INVESTIGATION OF MESO-SCALE TRANSPORT PROCESSES BY MEANS OF A PUFF MODEL

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INTRODUCTION

The Hungarian Meteorological Service has responsibility for maintaining transport models. Its aim is to provide forecasts for the dispersion of pollution in case of accidental release of potentially dangerous materials into the atmosphere. Two models are available for these reasons in our institute, one is for the local and the other is for the regional scale transport processes. In this paper we present the model used in case of local/meso scale transport processes.

In this work we studied how the diffusion of the polluted material has been controlled by the height of the mixing layer and the stability.

For the numerical part of the investigation, a mesoscale model was applied which was originally developed at RISO National Laboratory, Denmark. Its name is RIMPUFF. The model can simulate the pollution release to the atmosphere and its advection. The Lagrangian puff model simulates time-dependent continuous release by series of Gaussian puffs with fixed release rate. At each time step the model computes the advection and diffusion of individual puffs in accordance with the local meteorological parameters. The concentration distribution in an individual puff is supposed to be Gaussian in all three dimension. The individual puffs are advected by the wind field. The growth of all puffs is related to the atmospheric stability and downwind distance. The size of puffs have been calculated at each time step. The grid concentration is obtained at each grid point by summing up all the concentrations from the puffs in the grid. Expansion of a single puff with time is related to the diffusion process. Next to the surface layer it can be described as a function of the local turbulence intensities by the Pasquill-system.

SENSITIVITY ANALYSIS OF THE MODEL

Simulations were produced to get information about the model sensitivity to the stability, the mixing height and the release height. When the surface wind speed is 2 m/s, all of the Pasquill stability classes can occur so we use this value for our experiment. Mixing height intervals were determined using mixing depth categories suggested by the model authors for the stability categories (Table1.). The simulations were performed with 50m intervals in case of mixing height for all stability classes, and the release height was given: 1m, 10m, 50m, 100m in every cases.

Table 1. Mixing depths.

	Pasquill stability category					
	A	B	C	D	E	F
Suggested mixing depth (in metres)	2000	1500	1000	800	500	200
Examined intervals of mixing depth	2100-1800	1750-1300	1250-950	900-700	650-400	350-100

Our results shows that the concentration values are increasing when the mixing height is decreasing in all stability classes. The differences between the concentration maxima and minima were the bigger in case of F stability category when only the mixing height was changed. The most determinative case is the F Pasquill stability, when 200m difference in the mixing height causes more than 5 times greater differences in the concentration values 12 hours after the release, while in case of B stability category 400m differences in the mixing height resulted in doubled changes in the concentration values.

Changing the height of release did not result in essential differences between the concentration values. The effect of changing this parameter value yielded variation in the results in case of F stability.

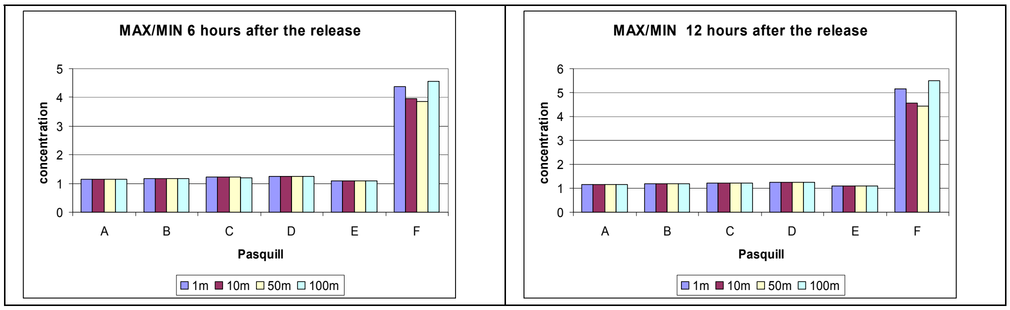

Figure 1. Maximum/minimum ratio of concentration values in case of different stability classes and in different release heights.

The experiment runs show that the 50m accuracy of the mixing height values is good, and it is a real request from our calculation method. Determination of the Pasquill stability is the most important thing, because the model is very sensitive for this parameter. The release height is the less important input parameter.

DETERMINATION OF THE STABILITY OF THE ATMOSPHERE

The diffusion and deposition of the pollution are affected by the stability of the atmosphere. The word-wide used Pasquill categories could be determined many ways, but some methods are not exact enough for programmers. We examined these methods and tried to find the best categorization, which can be the most efficient for our aims.

In Hungary three different tables are used which are developed by Szepesi et al.(1983) to determine the Pasquill stability indicator. In the tables the Pasquill categories are determined as the function of the following parameters:

a) surface wind speed, solar intensity and degree of cloudiness
b) surface wind speed and net radiation
c) surface wind speed and temperature gradient

There are not extreme differences between the tables, but the tables are based on different meteorological parameters. After the examination we have not realized essential differences between the three methods. We found that the method, which uses the surface wind speed and the lapse rate can be applied in the simpliest way. This method was not only the best method in case of applied measured data, but in case of data coming from numerical forecast models.

The following table shows the determination of Pasquill stability indicator by the surface wind speed and lapse rate.

u	ΔT/Δz (°C/100m)						
m/s	<1.5	-1.4-/-1.2	-1.1-/-0.9	-0.8-/-0.7	-0.6-0.0	0.1-2.0	>2.0
<1.0				C			G
1.0-1.9	A						
2.0-2.9		B	C			E	F
3.0-4.9					D		E
5.0-6.9		C					
≥7.0							

We prepared a program to calculate this category from the meteorological data which are measured or coming from numerical forecast models. We plane to use this program in case of industrial accidents.

The developed program determined the Pasquill categories for the area of Hungary, for a grid with spatial resolution of 10 x 10 km, and for 12 forecasted hours with a temporal resolution of 1 hour. For this reason we use the numerical weather prediction model ALADIN/HU. In the near future the spatial resolution of ALADIN/HU will be finer, which will result in finer grid spacing of Pasquill data sets as well.

DETERMINATION OF THE MIXING HEIGHT

The mixing height is the other determinative parameter of diffusion processes. This parameter represents the top of the layer through which relatively vigorous mixing can take place. At the mixing height smoke lose its buoyancy and stop rising.

The calculation methods of mixing height are also familiar. There are many well known methods to determine the height of this layer, but the every day usage of these methods causes some problem for programmers. The methods are too difficult or needed such of meteorological parameters which are not measured at every meteorological stations or the output fields of the numerical weather prediction models are not included. Our aim was not only to choose a method which can be used in an easy way, but the result represents the processes such a way which was determined by the results of the sensitivity analysis.

In the last years the output fields of the numerical weather prediction models include the boundary layer height and meteorological data with fine vertical resolution in the lower atmosphere. These information are very useful for dispersion modelers, but not enough. In the next years the evolution of the limited area numerical weather prediction models will be significant, and many of them will be able to determine meteorological data needed for the dispersion models.

The numerical weather prediction model ALADIN/HU does not have information about the mixing layer height so far, this is the reason why we have to investigated a program which can determine this important parameter for RIMPUFF.

Our program calculates the mixing height using the following data of the ALADIN/HU: wind speed, temperature, humidity profile. The program uses the bulk Richardson number calculation method. Experiments verify that the critical values of the bulk Richardson number indicate the top of the mixing layer. This critical values are between 0.15 and 0.35. In Hungary this critical value is 0.25, based on experimental calculations. In our calculation we expected that the wind speed is zero at the surface.

$$Ri_B = \frac{gz(\Theta_v - \Theta_s)}{\Theta_s(u^2 + v^2)},$$

where:
- θ_s: virtual potential temperature at the surface,
- θ_v: virtual potential temperature at z height,
- z: mixing height,
- u: horizontal wind component in x direction,
- v: horizontal wind component in y direction.

CONCLUSIONS

We displayed some of our results to demonstrate the role of the stability and the mixing height in the diffusion processes. We described the program system which calculated dispersion parameters for RIMPUFF.

The developed program system runs in every hour automatically and calculates the stability and mixing height for every grid point. The input files contained meteorological data (wind speed, wind direction, precipitation), and stability and mixing height are produced automatically as well. In case of an industrial or nuclear accident the expert can run RIMPUFF in time. For the first time step the observed/analyzed data, while for the next 12 hours the output data of ALADIN/HU are used.

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