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SPATIALLY AND TEMPORALLY HIGH-RESOLUTION QUANTITATIVE PRECIPITATION DATA AND COMBINED UTILIZATION OF WIND FIELD MODELS WITHIN THE ATMOSPHERIC RADIONUCLIDE TRANSPORT MODEL ARTM

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Abstract: Atmospheric dispersion modelling for regulatory purposes aims to simulate real atmospheric dispersion as close as possible. New available datasets, like in the following case the spatially and temporally high-resolution quantitative precipitation data from the Deutsche Wetterdienst (DWD), have been effectively included into the atmospheric dispersion modelling code ARTM. Furthermore, the combined utilization of both, the microscale wind field model MISKAM and the mesoscale diagnostic wind field model TALdia within one single dispersion simulation has been implemented and tested. By that, advantages of microscale wind field models, which can provide good description in an urban environment with the flow and turbulence field highly influenced by buildings, and mesoscale wind field models in the surrounding area, where the flow is dominated by the orography, can be combined.

Key words: *ARTM, MISKAM, TALdia, atmospheric dispersion, coupling of wind field models, precipitation data, DWD*

INTRODUCTION

The Atmospheric Radionuclide Transport Model (ARTM) is a mesoscale atmospheric dispersion model based on the Lagrangian approach and is used for regulatory purposes in Germany. ARTM simulates the atmospheric dispersion and deposition of discharged radioactive substances originating from nuclear facilities under routine operation, including size-dependent airborne concentration, wet and dry deposition as well as gamma-cloud shine of radioactive exhaust plumes within the simulated area.

SPATIALLY AND TEMPORALLY HIGH-RESOLUTION QUANTITATIVE PRECIPITATION DATA

ARTM is continuously adapted to the state-of-the-art of science and technology. The newest version of ARTM (3.1.0) can use spatially and temporally high-resolution quantitative precipitation data within its dispersion calculations. These data are provided by the routine procedure RADOLAN (Radar-Online-Calibration) of the Deutscher Wetterdienst (DWD, 2022). The data cover the whole territory of Germany and have a time resolution of one hour with a spatial resolution of 1 km^2.

To be able to use the RADOLAN data in ARTM, a program was developed, which automatically downloads the precipitation data from the RADOLAN data, tailors the corresponding precipitation data to the desired calculation area of ARTM, transforms the coordinate systems and interpolates the precipitation data onto the ARTM calculation grid.

Particularly in the case of short-term discharges of radioactive substances, spatially and temporally high-resolution quantitative precipitation data can have a relevant influence on the distribution of wet deposition in the simulation area, depending on how far the radioactive cloud has already traveled before the onset of precipitation. Thus, in contrast to previous versions of ARTM, in which only one global precipitation rate per hour for the whole simulation was applied, a more realistic calculation of the exposure of individuals in the population is possible by taking high-resolution precipitation information into account. An example for wet deposition, based on both approaches, is shown in Figure 1.

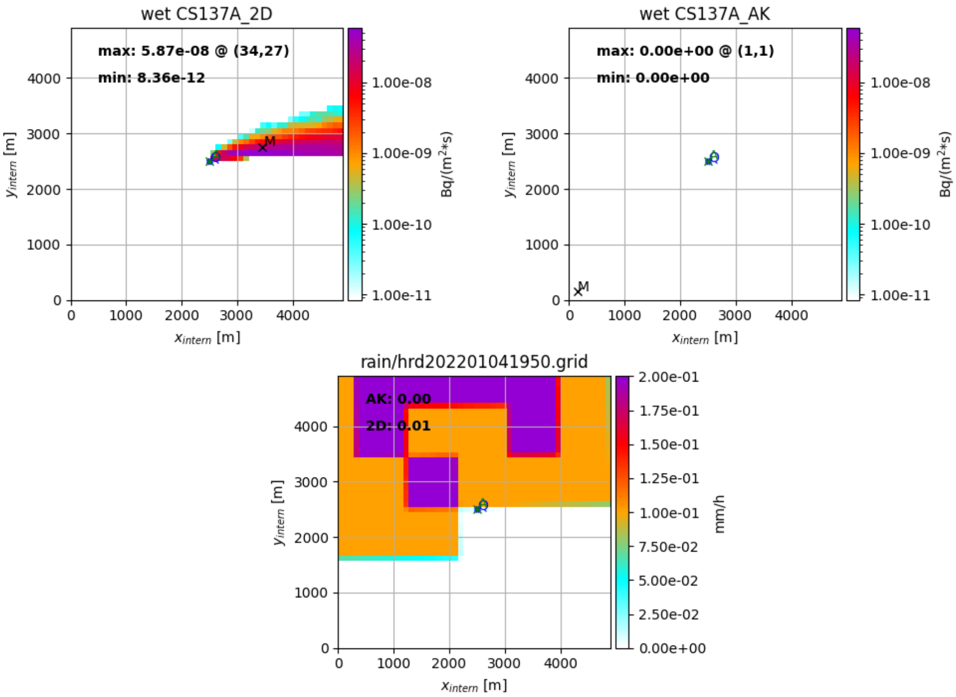

Figure 1. Wet deposition for Cs-137 for one time step without (right top, no rain assumed at the point of release marked with a Q and the weather station at the same position marked with an A) and with high-resolution precipitation information (left top). The bottom figure shows the high-resolution precipitation information which have been used within the calculation of the wet deposition (left top).

Based on the distribution of the precipitation data (Figure 1, bottom), rain falls in the north of the weather station, but not in the south. Thus, the calculation with only one global precipitation rate per hour for the whole simulation area (Figure 1, right top) assumes no precipitation and therefore no wet deposition. However, when calculating with high-resolution precipitation data (Figure 1, top left), wet deposition occurs.

COMBINED UTILIZATION OF WIND FIELD MODELS

A second improvement in ARTM 3.1.0 is the possibility of utilizing two independent wind field models within one dispersion calculation. Whereas the microscale prognostic wind field model MISKAM (Eichhorn, 2013) can be used in the inner region, where the turbulence properties are mostly influenced by buildings, the diagnostic mesoscale wind field model TALdia can be used in the outer region, where turbulence properties are dominated by the orography of the simulated area.

The analysis of both wind field models has shown that differences in wind speeds at a given height cannot be equalized without significantly changing the wind and turbulence profiles. The neutral stratifications in MISKAM showed the smallest deviation of both initial fields when considering all roughness lengths and dispersion classes. For this reason, in the case of a combined calculation of both wind field models, it was decided to use the MISKAM wind fields with a neutral stratification, regardless of the TALdia dispersion classes.

The inflow conditions with which the MISKAM inflow profile is defined had to be determined for the combined calculation of TALdia and MISKAM within one ARTM simulation. It is assumed that the anemometer position for which the meteorological time series is available is not in the inner field of

MISKAM with buildings to be resolved but in the outer field with structured terrain. Due to the dependence of the wind profiles on the terrain, the anemometer position must be transferred to the inner field. For this purpose, a program was developed and tested.

Two different implementation approaches were examined and compared to determine the average wind speed component, which is used for the transport of radionuclides during the transition to the external wind field of TALdia. Due to the sometimes-significant deviations in the wind fields of MISKAM and TALdia, especially at higher altitudes, an approach was chosen as standard for the new version of ARTM in which the wind speed components during the transition were simply averaged over both wind fields. Although this approach leads to a significant increase or reduction of the concentration at the interface of both wind fields in the test cases considered, the wind and turbulence profiles from TALdia with the associated VDI guideline 3783, Sheet 8 (VDI, 2017) are used in the far field of dispersion. An example, for the ground-layer activity concentration of C-14 for the sole calculation with MISKAM, the combined calculation with MISKAM and TALdia and their relative deviation is shown in Figure 2.

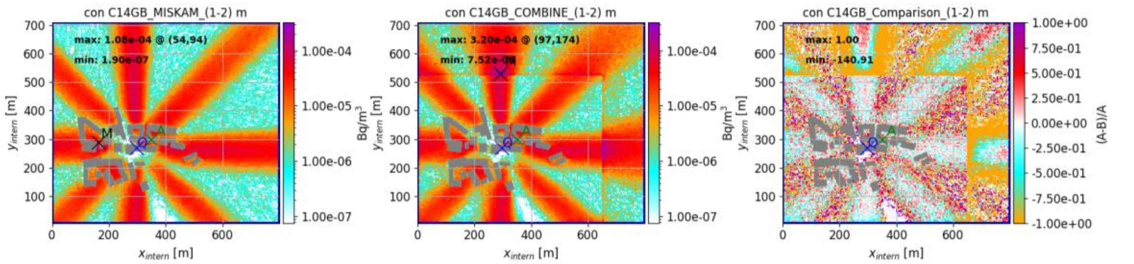

Figure 2. Ground-layer activity concentration of C-14 for the sole calculation with MISKAM (left), the combined calculation with MISKAM and TALdia (middle) and their relative deviation (right). Wind speed components during the transition were simply averaged over both wind fields in this approach. The cross Q marks the position of the source, A the anemometer position and M the position of the maximum deposition.

The second approach, in which the wind speed components of TALdia are adjusted to those of MISKAM at the interface of both wind fields, is implemented as well in ARTM. Compared to the first approach, the increase or reduction of the concentration at the interface is significantly reduced as can be seen in Figure 3. However, it should be noted that dispersion in the far field no longer corresponds to the German VDI guidelines.

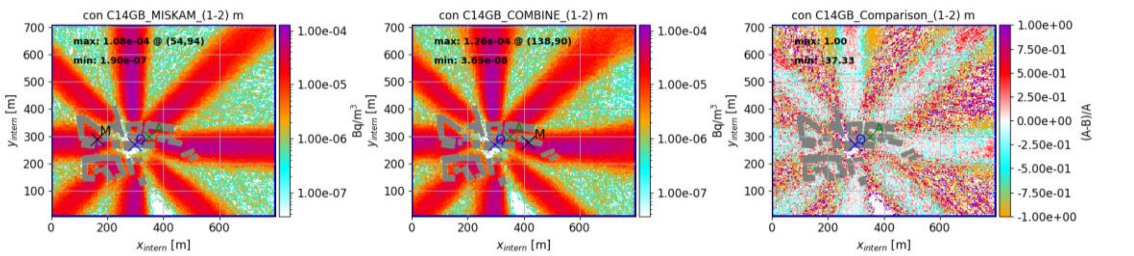

Figure 3. Ground-layer activity concentration of C-14 for the sole calculation with MISKAM (left), the combined calculation with MISKAM and TALdia (middle) and their relative deviation (right). Wind speed components of TALdia are adjusted to those of MISKAM at the interface in this approach. The cross Q marks the position of the source, A the anemometer position and M the position of the maximum deposition.

SUMMARY

Spatially and temporally high-resolution quantitative precipitation data from the DWD, have been effectively included into the newest version 3.1.0 of the atmospheric dispersion modelling code ARTM. For short-term discharges of radioactive substances, the use of spatially resolved precipitation data can lead to significant differences in soil contamination, since for wet deposition at a certain location, the passage of the radionuclide cloud must coincide with a rain event at this location and not with a rain event at a measuring station that may be further away. But even for long-term discharges of radioactive substances, taking spatially resolved precipitation into account can lead to significant changes. Particularly in rain-poor regions with only a few (highly) intense precipitation events, the use of 2-dimensional precipitation data lead to a more realistic simulation of wet deposition. Since these precipitation events often do not have a large spatial extent, station measurements are only partially representative for a larger simulation area. If only a few such events occur within an annual period, then these few heavy rain events can dominate the wet deposition. The further development of ARTM is therefore an important step towards a more realistic calculation of exposure to gamma soil radiation and ingestion.

Another improvement of ARTM is the possibility of a combined utilization of the microscale wind field model MISKAM and the mesoscale diagnostic wind field model TALdia within one single dispersion simulation. MISKAM has its strengths particularly in urban areas, where strong turbulence from buildings influences the spread of discharged radioactive substances. MISKAM always assumes flat terrain. To respect the effect of orography in mesoscale ranges, the diagnostic wind field model TALdia can be used for areas where turbulence from buildings is negligible. The combined calculation therefore enables a more realistic calculation, particularly for releases in urban areas in combination with structured terrain in the outer mesoscale range. Studies have shown that differences in wind speeds at a given height cannot be equalized without significantly changing the wind and turbulence profiles of both models. Due to the sometimes-significant deviations in the wind fields of MISKAM and TALdia, especially at higher altitude levels, a standard approach was chosen for the new version of ARTM, whereby the wind speed components during the transition from MISKAM to TALdia were simply averaged over both wind fields. Although this approach leads to a significant over- or underestimation of the concentration at the transition region in the test cases considered, the wind and turbulence profiles from TALdia are used in the far field of dispersion. In the future, it could be interesting to investigate to what extent other models, in addition to MISKAM, describe the influence of turbulence from buildings in urban areas. Their compatibility with the VDI Guideline 3783, sheet 8, the diagnostic wind field model TALdia and as well ARTM could then be examined.

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