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ASSIMILATION TECHNIQUES IN CONSEQUENCE ASSESMENT OF ACCIDENTAL RADIOACTIVITY RELEASES - THE WAY FOR INCREASE OF RELIABILITY OF PREDICTIONS

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Motivation

The main objective of the grant project actually studied in the IITA is advancement, implementation and testing of broad palette of assimilation techniques. Results are already available for application from pure interpolation methods over empirical method of successive corrections up to the statistically constant method of optimal interpolation (OI). First results related to the advanced statistical methods taking into account time evolution of model error covariance structure are published in [4]. The assimilation subsystem is online connected to ORACLE database with direct access to short-term meteorological forecast and radiation measurements from EWS.

There are three main sources of information that are optimally blended together during assimilation objective analysis:

- Physical knowledge embodied into the model
- Expert judgement related to model and scenario uncertainties
- Measurements incoming from terrain

Implemented statistical assimilation techniques have been so far tested using artificial measurements usually simulated by the same environmental model (sometimes the procedure is called *twin experiment*). We suppose that now is time to clarify the problem which data can be provided by existing Radiation Monitoring Network (RMN) of the Czech Republic for data assimilation procedures.

Though the model requirements so far exceed possibilities of monitoring in the Czech Republic, the cooperation between modellers and monitoring has growing importance. That is the main reason why assimilation subsystem of the HARP code is developed in cooperation with National Radiation Protection Institute (NRPI) which is administrator of RMN. Among other things the assimilation requirements should be reflected in the future architecture design and development of the Czech RMN. Selected components of the RMN which could be exploited in data assimilation are described below.

Radiation Monitoring Network of the Czech Republic (RMN)

Early Warning Network (EWN)

Territorial Network consists of 54 measuring point equipped by dose-rate meters (5 stations with additional scintillation spectrometers) positioned 1m above ground level, working in 10-minutes integration intervals, transferring data into the central database each 10 minutes (16 stations) resp. each hour/30 minutes (38 stations - normal/emergency situation).

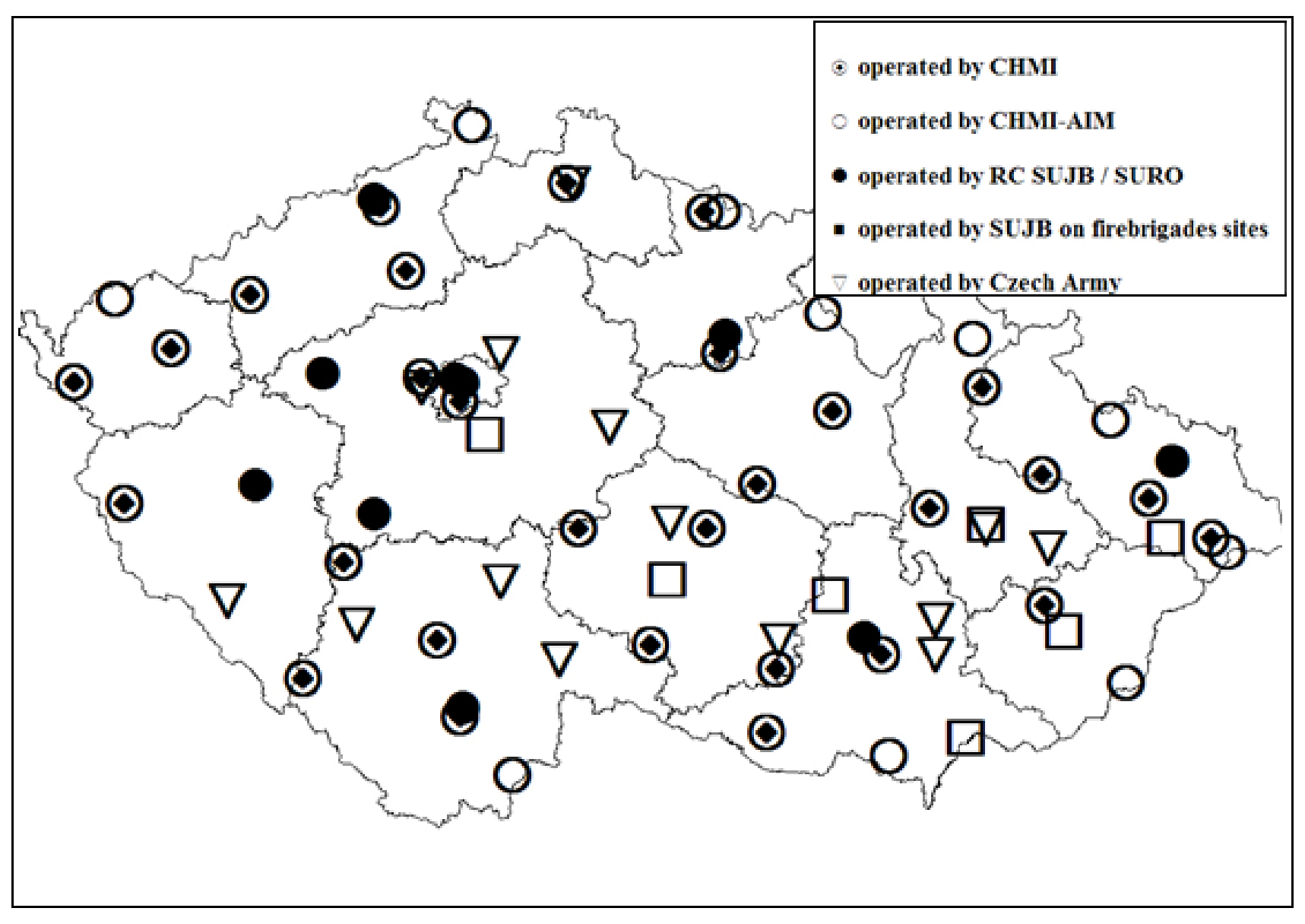

Figure 1. Configuration of territorial network of the EWN.

Teledosimetric systems of NPPs consist of two circles. The inner circle is positioned on the NPP fence. 27 stations 2,5m above ground for NPP Dukovany (EDU) and 24 stations 1,5m above ground for NPP Temelín (ETE). The outer circle consists of 8 stations 2,5m above ground for EDU and 7 stations 3m above ground for ETE. The dose-rate data are transfered each 4 minutes. ETE configuration see in the Fig. 2.

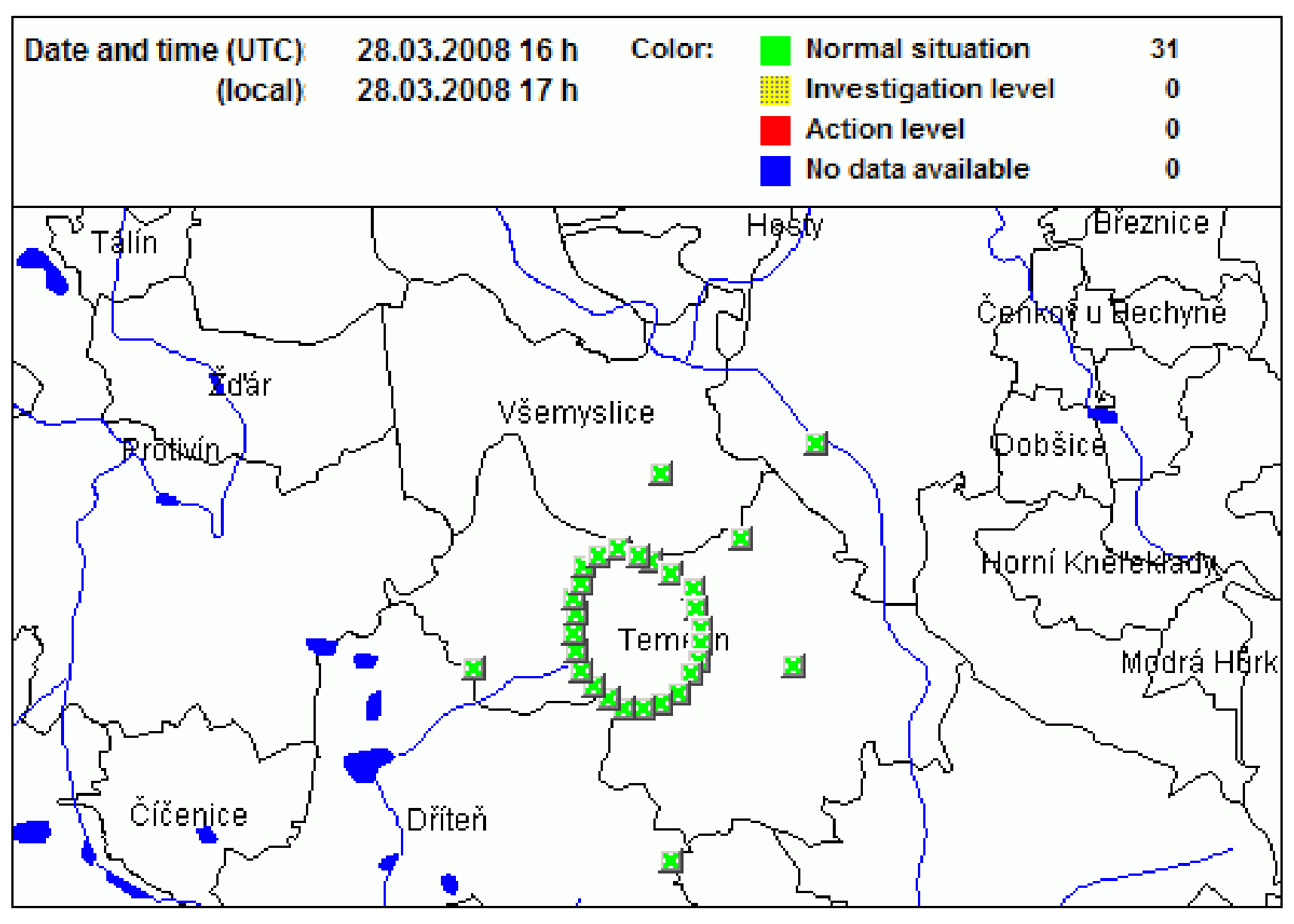

Figure 2. Inner (on fence - 24 stations) and outer (7 stations) circles of TDS Temelín.

ThermoLuminiscent Dosimetry Network (TLD)

Territorial TLD Network consists of 185 measuring points, approx. 2/3 of the them positioned in open space 1m above ground level, 1/3 in buildings in the same locations, TL-dosemeters exchange period in normal situation is 3 months, in emergency situation can be shortened significantly. The results are available after a few days after exchange (delay due to necessary time to deliver the TLD to the central laboratory for measurement and for processing the results).

Local TLD Networks around NPPs Two networks for each NPP, one operated by RC SÚJB/SÚRO, EDU 12 measuring points (positioned 3m above the ground level), ETE 9 measuring points, one operated by NPP operator, approx. 35 measuring points for each NPP (positioned 3m above the ground level). Exchange period is the same as in case of Territorial TLD Network.

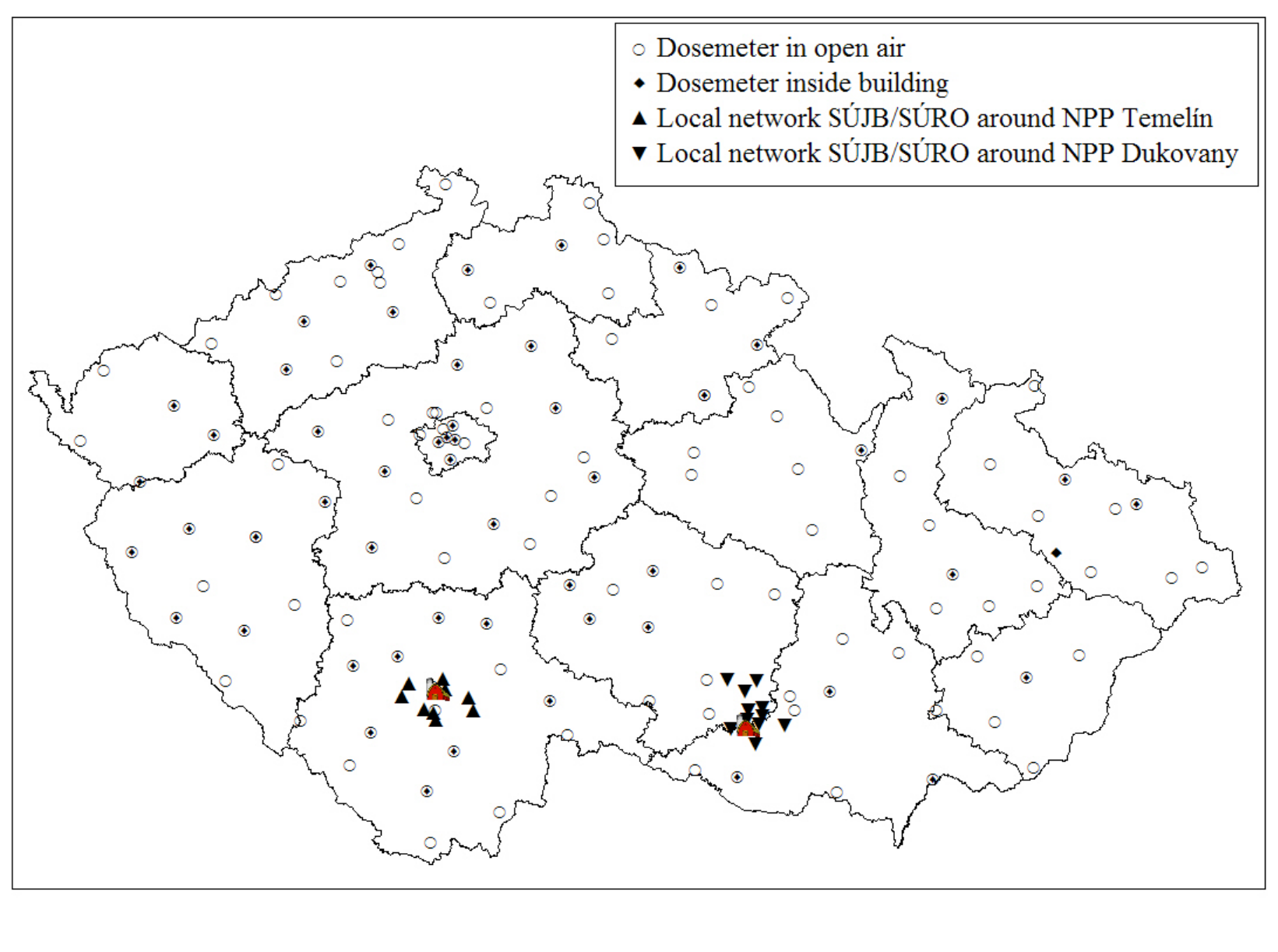

Figure 3. Configuration of Thermoluminiscent Dosimetry Network of the Czech Republic

Other permanent components of RMN

Food contamination monitoring points (FCMP) for periodical sampling and analysis of foodstuffs and feedstuffs.

Air contamination monitoring points (ACMP) with aerosol and fallout sampling equipment, laboratory $\alpha/\beta/\gamma$-spectrometry.

Mobile Groups (ground based) composed of together 36 units operating on-call, half of them available in 2-hours stand-bye (plus time necessary for driving to the emergency area), expected to operate after the cloud passage. Are aimed to detail monitoring of dose-rate and activity of radionuclides in the affected area (in situ). Quicker response is expected for mobile group of each NPP. Mobile groups are equipped by a dose-rate/dose meters, monitoring on-the-way on selected routes, storing measured dose-rate values together with the coordinates and date/time information into a on-board computer, transferring data into central database after return from the route to a local base, results available in the form of overview maps and tables.

Figure 4. International excercise of the mobile group: Czech participation in ISIS 2007, Austria.

Additional RMN components activated during emergency

Airborne mobile groups Composed of 2 units, one of SÚRO (supported by the helicopter provided by Army or Police) and one of the Czech Army, operating on-call, available in approx. 12-hours stand-bye.

Figure 5. Aerial monitoring.

The units are expected to operate after the cloud passage aimed to quick monitoring of large affected areas. The results are available approx. few hours after return from the flight in the form of overview maps.

Figure 6. Aerial monitoring.

Water contamination monitoring points for periodical sampling analysis of both surface and drinking water.

Example of assimilation scenario with local rain

Hypothetical one-hour release of total activity $1.32E+12\ Bq$ of radionuclide ^{137}Cs from NPP is simulated. Release height is 45 meters, atmospheric stability category is D according to Pasquill, short-term meteorological data extracted from $ALADIN$ format is provided by the Czech meteorological service.

Table 1. (a) measurement point No.; (b) activity deposition before DA $[Bq.m^{-2}]$; (c) measured value $[Bq.m^{-2}]$; (d) assimilated value $[Bq.m^{-2}]$

(a)	(b)	(c)	(d)
1	1.92E+01	6.63E+02	2.05E+01
2	7.27E+01	4.53E+02	7.27E+01
3	3.04E+01	4.89E+02	3.04E+01
4	4.23E+00	3.62E+02	1.19E+01

The following assimilation scenario is formulated: Segmented Gaussian plume model (SGPM) predicts deposition of ^{137}Cs on the terrain just at a moment when the radioactive plume is gone. Let calculated deposition is forecasted by state vector of background field values $\boldsymbol{x}_f$ of dimension n (number of points of calculation polar grid). Let vector $\boldsymbol{y}$ of available measurements (incoming just at t_{gone}) has dimension $p << n$. The aim is to assimilate observations with the model prediction using Optimal interpolation method (OI) of objective analysis, see [5]. The resulting analysis vector $\boldsymbol{x}_a$ of dimension n is found by means of weight matrix $\boldsymbol{W}$, which is determined on the basis of minimization the analysis error covariance, as:

$$\boldsymbol{x}_a = \boldsymbol{x}_f + \boldsymbol{W}(\boldsymbol{y} - \boldsymbol{H}\boldsymbol{x}_f) \qquad (1)$$

Form of weight matrix $\boldsymbol{W}$ results from least squares analysis:

$$\boldsymbol{W} = \boldsymbol{B}\boldsymbol{H}^T(\boldsymbol{H}\boldsymbol{B}\boldsymbol{H}^T + \boldsymbol{R})^{-1} \qquad (2)$$

Matrices $\boldsymbol{B}$ and $\boldsymbol{R}$ are covariance matrices of the model errors and measurement errors and $\boldsymbol{H}$ is matrix of linearized observation operator which evaluates model value in measurements positions. For research purposes we have considered for this example only one random input model parameter: local rain between hour $5-6$ of the plume spreading with uniform distribution of rain intensity within interval $[0; 2 \cdot v^{nom}]$; $v^{nom} = 3mm \cdot hour^{-1}$. Four measurements are simulated according to Table 1. Both the leftmost measurements No. 2 and 3 in Fig. 7 lie outside of the rain zone. Then, the sample model error covariances are always zero there (physical knowledge is reflected) and model prediction in this points is not modified after assimilation, see [7]. The same physical principle explains the substantial activity decrease behind the rain zone.

Conclusion: Statistical assimilation techniques preserve physical knowledge of the model.

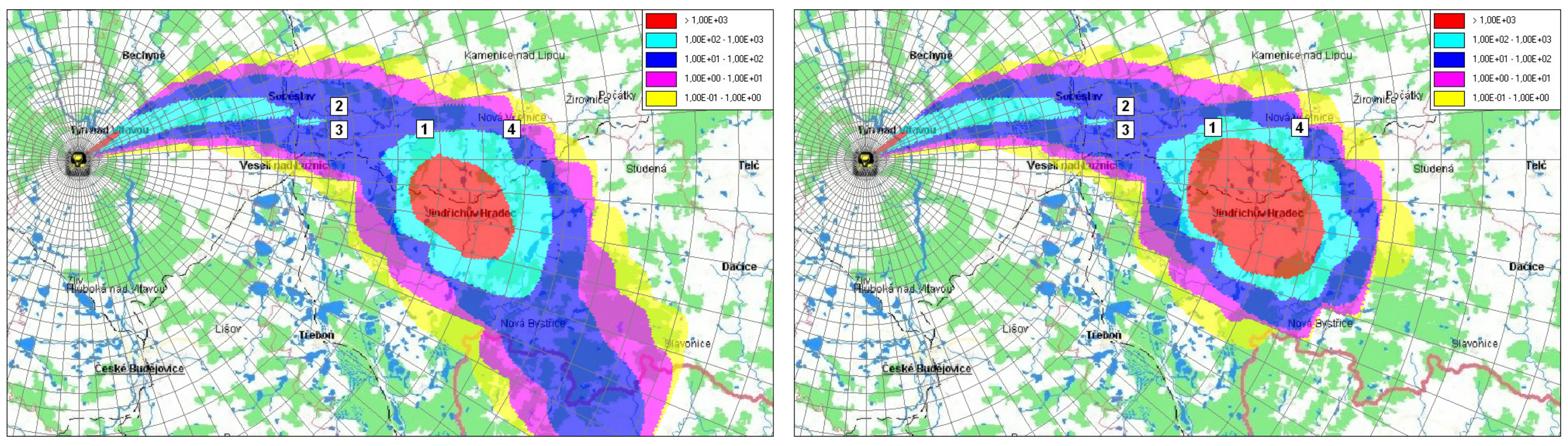

Figure 7. Activity of ^{137}Cs $[Bq.m^{-2}]$ deposited on terrain, local rain between hours 5 and 6 after the release start. 4 measurements (white squares). **Left:** Before assimilation, deterministic calculation with fixed rain intensity $v^{nom} = 3mm \cdot hour^{-1}$; **Right:** After the assimilation, sample covariance matrix $\boldsymbol{B}$ was constructed via M-C simulation with the only random variable v from uniform distribution $U(0;\ 2 \cdot v^{nom})$.

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