginalized particle filtering.

Firstly, data assimilation methodology for the early phase of an accident was developed. It employs particle filtering with adaptive selection of proposal density for estimation of the most important variables describing the aerial propagation of radionuclides. The general methodology is applicable to all parametrized atmospheric dispersion models. It was demonstrated on a simulated release, where a bias of the basic meteorological inputs and the source term were corrected using available gamma dose measurements.

Secondly, for the purpose of data assimilation in the late phase, we extended the idea of marginalized particle filtering to analytically intractable approximate filters. The result is a hybrid data assimilation methodology, where multiple ensemble filters are run in parallel. The methodology was applied to joint estimation of the spatial distribution of deposition on terrain and estimation of the speed of radionuclides removal due to environmental processes in a simulated release scenario.

The proposed algorithms implemented in the decision support system HARP (HAzardous Radioactivity Propagation).

8 Resumé

V případě radiační nehody jsou aktualní informace a prognózy vývoje radiační situace včetně možných následků nutné pro zajištění podpory krizového řízení. Spolehlivost těchto předpovědí lze úspešně zvýšit využitím tzv. “data asimilačních” metod, což je skupina matematických metod umožňujících statisticky optimálně zkombinovat měřená data s předpovědí numerického modelu. Předkládaná disertační práce se zabývá aplikací pokročilých data asimilačních metod v oblasti radiační ochrany se zaměřením na zpřesňování predikcí následků úniků radioaktivních škodlivin do životního prostředí.

Hlavní přínosy disertační práce spočívají v návrhu a implementaci sekvenčních data asimilačních metod použitelných jak v časné tak i pozdní fázi radiační nehody. Asimilace je v této práci chápána jako speciální případ rekurzivní bayesovské filtrace. Na rozdíl od předchozích prací na toto téma, kde byly navrhované data asimilační algoritmy založeny na kalmanovské filtraci, v předkládané disertační práci se zaměřujeme na sekvenční metody Monte Carlo, přesněji na particle filtry.

Navrhovaný asimilační algoritmus pro časnou fázi radiační nehody využívá particle filtry s adaptivní volbou vzorkovací hustoty (tzv. proposal hustoty). Tato metodika je aplikovatelná na všechny parametrizované atmosférické disperzní modely. Metodika byla demonstrována na simulovaném úniku z jaderného zařízení, kde vstupní meteorologická data a zdrojový člen byly zkorigovány na základě měření dávkového příkonu.

Navrhovaný asimilační algoritmus pro pozdní fázi radiační nehody je založen na marginalizované verzi particle filtru, kde původní filtr byl rozšířen i na neoptimální přibližné filtry. Výsledkem je hybridní data asimilační metoda, kde několik ensemble filtrů je paralelně propagováno. Metodika byla aplikována na odhadování prostorového rozložení depozice radionuklidů na terénu jakožto následku simulovaného úniku. Souběžně byla odhadována rychlost odstraňování aktivity z povrchu.

Asimilační metodiky jak pro časnou tak pozdní fázy jsou implementovány v systému pro podporu krizového rozhodování HARP (HAzardous Radioactivity Propagation).