MESO-SCALE RANGE (EUROPEAN) MODELLING OF RADIOACTIVE CLOUD DISPERSION AND RADIOLOGICAL IMPACTS (ESTE)

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Abstract

Environmental spatial modelling is applied in the expert system ESTE for radiological impacts assessment of releases of radioactive gases and aerosols into atmosphere of the environment in case of nuclear accident or incident. Atmospheric dispersion of radioactive substances from the point of accident is modelled in small and meso-scale range (focused on the European territory). Comprehensive models for pollutants dispersion modelling are applied in the system. As the inputs to the spatial model various geodata is required including complex numerical weather prediction data for a considerable part of Europe, terrain roughness, results of real monitoring - measured dose rates throughout Europe from the European monitoring system EURDEP (European Radiological Data Exchange Platform) and the latest statistical data. Besides the calculations of radiological parameters (doses, dose rates, activities deposited on the terrain, doses caused by inhalation of radioactive substances) the final aim of our specific spatial modelling is to identify the need for implementation of protective measures to the impacted area in large (European) scale. Protective measures can be applied like urgent measures (for example sheltering or evacuation of inhabitants, iodine prophylaxis), preventive measures and measures which are applied to the agriculture or food industry. In the process of spatial modelling the improved data assimilation was developed and implemented into ESTE system. The aim of data assimilation process which is performed "on the way" at various stages of our modelling is to assimilate modelled calculated parameters to actually monitored rates (and to substitute the parameters of model with really monitored parameters and apply them in the next step of modelling).

Keywords: modelling of radioactive cloud dispersion, nuclear accident, radiological impacts, protective measures, data assimilation

1 INTRODUCTION

The expert system ESTE (**E**mergency **S**ource **T**erm **E**valuation Code) represents a geoinformation system and software for radiological impact assessment in the countries of European territory in case of radiation accident. The environmental spatial modelling is applied in the specific algorithms of the system. Our approach is to assess the source term (accidental release of radioactive substances into the atmosphere), to model the dispersion of radioactive puffs and, on the base of the results of modelling, to evaluate radiological impacts (like activities, doses, dose rates and avertable doses). Avertable doses and recommendations of protection measures and precautionary measures in agriculture and food industry are the most important results of the modelling in the global European aspect. These results show what is the amount of dose which can be averted if selected protective measures are applied (evacuation or sheltering of inhabitants, application of I-prophylaxis). Another possible output of the model calculation is the recommendation of measures which could be applied in agriculture. The aim is to recommend measures which can minimize the loss of farmer's production, such as closing stables and greenhouses, putting livestock into stables, stopping inflow to cisterns or to identify regions where various other measures to agricultural production cannot be excluded (ban on the sale of agricultural products or exclusion of the products from food chain).

2 MODELLING OF POLLUTANTS DISPERSION

The initial event for the modelling is information on the release of radioactive gasses and aerosols into the environment or information about prediction of such a release or increased response of gamma dose rate monitors network (the online monitoring system EURDEP- European Radiological Data Exchange

Platform) across the European countries. Dispersion of released activity across Europe in ESTE system is described and solved by Lagrange Puff Trajectory Model (LPTM) and Lagrange Particle Model (LPM). The system is running online with all its calculations. Therefore, the real-time calculation of atmospheric dispersion based on Monte Carlo simulation and LPM is performed with utilization of GPGPU (General-Purpose computation of Graphics Processing Units) with CUDA (Compute Unified Device Architecture) capability for acceleration. Moreover, a module for the calculation of a great set of dosimetic parameters on the territory of Europe is developed.

In case of radioactive release, the initial amount of particles is created and appropriate meteorological data is prepared (interpolated). In the process of modeling, the position of each particle is calculated using the local meteorological situation to determine the turbulent movement. Dry and wet deposition is calculated for each particle and together with pollutant concentration mapped in the resulting grid. Time integrated concentration and other radiological parameters are calculated from the grid cell. These operations are simple matrix addition and multiplication by the scalar. Our approach provides the advancement of the model by calculating the full set of radiological parameters which are used as criteria for radiological protective measures in case of nuclear or radiation accident. At the end of the simulation, the calculated radiological parameters are stored from the grid into the shape file and are presented to the user in the form of geodata-maps with the attributes of radiological situation. The output geodata formats are compatible with standard formats and therefore the utilizable results could be transfer to other GIS systems.

3 INPUT AND PRE-CALCULATED DATA

Advancements of geoinformation sciences and technologies have also influence on the global approach to the modelling in the field of nuclear software applications because the system is working with the data (input and output data) which has some spatial phenomena relative to a geographic area. Demand on input data, modelling and creating outputs emphasizes the importance of GIS platform implemented in the system and one of its options to work and integrate the spatial data. Before the process of spatial modelling begins and the evaluation of source term starts, various inputs are required.

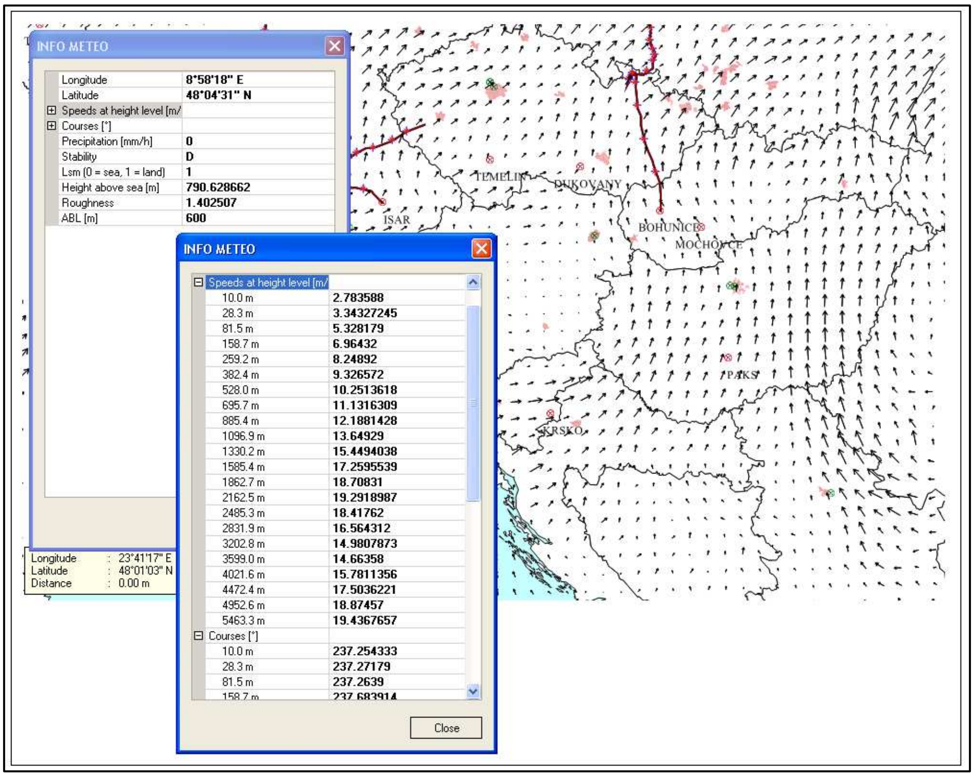

Fig. 1. Numerical weather prediction in ESTE EU system: wind vectors at height 400 m above the terrain and example of meteorological parameters in selected point

One group of inputs is being gathered by ESTE online, the other is prepared and stored inside the system. First is the prediction of meteorological parameters (Fig.1 - Numerical Weather Prediction) for the next 48 hours (or, better, up to 7 days) in the GRIB (GRIdded Binary) format entering into the model of ESTE in real-time, twice per day. The spatial resolution of currently used meteorological data is 25 km (in Lambert conformal conic projection) and time resolution is 3 hours.

Examples of numerical weather prediction parameters used as the inputs to the model:

- specific humidity
- dew point temperature
- temperature
- surface pressure
- total cloud cover
- boundary layer height
- convective precipitation
- land/sea mask
- orography

System on its input requires also the statistical data with the number of population (by towns and age categories) gathered from national statistical offices. Values are joined with the spatial information – points of the places and towns in Europe. Data from the Corine Land Cover project (classified land cover and land use data using Landsat imagery) are necessary for the roughness calculations.

Further online inputs are the dose rate data from the European monitoring system EURDEP, the conversion factors (prepared for positions of gamma dose rate monitors) and the database of pre-calculated (hypothetical) source terms for every European power reactor. This database is calculated in advance. Various states of the reactor fuel and various states of radiological barriers which should prevent radionuclides from the reactor to escape to the environment are taken into account. Predicted source term (release to the atmosphere of the environment) is assimilated according to actual knowledge of the state of the fuel and the barriers. Basic typical pre-calculated source terms implemented in ESTE systems are for LOCA (Loss of Coolant Accident), SGTR (Steam Generator Tube Rupture) and Interfacing LOCA (specific type of LOCA) events (with various states of the core, containment and containment depressurization system) and reactor shut down source terms (release from fuel assembly damaged during fuel manipulation or releases from the reactor fuel pool). The total amount of pre-calculated expected source terms for specific nuclear installation in the database of ESTE system is about 50.

4 DATA ASSIMILATION IN THE MODELLING OF DISPERSION

The aim of modelling and data assimilation process is to determine predicted source term which copes with the really measured radiological symptoms at the nuclear power plant (NPP) installation (Fig.2) or with the responses of dose rate monitors across the Europe (EURDEP network) and to determine radiological impacts which are not in contradiction with really measured radiological parameters.

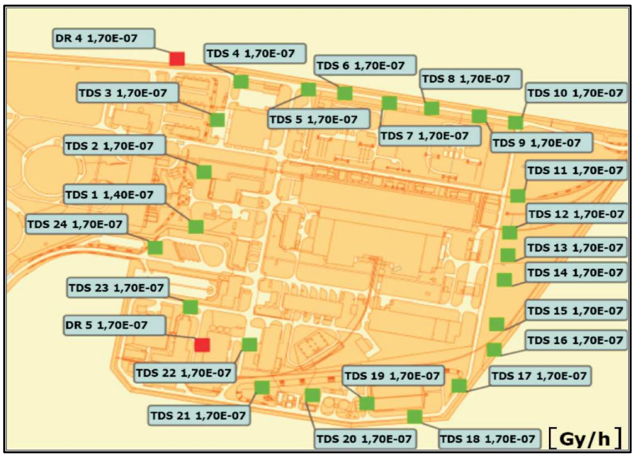

Fig. 2. Location of the 24 teledosimetric monitors around the reactor building of the Jaslovské Bohunice NPP

Predicted source term (release of radioactive gasses and aerosols to the environment – expected but maybe never realized) is taken from the database of pre-calculated hypothetical source terms and is used as an input for dispersion modelling and calculation of radiological parameters. Results of this calculation serve as base for urgent protective measures assessment. All above mentioned steps are performed even in the pre-release stage (before real release starts). At the second stage, during the release phase of the accident, further data assimilation process is applied. Predicted source term is assimilated to parameters really measured in a close vicinity of the nuclear installation. Re-calculation of predicted source term is based on the specific conversion factors which are prepared for every position of gamma dose rate monitor. This phase of data assimilation process enable us to evaluate so called "real release" in Bq per time interval. Really observed source term (in Bq per time interval) is then modeled in the atmosphere and "real" radiological situation in the vicinity of the installation is calculated. Results of this calculation enable us to prepare more correct and more accurate results (maps) of radiological impacts. The last stage of data assimilation process consists of assimilation of radiation situation modeled to the radiation situation really monitored across the Europe. At this stage, maps of actual radiological impacts are recalculated in order to obtain better agreement with measured values. Another benefit from this stage of data assimilation process is correction (increase or decrease) of the activity in radioactive cloud which is disposable for further dispersion modeling in the atmosphere. In such case, these corrections enable us to obtain calculated maps of real radiation situation which correspond better with really measured radiation situation.

5 RESULTS

The prediction of radiological impacts is modelled in a close vicinity of nuclear installation up to the area of Europe. The predicted source term is used to calculate radiological impacts in emergency. Results of these calculations are automatically used for assessment of urgent protective measures. Real release is a release of radioactive substances into the atmosphere, which was observed and its symptoms were detected. According to the calculation of real release, the real impacts are modelled (Fig.3) as impacts before as well as after steps of data assimilation process.

Results of our spatial modelling are implemented in the decision support systems ESTE, which are the real time systems intended for nuclear emergency response, assessing the source term, calculating radiological impacts and assessing the urgent protective measures. Systems ESTE are used by various crisis centers in Slovakia, Czech Republic, Austria and Bulgaria. Online running systems are connected to the source of numerical weather prediction data, relevant data from nuclear installations and radiological monitoring network. The outputs of the can be very useful for the members of emergency response group in the crisis centers at the national level.

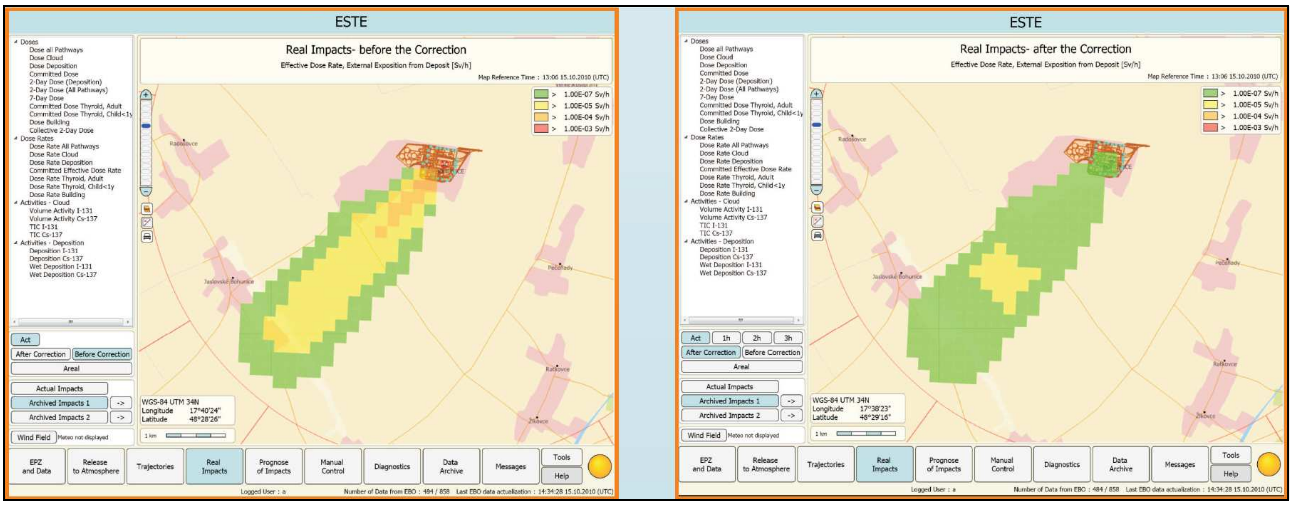

Fig. 3. Example of Results – Calculated map of Real Impacts (before and after correction)

6 CONCLUSIONS

Comprehensive atmospheric dispersion model and improved data assimilation process which is performed "on the way" at various stages of modelling is implemented in the expert system ESTE, which is used by various emergency response centers in case of nuclear accident or incident. In the process of modelling, the crucial role of input geodata, like numerical weather prediction data, land cover and land use data, data with really measured dose rates across the Europe, is presented.

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doplnenie názvu a abstraktu v slovenčine (nebolo zaslané pri prihlasovaní príspevku):

názov SK:

Modelovanie šírenia rádioaktívneho mraku na stredné vzdialenosti v Európskom meradle a modelovanie rádiologických dopadov (ESTE).

abstrakt SK:

Priestorové modelovanie šírenia únikov rádioaktívnych plynov a aerosólov do atmosféry v prípade jadrovej havárie alebo inej udalosti je využívané v expertnom systéme ESTE na stanovenie rádiologických dopadov na životné prostredie. Atmosférická disperzia rádioaktívnych látok z miesta úniku je modelovaná na krátke a stredné (meso-scale) vzdialenosti, so zameraním na území Európy. V systéme ESTE sú využívané pokročilé modely atmosférickej disperzie rádioaktívnych polutantov. Na vstupe do priestorového modelu sa využívajú rôzne geodáta, ako dáta numerickej predpovede počasia (poľa vetra) pre značnú časť Európy, dáta reálneho monitorovania dávkových príkonov z celoeurópskeho monitorovacieho systému EURDEP, atď. Popri výpočtoch radiačných parametrov (dávky, dávkové príkony, aktivity deponované na teréne, úväzky dávok spôsobené inhaláciou rádionuklidov) je konečným cieľom tohto špecifického priestorového modelovania identifikovať potrebu implementácie ochranných opatrení na obyvateľstvo na zasiahnutom území v rozsiahlom (európskom) meradle. Ochranné opatrenia môžu byť aplikované ako urgentné (evakuácia, ukrytie, jódová profylaxia), preventívne a opatrenia, ktoré sa týkajú poľnohospodárstva a potravinového reťazca. Do procesu priestorového modelovania je v systéme ESTE začlenený zdokonalený proces asimilácie modelom vypočítaných dát k dátam reálne meraným. Cieľom tohto procesu asimilácie, ktorý je vykonávaný "počas behu výpočtov" v rôznych etapách modelovania, je prispôsobiť modelové predpoklady čo najviac reálne meraným predpokladom alebo parametrom, nahradiť hypotetické predpoklady modelu tými reálne stanovenými parametrami a aplikovať ich v ďalšom kroku modelovania.

kľúčové slová: **modelovanie atmosférickej disperzie rádioaktívnych polutantov, jadrová havária, radiačné dopady, ochranné opatrenia, asimilácia dát.**