PARAMETER STUDY WITH THE ATMOSPHERIC DISPERSION MODEL ADPIC

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Abstract: The quality of a dispersion calculation and dose prognosis has been examined by variation of three parameters central to modelling: time resolution of the input meteorological wind fields, horizontal spatial grid resolution, and number of particles emitted during the simulation. As dispersion engine, the ADPIC (atmospheric diffusion particle-in-cell, version 5.0) code has been used, including its dose module, in the form currently implemented into the prognosis system of ENSI. For one Swiss nuclear power plant site, a number of different source term scenarios have been defined and these have been subjected to variation in the aforementioned parameters. The plots for external cloud dose have been examined visually to determine the lower bounds of the three parameters still permitting a dose prognosis of acceptable quality. We find that the horizontal spatial resolution and the time resolution of the input meteorological wind fields determine the outcome critically. The number of particles emitted can be varied within a surprisingly large interval while still permitting qualitatively similar dose prognoses.

Key words: *Dispersion calculation, parameter study, ADPIC.*

INTRODUCTION

Every numerical model contains a number of parameters whose values have to be chosen from within an interval by the modeller. Some of these values have a direct influence on the running time, thus a sensible choice can enhance performance without reducing numerical precision discernibly. Our aim was to test the influence of three such parameters (time resolution of the input meteorological wind fields, horizontal spatial grid resolution, and number of particles emitted during the simulation) on the resulting dose prognosis.

SETUP AND METHOD

At ENSI, atmospheric dispersion modelling is done using the ADPIC code (atmospheric diffusion particle-in-cell, version 5.0), originally developed by Lawrence Livermore National Laboratory. Wind fields are generated from COSMO2 model output data by the MEDIC and MATHEW codes, ensuring mass consistency and a vanishing divergence.

The ADPIC code’s many options have for the greater part been fixed to specific values permitting an optimal modelling for Swiss purposes. Among others, release locations have been fixed to the four Swiss nuclear power plants positions as well as the research institution PSI. As a result, dispersion calculations can currently only be performed for northern Switzerland. Input data for the wind fields have been fixed, too, to use either the numerical weather prediction prognosis of MeteoSwiss’s COSMO2 model (Calpini *et al.* 2011) or – where available – measurement values.

For this study, eight scenarios (source terms) were defined using the values given in Table 1. These scenarios have no relation whatsoever to emergency preparedness and scenarios of reference defined therein.

Table 1: Source term definition for the different scenarios.

Scenario	A	B	C	D	E	F	G	H
Release duration [h]	1	1	4	4	6	6	5	5
Simulation duration [h]	2	2	6	6	8	8	7	7
Start time for meteorology	11 Jan. 2011, 17:30	11 Jan. 2011, 17:30	9. Jan. 2011, 22:00	9. Jan. 2011, 22:00	9. Jan. 2011, 00:00	9. Jan. 2011, 00:00	8 Feb. 2011, 16:30	8 Feb. 2011, 16:30
Activity release time dependence (first half and second half of release duration time)	2/3 1/3	1/5 4/5	2/3 1/3	1/5 4/5	2/3 1/3	1/5 4/5	1/4 3/4	1/5 4/5
Release height [m] (first half and second half of release duration time, if different)	70	20 50	70	20 50	70	20 50	70	20 50
Thermal release energy [MW]	0	0.01	0	0.01	0	0.01	0	0.01

All scenarios used 3.0E18 Bq of noble gases, 1.0E16 Bq of iodine (purely elemental), and 1.0E15 Bq of aerosols. The composition of the nuclide vector and the relative abundances were taken from the generic, ENSI standard activity vector. Among the results, dose prognosis for external cloud dose by noble gases, inhalation cloud dose by iodine, and external ground dose by aerosols were chosen for comparison.

The three parameters varied for this study were

- time resolution of the input meteorological wind fields
- horizontal spatial grid resolution
- number of particles emitted during the simulation

Time resolution of the input meteorological wind fields was chosen from among the three values 10 min, 30 min, and 60 min. The numerical weather prediction data resulting from COSMO2 prognosis done by MeteoSwiss is provided to ENSI with a time resolution of 10 min. From this data, the pre-processor scripts generate ADPIC's default wind fields with a time resolution of 10 min as well as additional wind fields spaced temporally by 30 min and 60 min.

Horizontal spatial grid resolution can be chosen as either 250 m, 500 m, or 1'000 m. This defines the grid spacing in horizontal direction on which the dispersion calculation will be performed. Additionally, ADPIC uses fourfold nesting when calculating the concentrations and resulting doses, and thus the innermost cell size will be 15.6 m, 31.3 m, or 62.5 m. However, a sophisticated optimisation procedure included within the pre-processor reduces horizontal and vertical grid resolution as well as the time step for plotting if necessary, based on the timespan to be simulated.

The ***number of particles emitted during the simulation*** per nuclide group (noble gases, iodine, and aerosols) influences the statistics required for calculating the airborne concentration and ground contamination per cell as well as the resulting dose prognosis crucially. Values between 1'024'000/h and 250/h were chosen, in accordance with the horizontal spatial resolution to ensure the same relative number of particles per grid cell.

Table 2: Number of particles emitted per nuclide group coupled to horizontal spatial resolution.

	250 m	**500 m**	**1'000 m**
High statistics (reference set)	1'024'000/h	1'024'000/h	1'024'000/h
Standard, upper limit	256'000/h	64'000/h	16'000/h
Standard, lower limit	64'000/h	16'000/h	4'000/h
Reduced statistics	16'000/h	4'000/h	1'000/h
Poor statistics	4'000/h	1'000/h	250/h

For every combination of scenario (8), horizontal spatial grid resolution (3), time resolution (3), and number of particles (5), one ADPIC simulation has been run (total 360 runs). Per scenario, the one run with both highest number of particles and best time and spatial resolution has been taken as reference case ('reference run') against which the other runs ('variation runs') have been compared.

The results were analysed in two different ways: Firstly, we compared the dose prognosis map overlays resulting from the runs visually for significant differences in shape and location. Secondly, we analysed the difference between the maximum dose value of the reference run and the maxima of the variation runs. Simply comparing the numerical values alone, however, could pretend only little deviation from the reference run while effectively masking a contorted or laterally shifted picture. We therefore additionally evaluated the lateral and longitudinal deviation of the maximum's position (relative to the reference case) for one specific scenario and dose type.

FIRST RESULTS

Visual comparison of dose prognosis map overlays quickly shows the strong effect of horizontal spatial grid resolution, especially in a region with complex orography (Fig. 1).

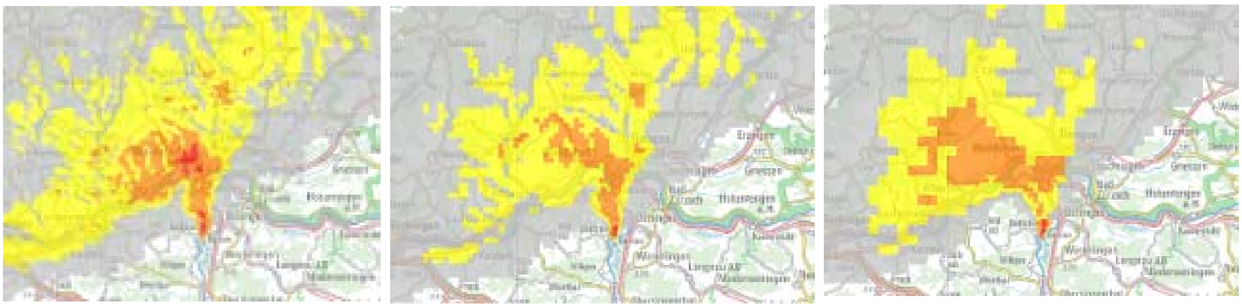
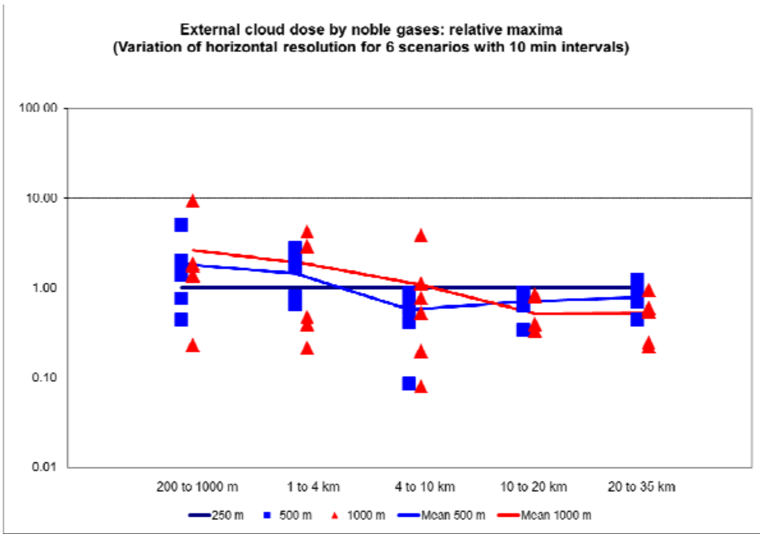
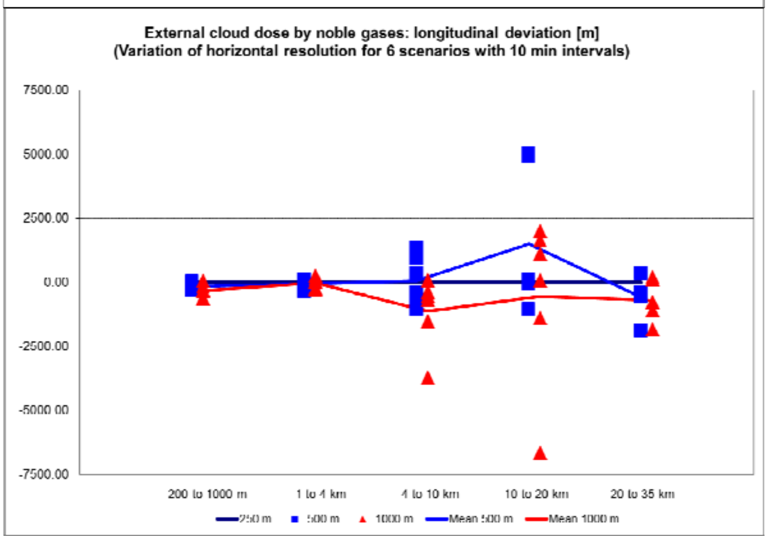


Figure 1: External cloud dose prognosis map overlays for three different horizontal spatial grid resolutions. From left to right: 250 m, 500 m, and 1'000 m; time resolution 10 min and high statistics number of particles for scenario F. Maps courtesy of SwissTopo.





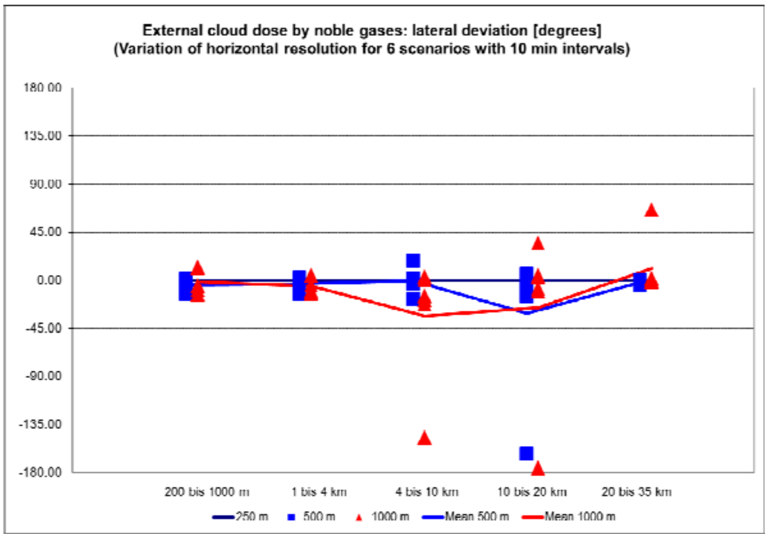


Figure 2: Evaluation of the dose prognosis maximal values: relative numerical values, longitudinal and lateral deviations. Variation of the horizontal spatial grid resolution with 500 m in blue and 1’000 m in red. Vertical axis as described in title, horizontal axis downwind distance intervals. Scenarios A through F.

Evaluation of numerical values and positions of the maxima shows a clear tendency for marked lateral and longitudinal deviation for larger horizontal grid spacing (Fig. 2). Interestingly enough, the deviation is largest in the range of about 10 to 20 km from the source, with better agreement at shorter and larger distances.

Further analysis needs to be done to evaluate the dependence on time resolution of the meteorological input data as well as the number of particles emitted.

REFERENCES

B. Calpini, D. Ruffieux, J.-M. Bettems, C. Hug, P. Huguenin, H.-P. Isaak, P. Kaufmann, O. Maier, and P. Steiner 2011: Ground-based remote sensing profiling and numerical weather prediction model to manage nuclear power plants meteorological surveillance in Switzerland. *Atmos. Meas. Tech.*, **4**, p. 1617-25, doi: 10.5194/amt-4-1617-2011