# Real-Time Direct Link Between Meteorolocical- and Dispersion Models

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## Introduction

Poland is one of the largest emitters of various pollutants in Europe. This leads to serious contamination of natural environment in this country. Moreover, more than ten large nuclear installations (reactors) are located in the closest vicinity of Poland (see Fig. 3). This situation requires a tool for decision-support in case of nuclear incident. The research presented here is a part of more general, long-term modelling project and its possible application to the problem of short-time emission incidents. Author attempted to establish the on-line link between meteorological model (COSMO-LM) and dispersion model (REMOTA - REgional MOdel for Atmospherical Transport of pollutants).

## Models

1. Meteorological model is currently running in an operational manner at the Mesoscale Modelling Group at IMWM. It produces 72-hour forecasts of meteorological fields needed for the dispersion model, such as wind, precipitation intensity, cloud cover etc. The fields are two-dimensional (cloud cover or precipitation) or three-dimensional (e.g. wind or temperature) – from multiple levels [1]. For the dispersion model, also the eddy diffusivity coefficient is required. This is calculated using meteorological model results as input, with procedures developed by the Team for Modelling the Atmospheric Transport of Pollutants at IMWM, on the basis of PBL (Planetary Boundary Layer) Model from Washington University.

2. REMOTA is a simulation model, whish simulates the dispersion of multiple pollutants. The processes such as horizontal advection, vertical diffusion, dry deposition and wet removal are accounted for in the model. The governing equations are solved in the terrain-following co-ordinates. The numerical solution is based on the discretization applied on a staggered grid. Conservative properties are fully preserved by the discrete model equations. Advective terms in the horizontal directions are treated with the Area Flux Preserving method (Bott's type scheme) with boundary conditions assumed zero at incoming and "open" at outcoming flows; vertical turbulent diffusion – with the implicit Crank-Nicholson?s scheme. The bottom boundary condition is the dry deposition flux, while the top boundary condition is "open". Dry deposition velocity is postulated as a function of terrain roughness, friction velocity and diameter of a particle according to Sehmel's model, while washout ratio is assumed constant, but different for each pollutant.

## Link Description

The meteorological (LM) and dispersion (DM) models are interacting via IMWM Intranet. The results from the LM model (meteorological fields) are available on separate server and

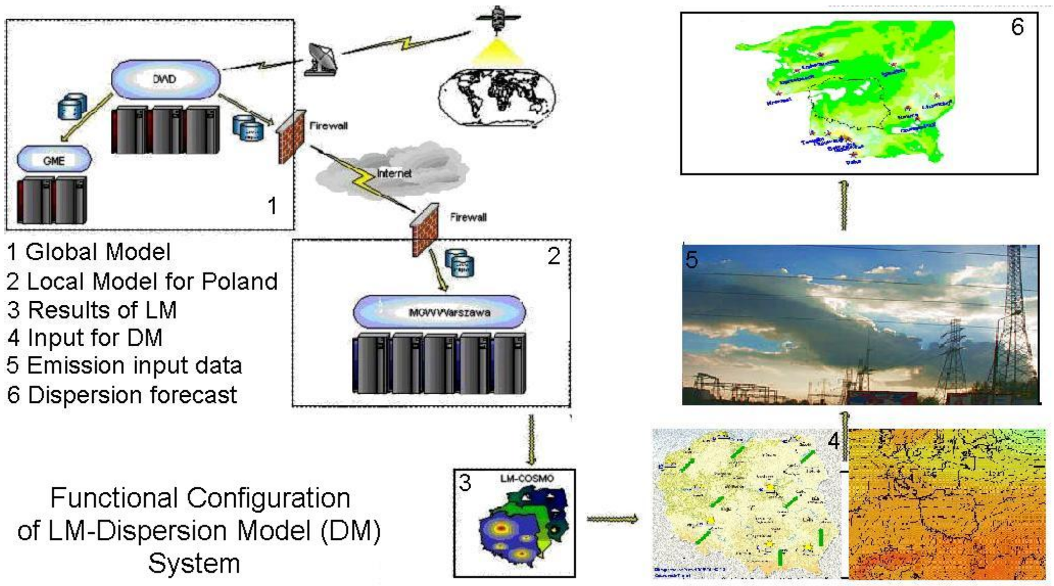


Figure 1: Functional configuration of LM-DM system.

path, accessible for DM preparation module. Once the results are ready (twice a day), it is possible to retract the necessary fields and to prepare meteorological input files for the DM. This retraction is fully automatic and depends only on the current date and time. Then, also in an automatic way, the full DM run (78 hours forecast with 27 output records) is performed.

### Dispersion Model Description

The three-dimensional, Eulerian DM model is based on similar model for Europe [2, 3]. The numerical grid system for this particular study consists of 193×161 cells of the size of about 14×14 km and five vertical levels. The model is composed of three main modules; the first sets parameters of the model (i.e. local deposition coefficient, washout ratio, dry deposition velocity), the second solves the advection-diffusion equation, and the last prepares output files for graphical presentation and statistical analysis. During a simulation, the program reads user-defined parameters, then it begins the main loop of calculations: reads all necessary input data (emissions, meteorological fields etc.), performs computations (advection, diffusion, deposition) and stores the results (if required). The governing transport equation is solved using the Area Flux Preserving method (horizontal advection, [4]) and a Crank-Nicholson method (vertical diffusion). In each time step, current concentration field is computed followed by total deposition (sum of dry and wet).

### Results

*a)*
The first model runs (tests in a small domain, 14-km grid, 57 × 51 nodes) produced concentration and deposition patterns for pollutant (chemically inert, for instance, primary dust) emitted from the high source located close to the centre of the model domain. This case represents the situation of short-term incident due to "emission catastrophe" of some sort. The patterns are shown in Figure 2.

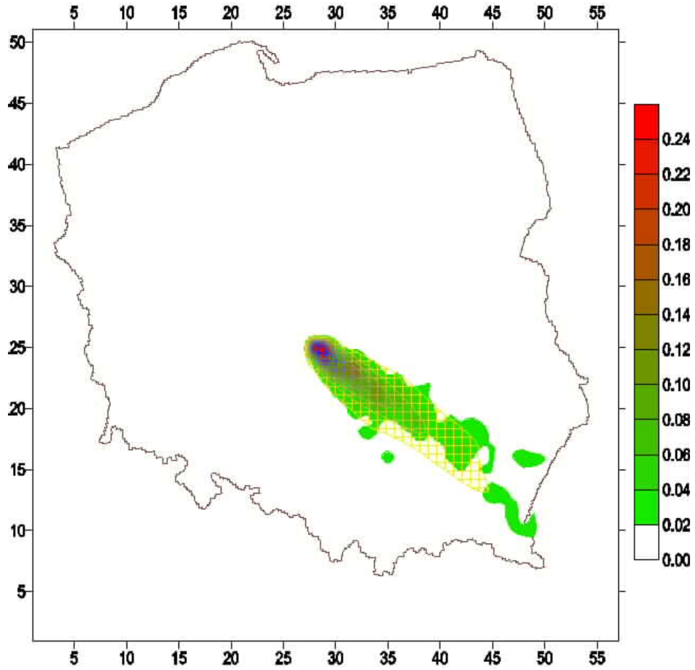


Figure 2: Model results - concentration and deposition (relative units) of test pollutant emission from February $9^{th}$, 2003 until February $11^{th}$, 2003.

*b)*
As it was mentioned earlier, more than ten large nuclear power plants (some build in the same manner as Chernobyl reactor) are located in the vicinity of Polish territory. Therefore, actual configuration for real-time, on-line link between models should include the full LM model domain, covering almost entire Europe. In this way more than 90% of all European nuclear installations are in taken into account in the computations.

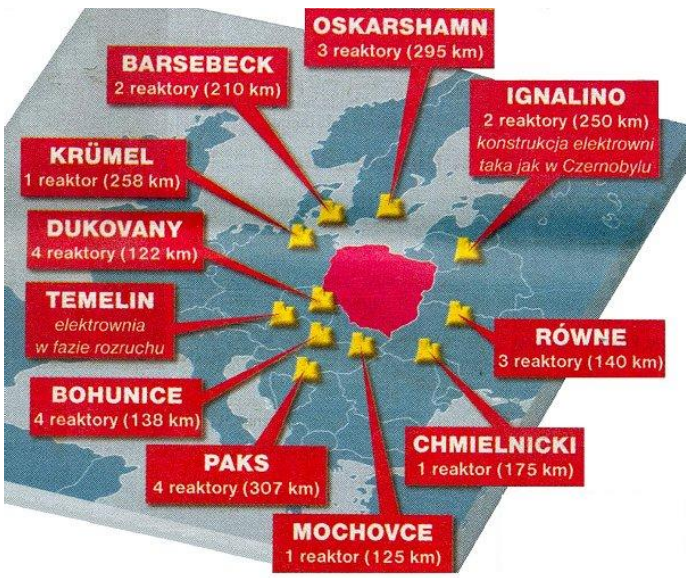


Figure 3: Nuclear installations in the vicinity of Poland (www.atomowe.kei.pl).

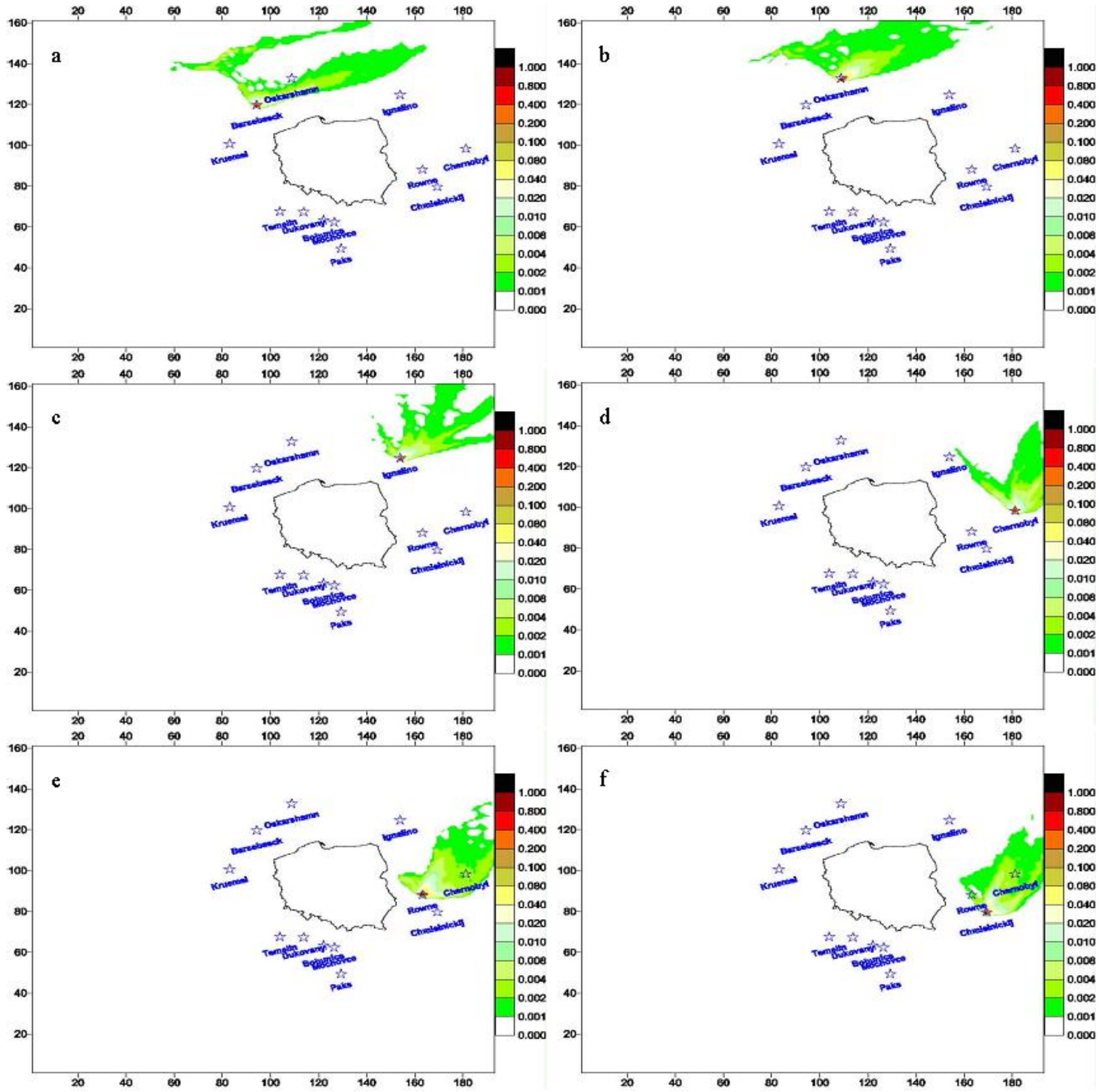


Figure 4: Dispersion of nuclear contamination in case of hypothetical accident in Barsebaeck (a), Oskarshamn (b), Ignalino (c), Chernobyl (d), Rowne (e) or Chmielnicki (f) Nuclear Power Plant. All forecasts valid for April $28^{th}$, 2003 to May $1^{st}$, 2003.

Following Figures 4 and 5 show the results of the simulations of hypothetical simultaneous accidents in all nuclear reactors in the closest vicinity of Poland. The results presented above were computed for rather symbolic date of April $28^{th}$, but for 2003. They show that in the case of an accident even country without a nuclear power plant is not safe from serious contamination.

*c)*

Additional work has been done for implementation of ozone and acidifying agents, like NO, $NO_2$, PAN, $HNO_3$, $NO_3$, $NH_4NO_3$, $NH_3$, $(NH_4)_2SO_4$, $SO_4$ and $SO_2$ in the DM model. To cover all photochemical transformations that apply to ozone and $NO_x/SO_x$, one should use a chemical scheme with more than hundred reactions. So, as the first approximation of the problem, a simple scheme for the photochemistry (EMEP, 1993) was applied (EMEP, 1993) in DM (see Figure 6 below).

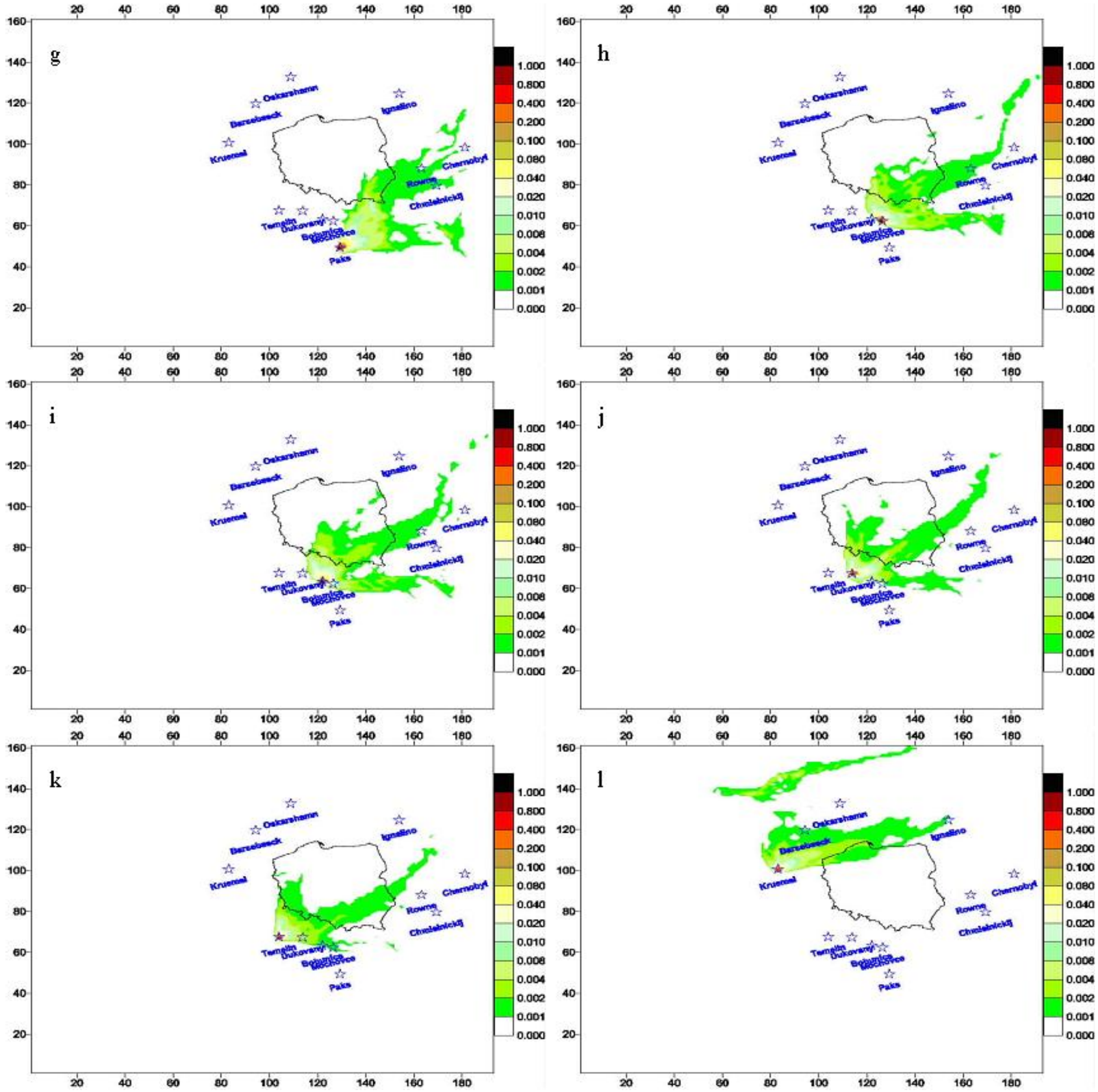


Figure 5: Dispersion of nuclear contamination in case of hypothetical accident in PAKS (g), Mochovce (h), Bohunice (i), Dukovany (j), Temelin (k) or Kruemel (l) Nuclear Power Plant. All forecasts valid for April $28^{th}$, 2003 to May $1^{st}$, 2003.

As an example of model performance concerning photochemical pollutants, the patterns of the deposition of nitrogen and sulphur and of concentration of ozone are presented in Figure 7. They are calculated for May $7^{th}$, 2003 due to emission from fictitious source located in the centre of Poland.

## Conclusions

The main results of this study can be summarized as follows:

- An operational link between meteorological model and dispersion model for Poland has been established and tested. It is efficient and seems to work well.
- An operational version of the dispersion model for atmospheric transport and deposition of pollutants emitted in short-term emission incidents or accidents. This model takes into account radioactive and photochemical pollutants.

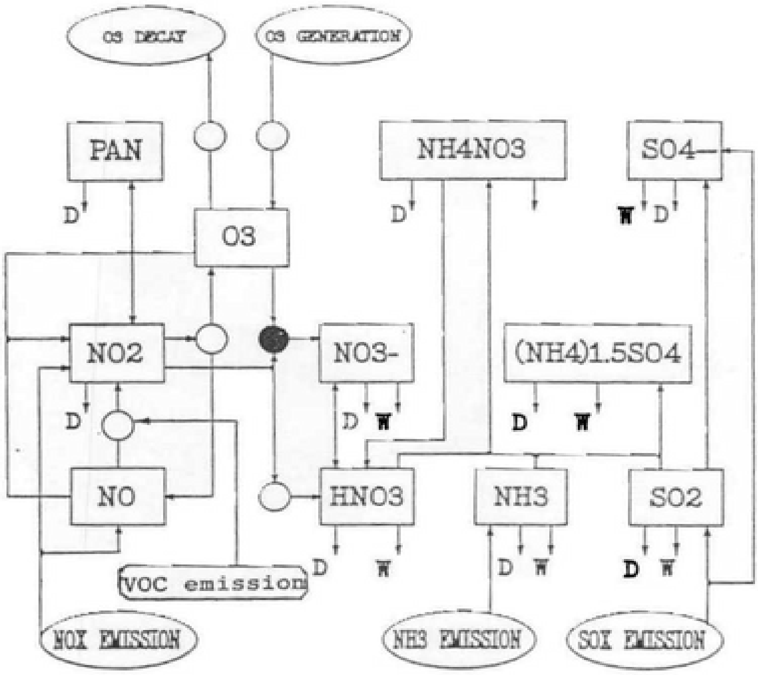


Figure 6: Physical- and chemical transformations for $NO_x/SO_x$ cycle, combined with ozone formation and depletion. D - dry-, W - wet deposition, ∘ - photochemical- and • - dark phase reactions (EMEP, 1993).

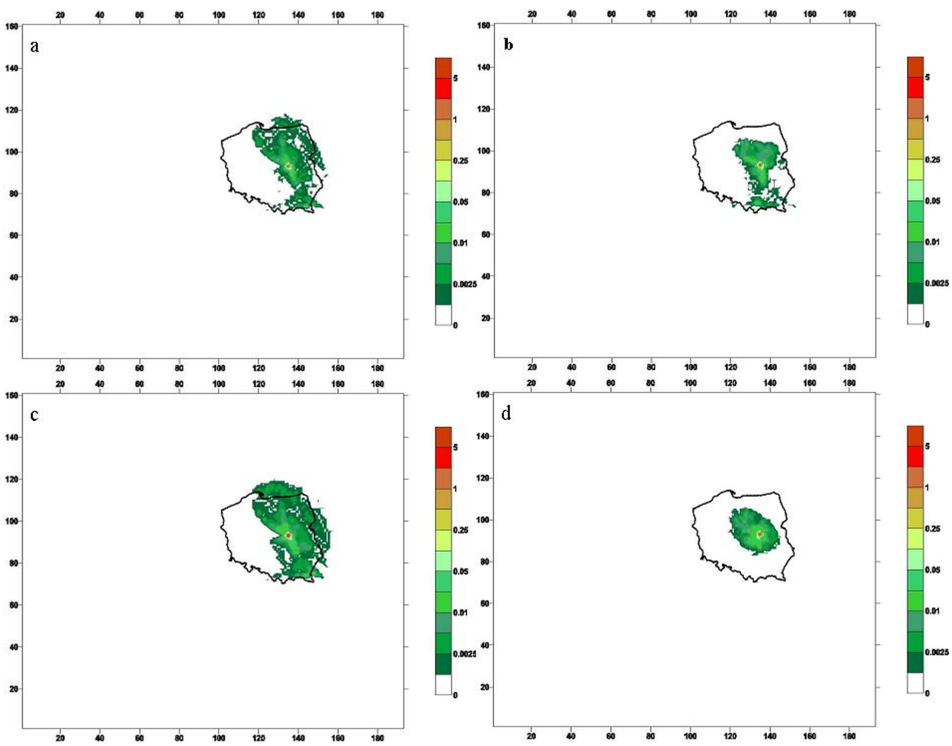

Figure 7: Deposition of oxidised (a) and reduced (b) nitrogen, deposition of sulphur (c) and concentration of ozone (d) due to emission from fictitious source located in the centre of Poland. Valid for: 07.05.2003 - 78 hours forecast. Deposition in relative units (mass deposited/mass emitted, %). Concentration units - ppbs over mean annual value of $O_3$ concentration.

This particular application of meteorological and dispersion (LM+DM) model, conneted online, can serve as a first estimate of a system simulating dispersion of dangerous pollutants emitted into the atmosphere during serious accidents. This system will be further improwed at IMWM.

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