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THE APPLICATION OF METEOROLOGICAL ENSEMBLES IN THE SINAC DECISION SUPPORT SYSTEM

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Abstract: The SINAC (Simulator Software for Interactive Consequences of Nuclear Accidents) program system has been developed in the Hungarian Academy of Sciences Centre for Energy Research and has been used as a decision support system in the Hungarian Atomic Energy Authority (HAEA). A new project was started to develop the SINAC system for the usage of ensemble meteorological data to investigate the uncertainties of the consequence analysis of nuclear facilities. The application of meteorological ensembles make it possible to characterize the impact of the meteorological uncertainties on the atmospheric dispersion and dose calculation. The advantage of using meteorological ensemble datasets in atmospheric dispersion modelling for the calculation of nuclear accident consequences is that the impact of meteorological parameters is directly reflected in the result. The new development of SINAC has been used to characterize the uncertainties of the atmospheric dispersion and dose calculation for the Hungarian NPP at Paks, with the usage of meteorological ensembles provided by the Hungarian Meteorological Service (OMSZ).

Additionally, the Centre for Energy Research is participating in the first work package (WP1) of the CONFIDENCE project (COping with uNcertainties For Improved modelling and DEcision making in Nuclear emergenCiEs) investigating the impact of input uncertainties on atmospheric dispersion and dose calculation models. In this project along with the uncertainties of the meteorological data, the model and source term uncertainties are examined as well.

In this work, the application of the newly developed module to use ensemble meteorological data in SINAC will be presented. The calculations results for the Hungarian Paks NPP with the meteorological data provided for the site will be evaluated.

Key words: *atmospheric dispersion, meteorological, ensemble, uncertainties, nuclear release*

INTRODUCTION

The SINAC (Simulator Software for Interactive Modelling of Environmental Consequences of Nuclear Accidents) program system (Szántó et al. 2012) has been developed in the Centre for Energy Research of the Hungarian Academy of Sciences (MTA EK) since the 1990's. The software was created as a decision support system for the Centre for Emergency Response, Training and Analysis (CERTA) of the Hungarian Atomic Energy Authority (HAEA) to analyze the environmental consequences in case of an accident of a nuclear power plant. Atmospheric dispersion, plume depletion by dry deposition and wash out, doses from cloudshine, groundshine, inhalation and ingestion; possible occurrence of early and late health effects are assessed by the software. Countermeasure like sheltering, evacuation and iodine prophylaxis can also be considered when calculating the radiological consequences. The development of a new version of SINAC was started recently with the goal of using meteorological ensembles to quantify and visualize the meteorological uncertainties and their effect on the atmospheric dispersion and radiological consequence assessment.

In the last couple of years there has been increasing tendency in the usage of meteorological ensembles to characterize the uncertainty of atmospheric dispersion models. The advantage of utilizing ensemble meteorology for atmospheric dispersion calculation of nuclear releases is that the effect of the uncertainty in the meteorological data appears directly in the results. It is important to mention that in case of decision support, there are limitation of using ensemble data as it increases the run time of the simulation and requires more computational capacity which could be disadvantageous in an emergency situation.

There is an ongoing research in the 1st work package of the CONFIDENCE project (COping with uNcertainties For Improved modelling and DEcision making in Nuclear emergenCiEs) with the participation of the Centre for Energy Research investigating the impact of input uncertainties on atmospheric dispersion and dose calculation models. The aims of the work is to identify the uncertainties and analyse their propagation through atmospheric dispersion models via the simulations of nuclear release scenarios. (De Vries et al. 2019) The participants of the work package also investigate the usage of ensemble input parameters in an operational context, and produce recommendations for using this approach for decision support in case of nuclear emergency. In the framework of this task, a new module was integrated into SINAC to handle meteorological data from limited area ensemble system provided by the Hungarian Meteorological Service (OMSZ). In this paper, the results of two simulations with such ensemble meteorological data for different weather situations and the fictional release of Xe-133 and Cs-137 are presented and possible visualizations of the environmental activity concentrations are shown.

METHODS

Atmospheric dispersion model

The atmospheric dispersion in SINAC is simulated with Gaussian puff model. In this model, the total amount of emitted material is distributed in a number of packages (puffs) and released based on a chosen time resolution. Gaussian distribution is assumed for the activity concentration of the puffs. The input requirements of atmospheric dispersion calculation models are the source term and meteorological data. Determination of these data is very difficult and often not accurate. Usually, spatial distribution of precipitation data by the numerical weather prediction models are the most uncertain.

In SINAC, the meteorological parameter values can be set manually or can be obtained from the meteorological data provided by the AROME numerical weather prediction model used by the Hungarian Meteorological Service (Szintai et al. 2015). Furthermore, the newly developed module enables SINAC to use several meteorological datasets pertaining to the same time period that are technically identical to AROME files, thus make it possible to do calculations with ensemble meteorological data.

Meteorological ensembles

ALADIN-EPS is running as an operational ensemble system of the Hungarian Meteorological Service (OMSZ) since 2008 (Horányi et al., 2011) with 11 members. This ensemble system is based on hydrostatic model version which has 8 km horizontal resolution. For that purpose of stepping towards the direction of a convection-permitting ensemble system, the test of the non-hydrostatic AROME model with 2.5 km horizontal resolution was started in 2012. Now OMSZ has the necessary experience to make it operational (Szintai et al. 2015) with the planned introduction of AROME-EPS in 2019. Concerning boundary conditions, ALADIN-EPS is coupled to the ECMWF-ENS and in the future AROME-EPS is also planned to be configured the same way (Szűcs et. al., 2016).

At this stage of the research, the aim was to mimic future operation of AROME-EPS and produce ensemble meteorological data for SINAC technically equivalent to currently generated deterministic AROME files. Accordingly, the first 9 members of the ALADIN-EPS were interpolated to AROME resolution which gave technically identical files to the expected ones from AROME-EPS (see Table 1. for further details). At the same time it has to be noted that the data is based on coarser resolution model runs. The domain of the produced meteorological data covers the Carpathian Basin with 2.5 km resolution shown in Figure 1.

Table 1. Spatial and temporal resolution of meteorological data of ALADIN-EPS.

Horizontal	Vertical	Temporal
Coordinates: model in Lambert, outputs in Latitude-Longitude	Coordinates: model in sigma-pressure hybrid, but output in pressure and height levels	Forecast Length: 36 h
Resolution: ~2.5 km, 1 h	Resolution: 60 model levels, 12 planetary boundary layer height-level and 32 pressure-level in output files	Resolution (time step): 1 h

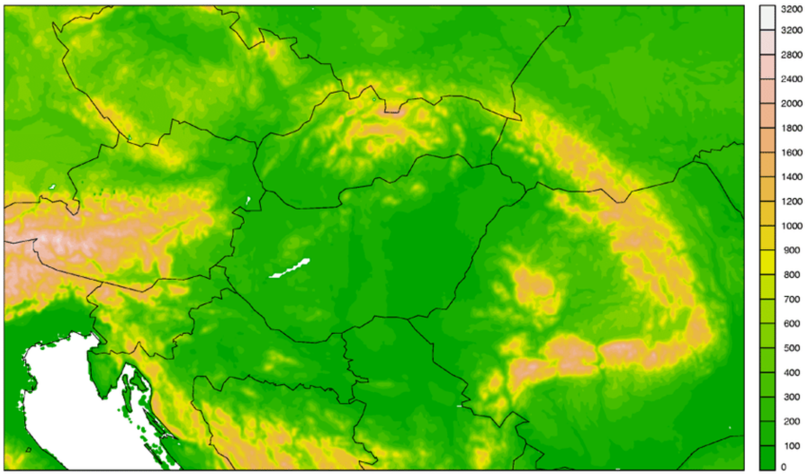

Figure 1. Topography of the AROME model domain covering the Carpathian Basin.

CALCULATIONS

The application of the newly developed ensemble module of the SINAC was tested with two meteorological datasets. In the winter case, the meteorological data starts at the 27th of January 2017 at 18:00 and in the summer case at the 14th of August 2018 at 18:00. In both cases, the characteristics of the release were the same except for the release time, which corresponds with the start of each meteorological dataset. In the examined simulations, the release duration was considered to be 12 h long and the released activity was $1 \cdot 10^{16}$ Bq of Cs-137 and $1 \cdot 10^{16}$ Bq of Xe-133 distributed equally in 360 puffs (puff release time resolution: 2 min). The release point was assumed to be the stack of the nuclear power plant at Paks in Hungary, the effective release height was 120 m.

The atmospheric dispersion calculation was conducted on a 600x600 km Cartesian-grid with the origin at the release point at Paks NPP. The results of the simulation were calculated on the same grid for hourly time steps for 24 hours beginning at the start of the release. The quantities that were produced in the simulation are the time integrated activity concentration in the air [$Bq \cdot s \cdot m^{-3}$] and the deposited activity concentration on the ground [$Bq \cdot m^{-2}$] with a 3 km spatial resolution.

RESULTS

The simulation results for the 9 meteorological ensemble members are shown in two different plot types. The contour plots can represent different values, the outer line can show the values above a chosen reference level or a given % of the maximum value. In case of decision support for emergency situations, this limit can be set to reference levels of emergency response actions (for example 37 $kBq \cdot m^{-2}$ of Cs-137 deposition). In the second plot type, the overlap for each ensemble member is shown displaying the number of results that have a higher value than a given limit at each grid point. Based on this plot, another visualization could be a given percentile of the result, for example 66 % percentile of the results would be where 6 or more members of the 9 overlap.

Winter release

Results for the deterministic run (using the first meteorological ensemble member) of the winter case are shown in Figure 2. The contours show the time integrated activity concentration of Xe-133 12 hours after the beginning of the release on the left side, and the contour lines for Cs-137 deposition at the end of the simulation 24 hours after the start of the release on the right side. In Figure 3, the same results are shown for all the member indicated with different colours. Most of the ensemble member results go in a slightly different direction than the results of the first (reference) member. The overall shape and direction of the plume however is similar for the different members, thus the variability of the meteorological ensemble members was moderate. The overlap of the same quantities for the 9 ensemble members are shown in Figure 4. On the left side of Figure 4, there is no area where the results of all members overlap, but on the right side there is thin band where in every case the deposition is higher than the chosen limit. In case of higher limits for the contour plot, the results of the different members can be more separate and have less overlap, thus have less confidence.

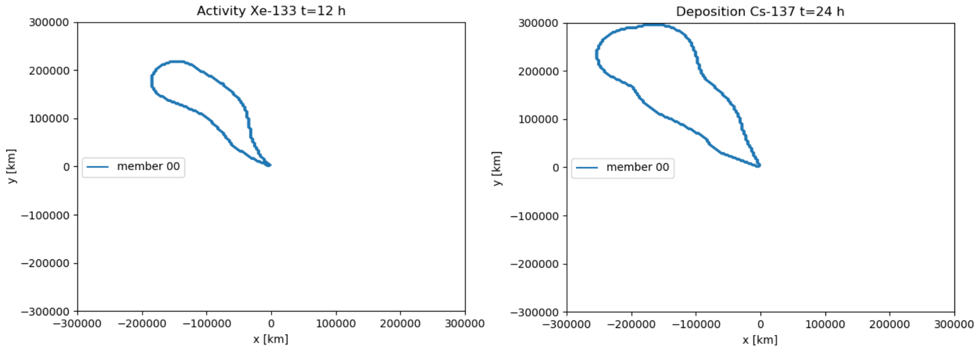

Figure 2. The Xe-133 time integrated activity concentration [Bq·s·m^{-3}] and Cs-137 deposition [Bq·m^{-2}] contours for the first meteorological ensemble member in the winter release case for time steps: 12 h and 24 h.

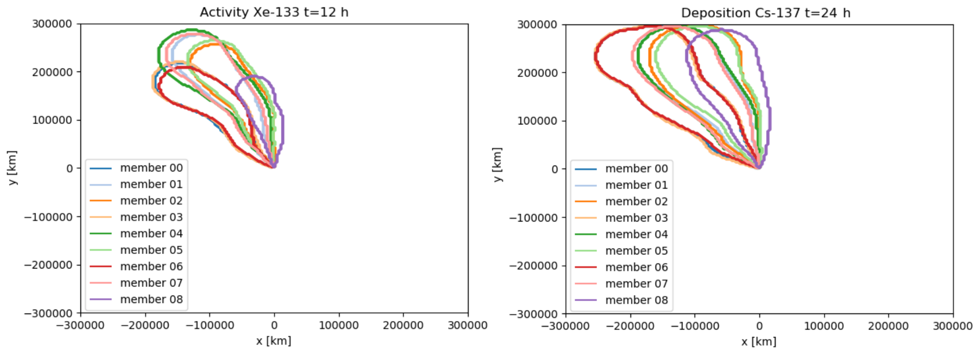

Figure 3. The Xe-133 time integrated activity concentration [Bq·s·m^{-3}] and Cs-137 deposition [Bq·m^{-2}] contours of the 9 meteorological ensemble in the winter release case for time steps: 12 h and 24 h.

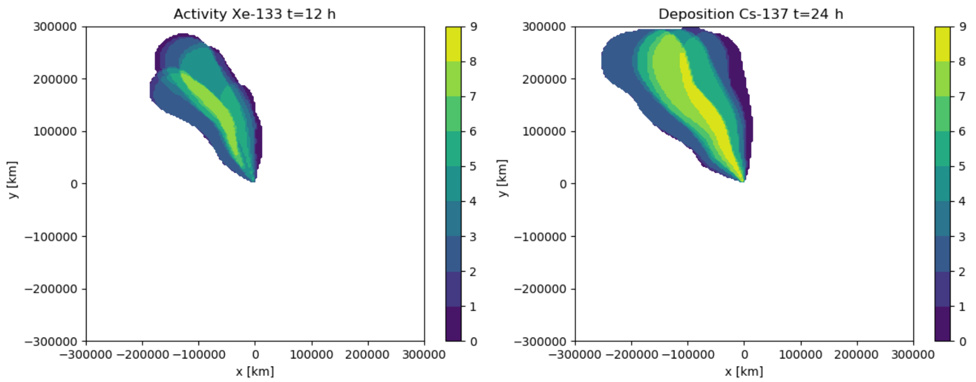

Figure 4. The Xe-133 time integrated activity concentration [Bq·s·m^{-3}] and Cs-137 deposition [Bq·m^{-2}] plots added up for the 9 meteorological ensembles in the winter release for time steps: 12 h and 24 h.

Summer release

In the summer case, the weather scenario is more dynamic, the variability of the meteorological parameters are higher than in the winter case. In Figure 5, the results of the deterministic run using the first meteorological member appear to have slower wind speed and less variant wind direction than some of the other members (shown in Figure 6). For a couple of meteorological members, the wind direction change and the higher wind speed results in a more spread plume and a larger impacted area. Figure 7 show how probable the presence of activity is in given areas, with higher probability where more members overlap.

The usage of meteorological ensembles can give a more detailed analysis of a release situation, showing not just one deterministic result, but also the uncertainties of the meteorological data.

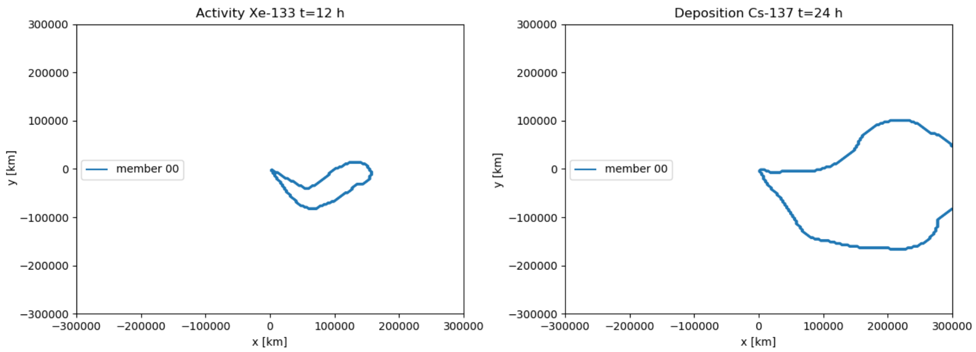

Figure 5. The Xe-133 time integrated activity concentration [Bq·s·m^{-3}] and Cs-137 deposition [Bq·m^{-2}] contours for the first meteorological ensemble member in the summer release case for time steps: 12 h and 24 h.

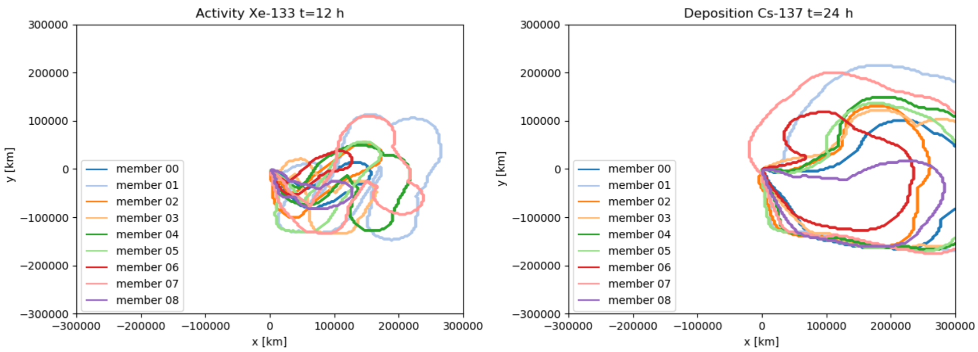

Figure 6. The Xe-133 time integrated activity concentration [Bq·s·m^{-3}] and Cs-137 deposition [Bq·m^{-2}] contours of the 9 meteorological ensemble in the summer release case for time steps: 12 h and 24 h.

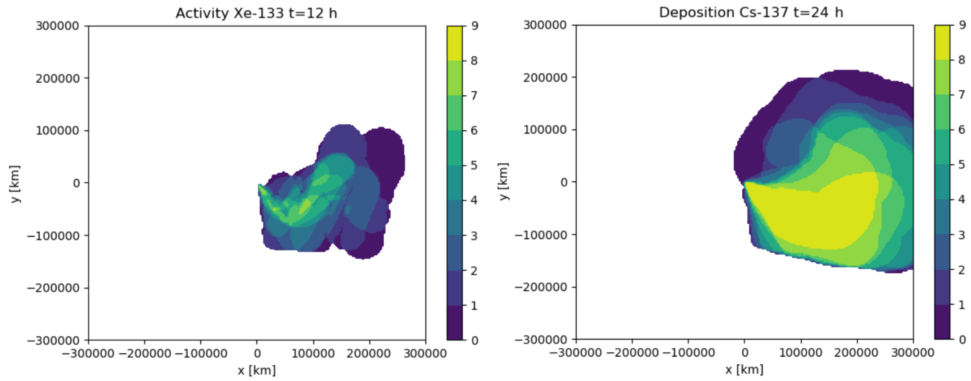

Figure 7. The Xe-133 time integrated activity concentration [Bq·s·m^{-3}] and Cs-137 deposition [Bq·m^{-2}] plots added up for the 9 meteorological ensembles in the summer release for time steps: 12 h and 24 h.

CONCLUSIONS

Simulations were made for two meteorological scenarios to show the application of the newly developed module of SINAC for using meteorological ensemble data. In the two cases, ensemble data provided by OMSZ was used, one representing a calm foggy situation in the winter and a second illustrating a convective summer situation. In the winter case, the meteorological variability of the different ensemble members is smaller, thus the impacted area summed for all the results is smaller. However, in the summer case more significant change in wind speed and wind direction results in bigger spread of the impacted area. We have shown possible visualizations of the results for several ensemble calculations to present the effect of meteorological uncertainty in the atmospheric dispersion calculation. Thus, the usage of meteorological ensembles is a good tool for showing and reducing the uncertainties of decision support in case of emergency situation.

In future work investigation of other types of uncertainties (source term, release conditions, model parameters) will be conducted including a more detailed study of visualization possibilities. Work will be continued with the goal of harmonizing the use of ensemble meteorological data and its introduction to operation in Hungary and internationally.

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REFERENCES

De Vries, H., Gertie G. Geertsema, I. Korsakissok, R. Périllat, R. Scheele, J. Tomas, 2019: Published sets of probability maps of threshold exceedance for scenarios. CONFIDENCE, EJP-CONCERT

Horányi, A., Mile, M., Szűcs, M., 2011: Latest developments around the ALADIN operational short-range ensemble prediction system in Hungary, *Tellus*, **63**, 642-651.

Szántó, P, S. Deme, E. Láng, I. Németh, T. Pázmándi, 2012: SINAC – Simulator Software for Interactive Modelling of Environmental Consequences of Nuclear Accidents (2nd Generation). *13th IRPA Congress*, Glasgow, Scotland

Szintai B., M. Szűcs, R. Randriamampianina, L. Kullmann, 2015: Application of the AROME non-hydrostatic model at the Hungarian Meteorological Service: physical parametrizations and ensemble forecasting. *Időjárás*, **119**, 241-265.

Szűcs, M., Sepsi, P. and Simon, A., 2016: Hungary's use of ECMWF ensemble boundary conditions. *ECMWF Newsletter*, **148**, 24–31.