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Abstract (max. 2000 char.):
Input to ERMIN, deposition of radioactive matter inside inhabited areas from releases both within and outside such areas, shall in a decision support system be produced by dispersion codes, followed by data-assimilation. The present work focuses on the differences in near surface concentrations and in depositions obtained with a code designed for dispersion of a release from a nuclear power plant, typically situated at a distance from densely inhabited areas, and a code specifically designed for predicting dispersion from sources inside urban areas. The codes applied are the RIMPUFF code, RIsø Mesoscale PUFF model from Risø National Laboratory, Denmark, and the UDM code, Urban Dispersion Model, from "dstl", Defence Science and Technology Laboratory, Porton Down, United Kingdom.
For an above-town release only small differences are seen between the codes, but for a in-town ground release, e.g. a dirty bomb, the UDM code predicts much larger concentrations in an area close to the release point and, if wind shifts occur, gives a rather different plume all over.

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1 Introduction

In the “ERMIN: Detailed technical design document”, Jones et al. (2005), it is stated that:
“ERMIN is a model for calculating the consequences within inhabited areas of accidental releases of radioactive material, from sources both inside and outside the inhabited area. It includes

- Initial deposition to different surfaces in the inhabited area
- The subsequent behaviour of material following its deposition, including the amount of material remaining on each surface as a function of time after the initial deposition, the concentration in air of material resuspended from the surfaces
- External β and γ exposure from deposited material
- Internal dose from inhalation of resuspended material
- The effects of countermeasures on the activities on each surface and on the doses in the inhabited area.”

ERMIN is going to be an integrated part of the decision support systems RODOS, Ehrhardt and Weiss (2000), and ARGOS, Hoe et al. (2000), and so it is of interest how well and how differently the dispersion codes of these systems produce the input to ERMIN, i.e. the near ground air concentration and the deposition of radioactive material in inhabited areas from sources outside and inside such areas.

RODOS shall use the ATSTEP dispersion program, Päsler-Sauer (1997), and possibly the RIMPUFF program, Mikkelsen et al. (1984), Thykier-Nielsen et al. (1998), while ARGOS shall use the RIMPUFF program and possibly the UDM program (Urban Dispersion Model), Hall et al. (2002), which is going to be included in the ARGOS suite of programs.

While ATSTEP and RIMPUFF are mesoscale dispersion programs to which towns are just areas of high surface roughness and changed deposition rates, UDM is a high resolution puff dispersion program in which each released puff interferes with buildings in a three stage process: first it interferes with single buildings getting trapped behind them and being "re-released" in less containing successive puffs widened to the size of the buildings. Later, when it has grown sufficiently, it interferes with arrays of buildings, and finally it sees the buildings just like ATSTEP and RIMPUFF.

ATSTEP and RIMPUFF may provide sufficient detail for plumes passing well above towns, but in-town releases may need to be handled with a code like UDM, if a high-resolution best estimate of the air concentration and deposition is wanted. The present report demonstrates the differences obtained in such cases between the two kinds of codes, here RIMPUFF and UDM, and might be used to evaluate to which extent this should influences the overall ERMIN project.

2 Codes

2.1 RIMPUFF

The Risø Mesoscale Puff model, RIMPUFF, Mikkelsen et al. (1984), Thykier-Nielsen et al. (1998), models the plume of released material as a number of individual puffs. With specified time intervals it releases a puff that holds the material being released during the next interval. A puff can be visualized as a kind of spherical or ellipsoidal cloud, a body of air and suspended released material, having a certain size. For the sake of calculation ease and physical sense, the suspended material is given a 3D-Gaussian concentration distribution. This is an approximation to the real fluctuating distribution in a plume, and at its tails it is not describing reality too well. For this reason RIMPUFF cuts it off at a user specified distance from the puff centre, the point of maximum concentration. The recommended cut-off distance is 3.7 standard deviations, where the concentration equals 0.001 times the centre concentration, and with this value RIMPUFF accounts for 97% of the specified release, far within any real release uncertainty.

Each puff is advected with the local wind speed at its centre, it grows in size due to the local turbulence - i.e. the concentration distribution flattens - its centre is raised as the puff strikes the ground in order to model the rise of the plume centre of mass, and its inventory can hold many different nuclides, the amount of which change due to radioactive decay and due to both dry and wet deposition to ground. Meteorological parameters needed by the model are obtained from a meteorological preprocessor, which is again based on either numerical weather prediction fields or meteorological measurements.

RIMPUFF delivers gridded fields of time-integrated ground concentrations, time-integrated gamma dose rates (i.e. gamma doses) from the puffs, time-integrated deposition rates (i.e. deposited amount) split on dry and wet deposition, and instantaneous gamma dose rates from deposited material, all for each specified nuclide. Iodine is further treated as a mix of differently depositing elementary, organic, and aerosol bound iodine. More than just the fields, RIMPUFF can calculate the same parameters for specific points, detector points, specified within the computation area.

2.2 UDM

The Urban Dispersion Model, UDM, Hall et al. (2002), is a puff model developed by "dstl", Defence Science and Technology Laboratory, Porton Down, United Kingdom. Depending on the density of buildings, it applies different dispersion parameterizations. With low building densities each released puff interferes with the single buildings downstream of it, and with higher densities the puffs interfere with compounds of buildings. The puffs get trapped behind the buildings and are slowly released from there as a succession of less containing puffs with dimensions determined by the building dimensions. Puffs whose centres pass over buildings are not trapped.

The present version of UDM runs interactively, and output to files can be specified for ground concentration and other parameters.

2.3 Code differences UDM-RIMPUFF

2.3.1 Number of puffs

UDM releases a high number of puffs, 1 per second, and of elliptical horizontal shape, the major axis parallel to the wind. RIMPUFF releases only one puff per minute holding the stuff to be released the coming minute, and the horizontal shape is circular. The 1 minute is the lowest time between puff releases in the actual implementation, set by the use of integer minutes for this specification.

2.3.2 Puff lift

RIMPUFF applies a feature called shear-rise. When the puffs grow and touches the ground the centre of mass lifts, and the shear-rise feature lets the puff centre heights increase accordingly.

UDM also lifts the puffs but using another scheme. Together with the wind velocity dependence on height probably also being slightly different, the puff lifting models shall induce differences.

2.3.3 Influence of buildings

To RIMPUFF single buildings or clusters of buildings have no direct effect, an indirect effect coming only from the specification of land cover class "urban".

UDM models the effect of single buildings and clusters of buildings by parameterization, not by a high resolution calculation of the flow around and over the buildings. Only buildings taller than the height of the puff center seem to influence a puff. Influencing buildings retain a part of the puffs content behind the building and releases it rather slowly in a number of puffs shaped by the building dimensions.

2.3.4 Deposition models

The present version of UDM, 2.2, contains no built in deposition model, for which reason such a model has been formulated and programmed as a postprocessor to UDM. It accounts for dry deposition only. It has been taken from an earlier version of RIMPUFF, which applied constant deposition velocities to grass for noble gasses, for elementary and organic iodine, and for aerosols. For deposition to other surfaces, land cover dependent factors were applied. The present UDM deposition postprocessor just uses the aerosol deposition, the deposition rate being the air concentration at ground level multiplied by the deposition velocity to grass, 0.001 m/s, and by the land cover factors: 0.1 for urban areas and for water, 2.0 for woods and 1.0 for rural areas. Being calculated by a postprocessor the deposition does not deplete the plume, but this is no real limitation, as dry deposition anyway only removes a very little part of the stuff in the plume. With no removal the total deposition gets proportional to the time-integrated concentration at ground level, the proportionality factors again being the deposition velocity to grass and the land cover factors.

RIMPUFF contains a rather sophisticated deposition model based on resistances to deposition, i.e. atmospheric resistance and surface resistance, and integration over the individual puffs. The simpler model developed for UDM can, however, also be used with RIMPUFF, and for the actual test cases it is the applied model.

3 Test case: Bristol

The dispersion of releases from two points in Bristol, UK, has been calculated with both UDM and RIMPUFF. The two points have the same horizontal position but one is 1 m above ground, and so down between buildings, the other is 30 m above ground and free of the buildings. The release amounts to 10 kg over 2 minutes. The wind is set to 5 m/s 10 m above ground, changing direction from 220° to 180° 10 minutes after start of release.

For RIMPUFF the actual two minute release is specified as a three minute release, i.e. three puffs are released. As the puffs are released at the start of the release time step, the third is released after two minutes. For a short release like this, and for comparison with a model releasing a puff every second, this is found better than using only two puffs.

Figure 1 shows three pictures of the 5×5 km calculation area plus an extract of the first of these, the actual map of Bristol as used by UDM. The second is the Google Earth picture of the area (http://earth.google.com), and the third is the land cover as extracted from the Corine 100 m resolution land cover map for most of Europe, Bossard et al. (2000), here interpolated to the used 50 m resolution and reduced to only 5 land-cover types. It is used for the deposition calculations and by RIMPUFF for surface roughness determination. The extract of the UDM map reveals the buildings near the release point.

3.1 Release 30 m above ground

For the release 30 m above ground, the UDM puffs do not interfere with the buildings, so the difference between the UDM and RIMPUFF calculations can be expected to be the minimal obtainable.

Some of the differences can be seen from figure 2 and 3, showing the 1-minute average air concentration at ground level for 9 to 10 minutes after start of release as calculated by the two codes. The maximum width of the puffs is almost equal, the UDM plume is longer with narrower ends and the RIMPUFF plume centre has traveled a little further due to having reached a larger height. The height difference has also added to the ratio between the maximum concentrations UDM to RIMPUFF, which is 2.3.

Figure 4 and 5 show the time-integrated concentrations at ground level after the plumes have passed out of the calculation area. UDM shows a somewhat wider plume than RIMPUFF and with somewhat larger concentrations. This is again the consequence of the lower UDM plume. The UDM maximum time-integrated concentration is 1.3 times the maximum RIMPUFF value. The "strange" widening at the southeast part of the UDM plume is due to UDM aligning all its elliptical puffs with the direction of the wind. When the wind shifts 40 degrees within a second, all the UDM puffs turn the same 40 degrees within that second.

The calculated deposition, shown in figures 6 and 7, is proportional to the time-integrated concentration and to the land cover dependent deposition velocity factors. The RIMPUFF and UDM results look almost equal, although UDM deposits the double of RIMPUFF, totally 0.033 kg versus 0.017 kg.

3.2 Release 1 m above ground

The real differences come with the release 1 meter above ground. The UDM puffs are heavily influenced by the buildings in the vicinity of the release point, while RIMPUFF just experiences the lower wind speeds at the lower heights.

The 1-minute concentration averages for 9 to 10 minutes after start of release, figure 8 and 9, shows for RIMPUFF an almost unchanged picture as compared to the 30 m release case. The plume has traveled a little less distance and the concentration is somewhat higher, all due to the lower plume height. The UDM plume, on the contrary, is significantly different from the 30 m case. After 10 minutes, i.e. 8 minutes after end of release, it is still in contact with the release point, and the maximum concentration, found close to this, is 10 times the concentration in the more distant high concentration spot, where the plume looks like that of the 30 m case, and the concentration is the same as in that case and as in the actual RIMPUFF plume.

For the time-integrated ground concentrations, figure 10 and 11, the RIMPUFF data are again very close to the 30 m case, just somewhat higher due to the lower plume. For UDM the plume has covered a much larger area than in the 30 m case. This is due to the plume getting widened by the buildings nearest to the release point, but in this case mostly due to the plume puffs having been captured behind these buildings are slowly released after the wind direction change.

The deposition follows the time-integrated concentration coupled with the land cover and again the RIMPUFF plot, figure 12, looks pretty much like for the 30 m release case while UDM, figure 13, gives a rather different pattern. The deposited amounts are 0.052 kg for UDM and 0.031 for RIMPUFF.

3.3 Release 1 m above ground, no wind shift

As a final test the same 1 m above ground release was run with no wind shift. The total deposition differs somewhat, 0.043 kg for UDM and 0.024 kg for RIMPUFF, but it is remarkable how the RIMPUFF and UDM depositions patterns in that case are almost equal except for very near the release point, where the buildings displace the UDM plume, figures 14 and 15.

4 Conclusion

For plumes passing well above towns the mesoscale RIMPUFF dispersion model does as well as the UDM model. It is when the release takes place so low that the plume really interferes with the local buildings or other obstacles, that a special urban dispersion model like UDM proves it value. For a radioactive release such a scenario might be expected in the case of a so-called dirty-bomb. The significant discrepancies in behavior between UDM and RIMPUFF can even in that case be localized to the vicinity of the release point as only buildings or clusters of buildings within a rather short distance from the release point, i.e. a few hundred meters, seem to influence the UDM plume. With timely wind direction changes this can, however, have consequences for larger areas.

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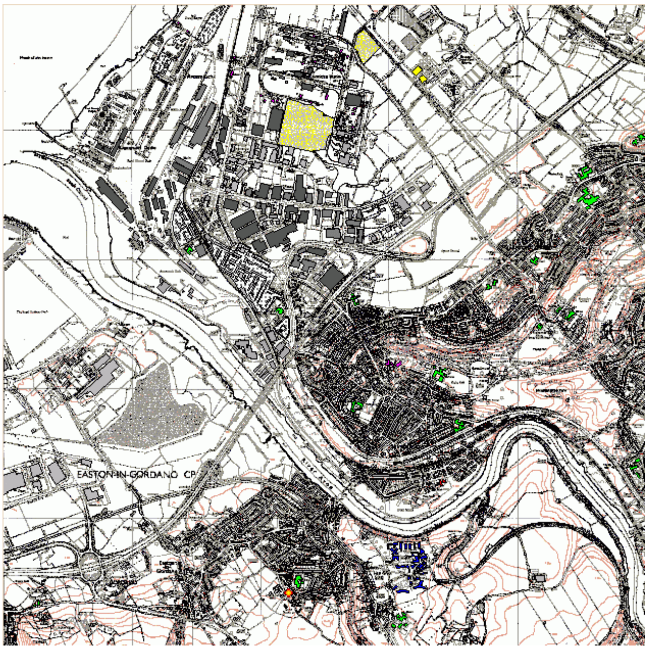
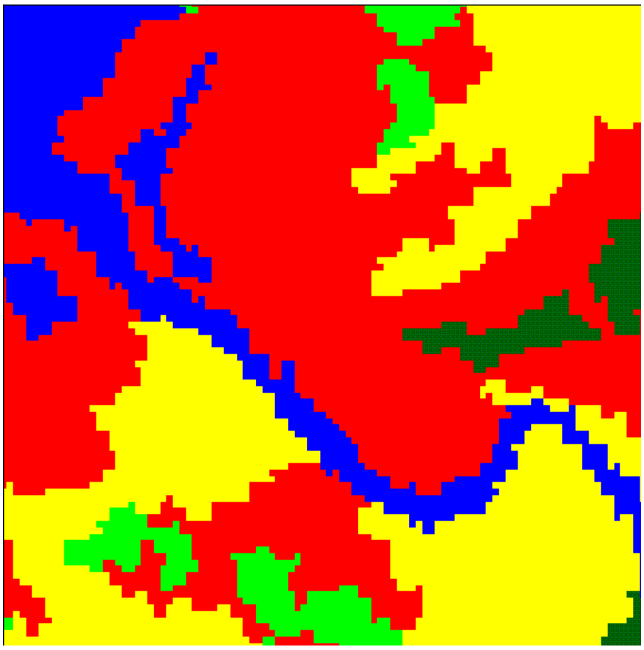
5 Figures

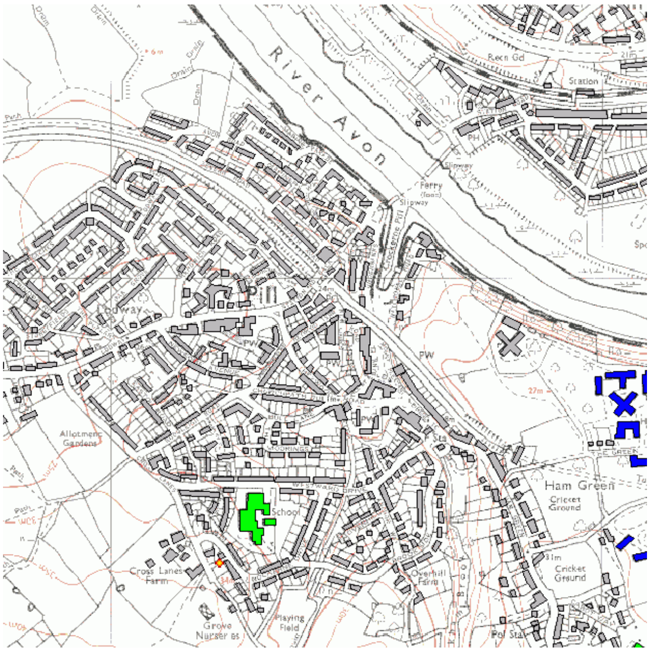


Map of southwest Bristol. 5×5 km calculation area. Release point: the yellow dot with red edge near the bottom, middle.

Extract of approximate calculation area from Google Earth.



Corine 100 m resolution land-cover reduced to 5 categories: Yellow: grass; blue: water; read: urban light green: rural; dark green: wood.



Enlarged extract of town map showing building details. Release point: the yellow dot with red edge near the bottom left of the middle.

Figure 1.

5.1 Release 30 m above ground

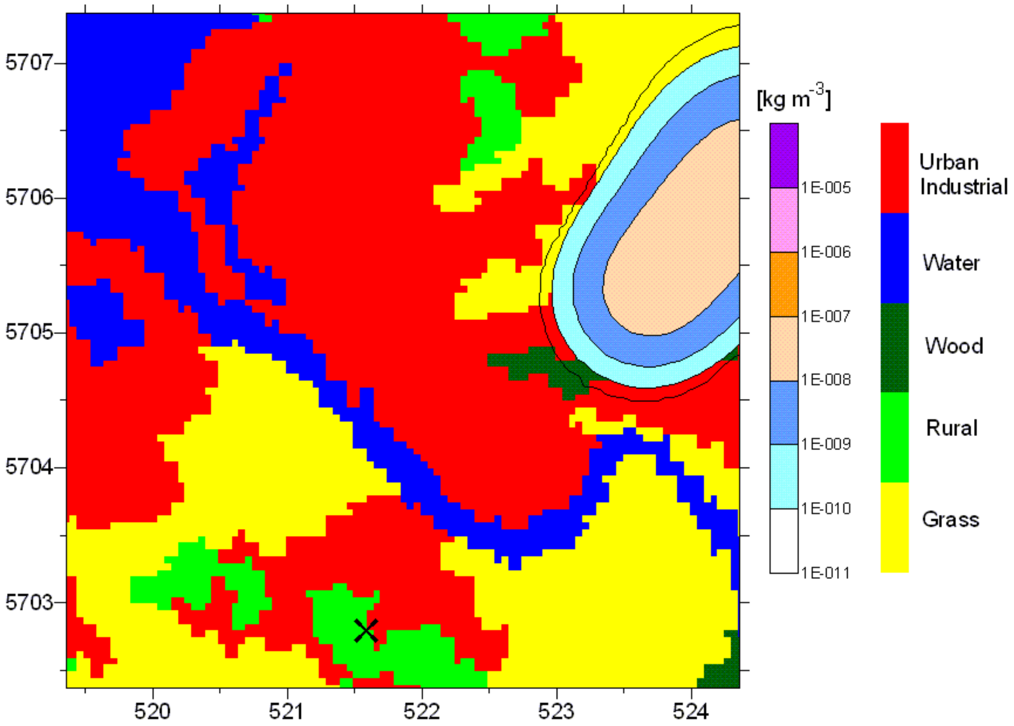


Figure 2: Average air concentration near ground from 9 to 10 minutes after start of release. RIMPUFF calculation.

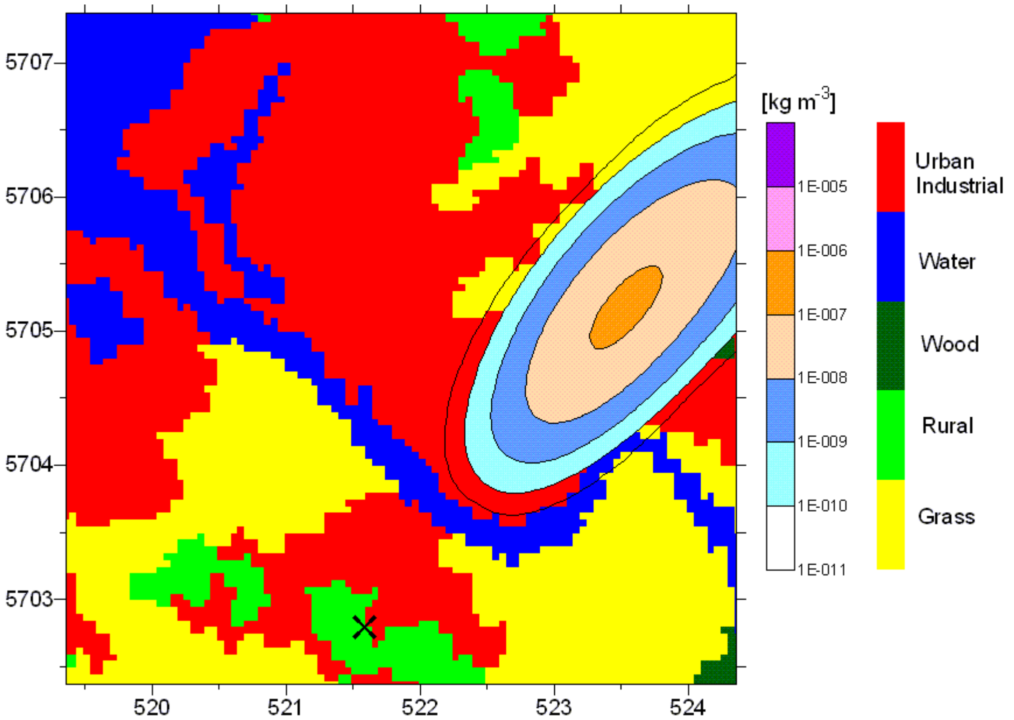


Figure 3: Average air concentration near ground from 9 to 10 minutes after start of release. UDM calculation.

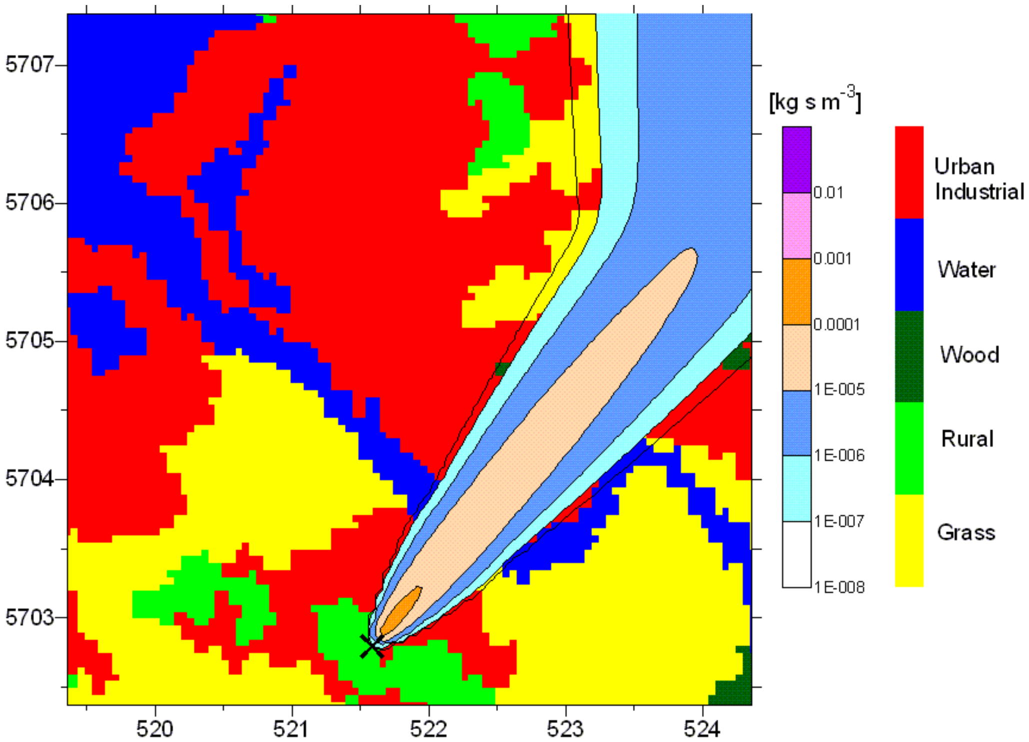


Figure 4: Time-integrated air concentration near ground after the plume has left the calculation area. RIMPUFF calculation.

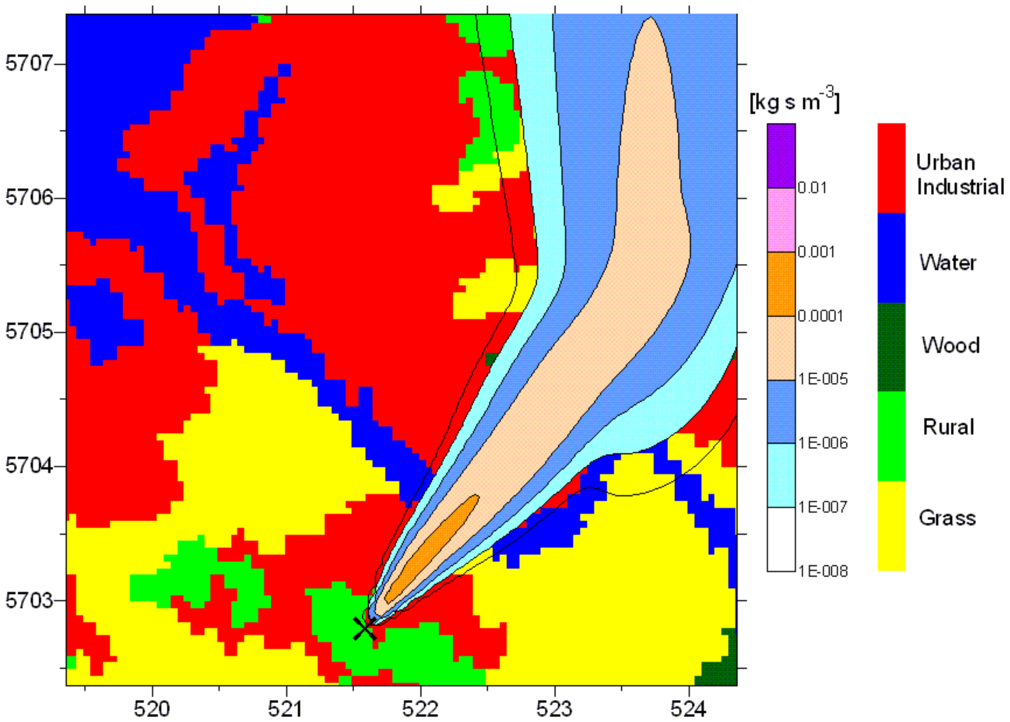


Figure 5: Time-integrated air concentration near ground after the plume has left the calculation area. UDM calculation.

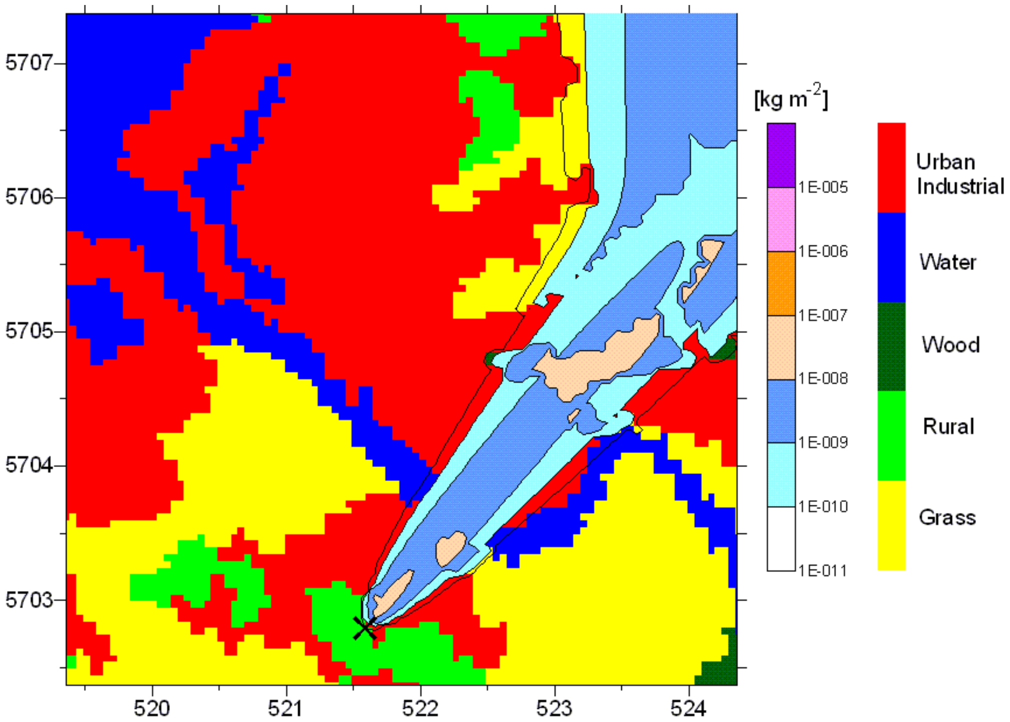


Figure 6: Total deposition to ground. RIMPUFF calculation.

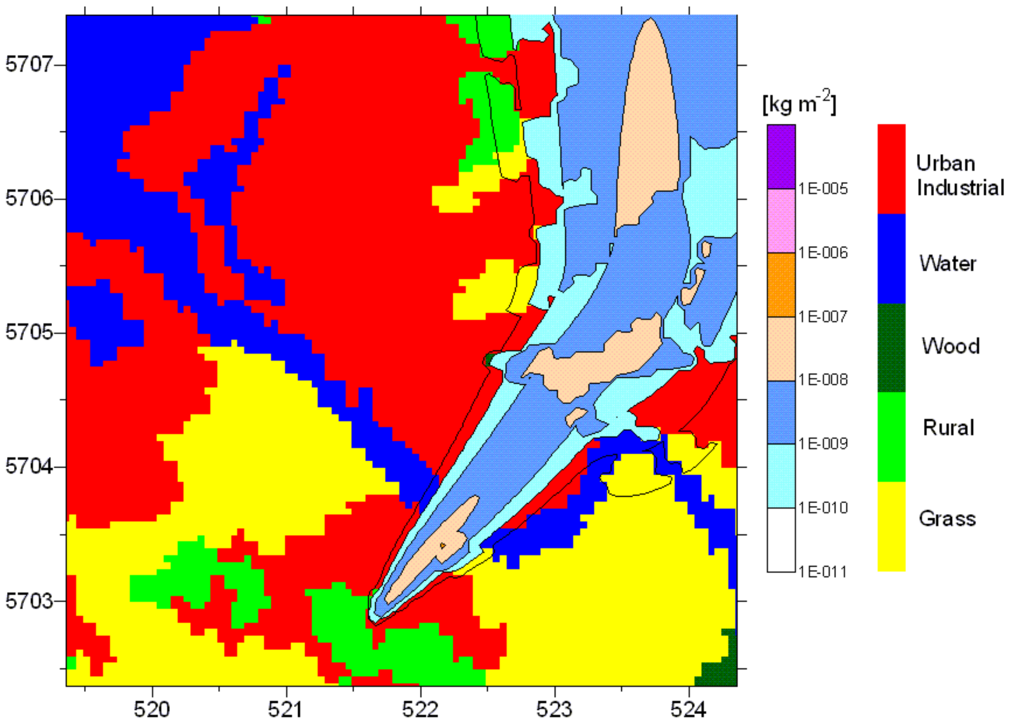


Figure 7: Total deposition to ground. UDM calculation.

5.2 Release 1 m above ground

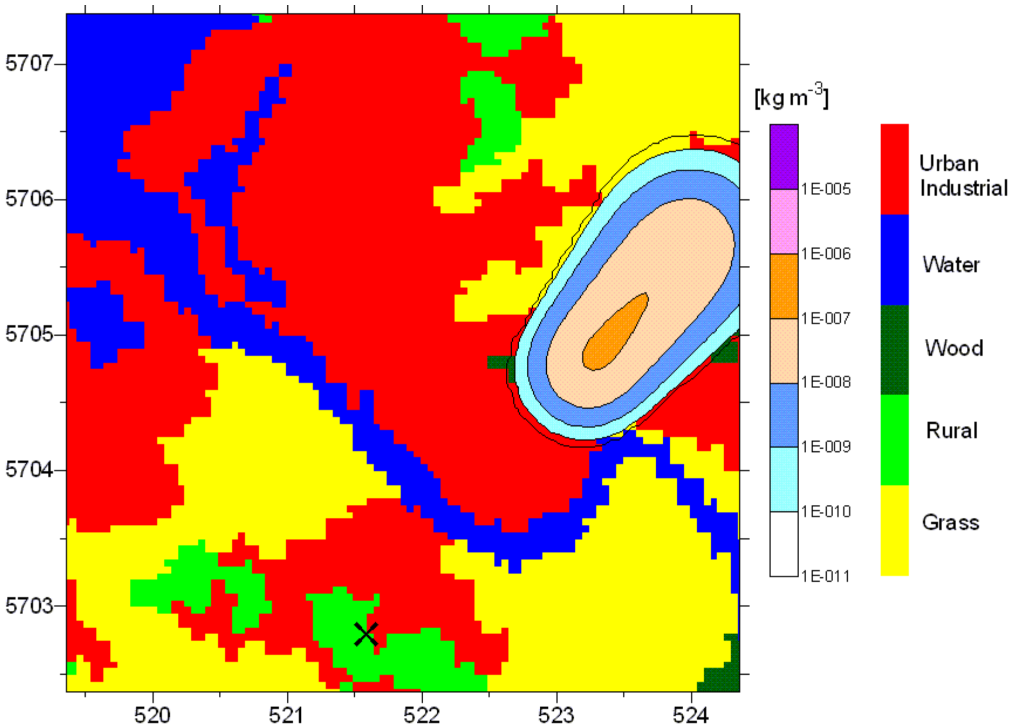


Figure 8: Average air concentration near ground from 9 to 10 minutes after start of release. RIMPUFF calculation.

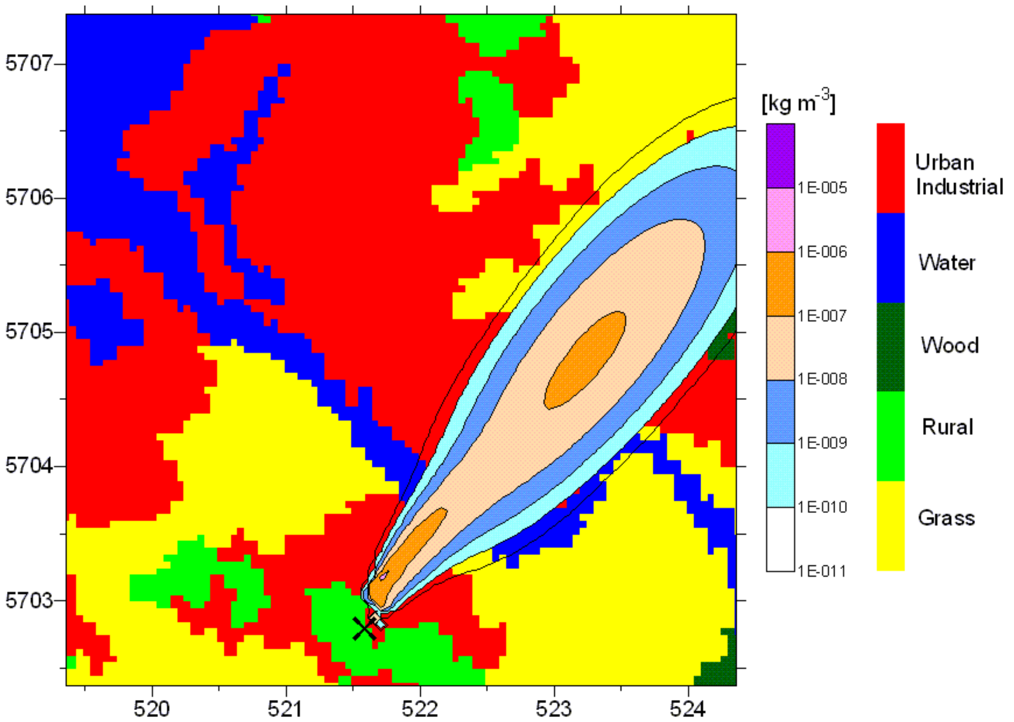


Figure 9: Average air concentration near ground from 9 to 10 minutes after start of release. UDM calculation.

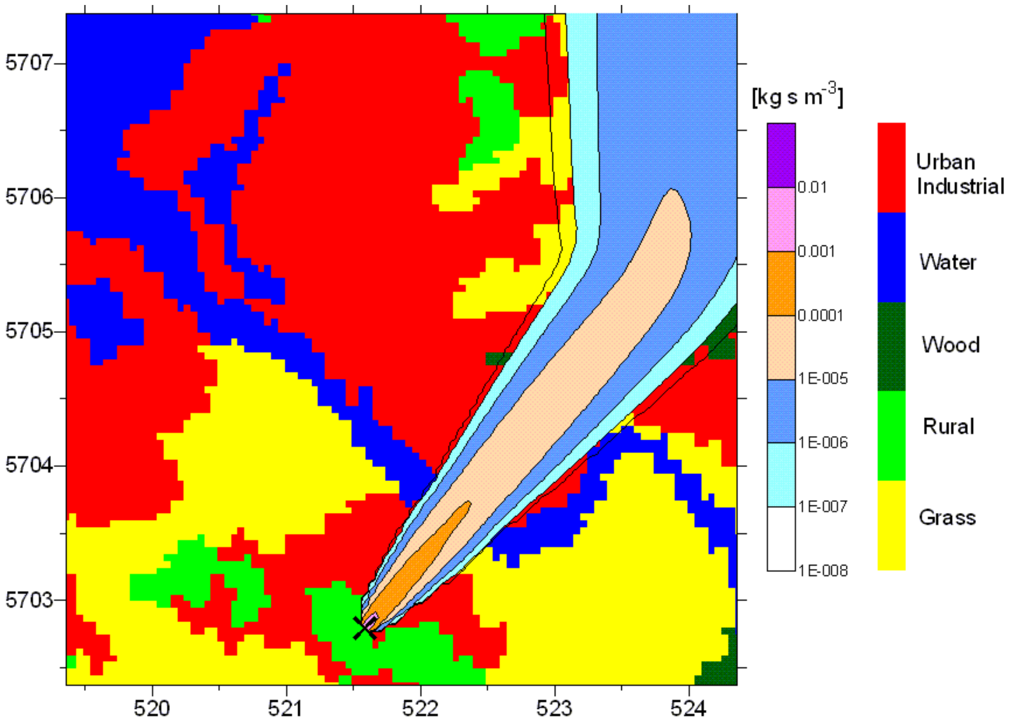


Figure 10: Time-integrated air concentration near ground after the plume has left the calculation area. RIMPUFF calculation.

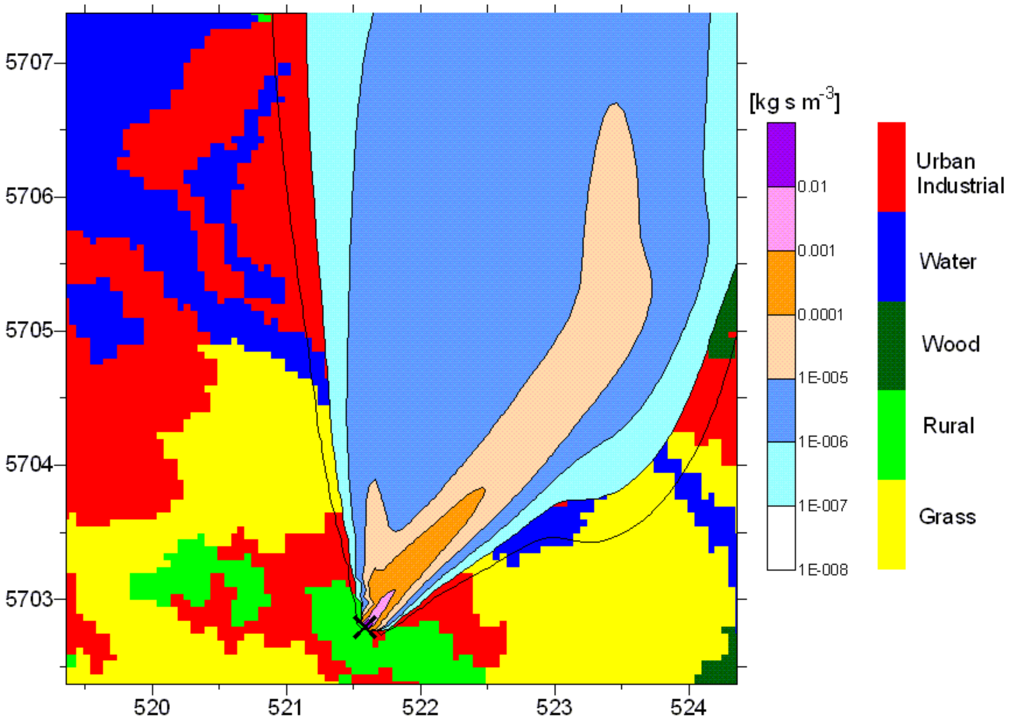


Figure 11: Time-integrated air concentration near ground after the plume has left the calculation area. UDM calculation.

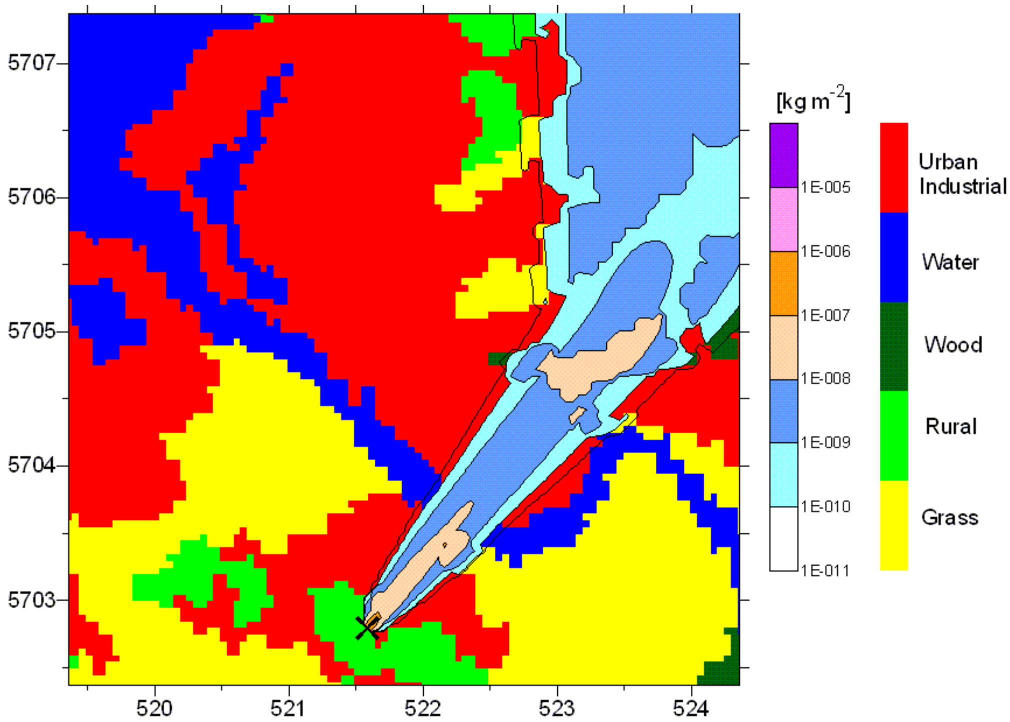


Figure 12: Total deposition to ground. RIMPUFF calculation.

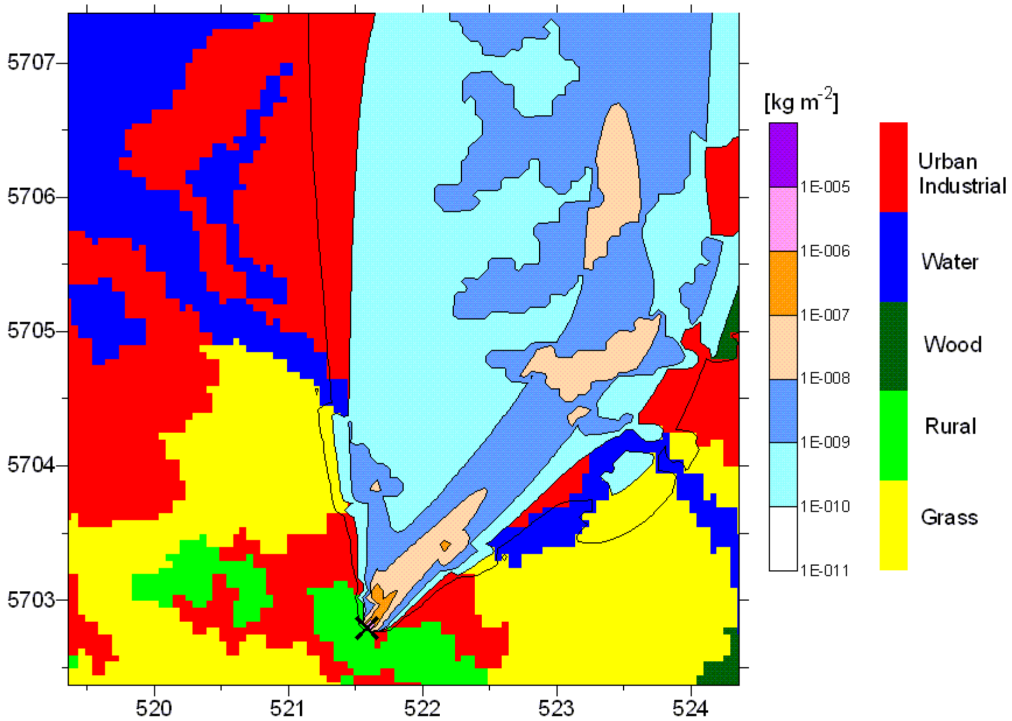


Figure 13: Total deposition to ground. UDM calculation

5.3 Release 1 m above ground, no wind shift

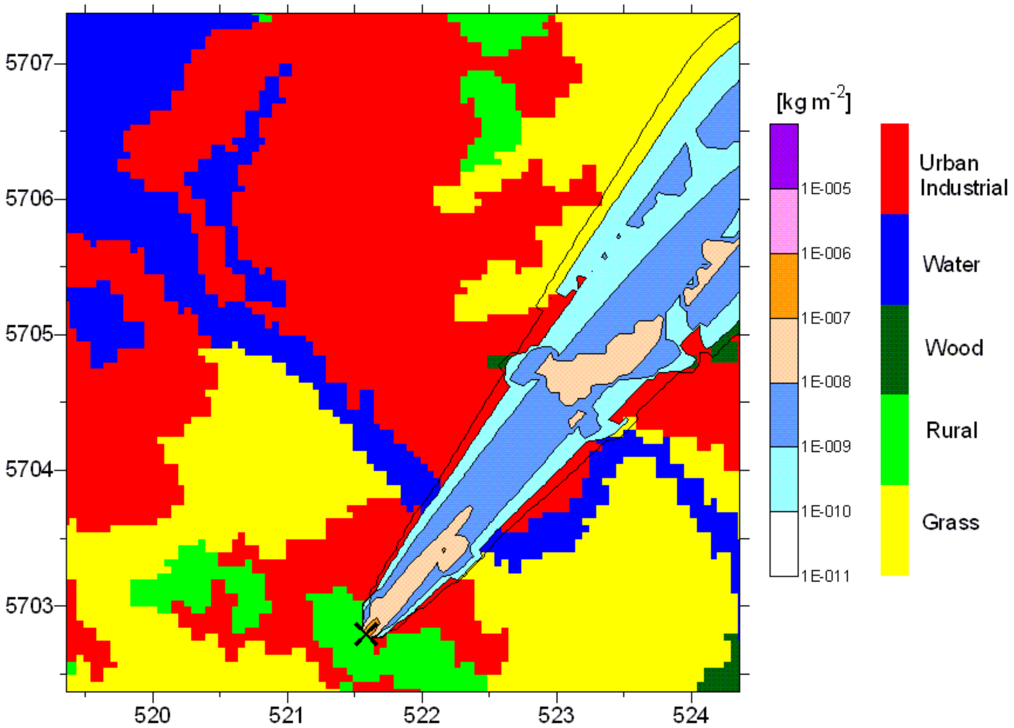


Figure 14: Total deposition to ground. RIMPUFF calculation.

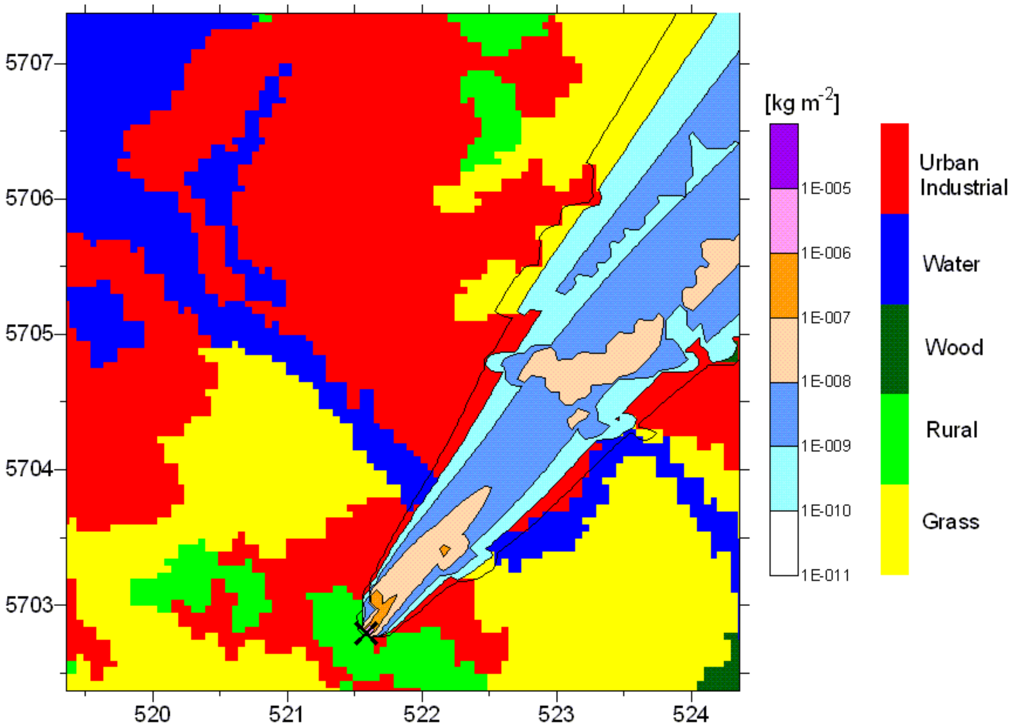


Figure 15: Total deposition to ground. UDM calculation.

Mission

To promote an innovative and environmentally sustainable technological development within the areas of energy, industrial technology and bioproduction through research, innovation and advisory services.

Vision

Risø's research **shall extend the boundaries** for the understanding of nature's processes and interactions right down to the molecular nanoscale.

The results obtained shall **set new trends** for the development of sustainable technologies within the fields of energy, industrial technology and biotechnology.

The efforts made **shall benefit** Danish society and lead to the development of new multi-billion industries.