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BULGARIAN EMERGENCY RESPONSE SYSTEM FOR RELEASE OF HAZARDOUS POLLUTANTS – FAST DECISION MODE

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Abstract: The fast decision mode of the emergency response system is designed to help the relevant authorities in making important decisions, concerning the evacuation of the population in case of toxic air pollution due to accidents in industrial sites.

The system is based on the following models: WRF, used as meteorological pre-processor; SMOKE – the emission pre-processor; CMAQ - the Chemical Transport Model (CTM) of the system. The pollutant is considered a tracer,i.e. it's chemical nature is not specified and it is only transported and deposited depending on meteorological conditions. The units are relative, since the amount and the coverage of the toxic spill, as well as the molar mass of the pollutant and the evaporation rate, are hypothetical.

The numerical results demonstrate the good performance of the models and the practical value of the fast decision mode of the emergency response system.

Key words: *air pollution modelling, US EPA models-3 system, toxic gases, emergency response*

INTRODUCTION

The present work demonstrates results produced by the Bulgarian system for emergency response in case of accidental harmful releases in the atmosphere. The system will supply the authorities, the relevant international organisations and the public with information, which will help to take proper measures for diminishing the damages. The modelling system is able to assist emergency managers in three stages:

In preparedness mode, "risk analysis" was performed for some selected sites (see Todorova et al., 2010 for the site of VEREYA-HIM, Yambol). These assessments can be of a direct use for the relevant national bodies for developing strategies for immediate emergency response (for example evacuation of people from the pollution exposed regions, proper assignment of medical teams) in order to minimize the pollution impact on human health. They also give valuable information for optimisation of the air quality monitoring network.

In the operational ("fast decision") mode the system produces fast short-term forecast of the pollutant propagation in local and regional scale, which is governed by the meteorological conditions. This information will help the authority decisions about the immediate measures and activities to be carried out in order to minimize the pollution impact on human health. This information will also warn the international community of possible trans-boundary harmful pollutant transport.

In the off-line mode the modelling system will produce a more detailed and comprehensive analysis of the possible longer-term impact of the harmful releases on the environment and human health in local to regional scales, including the whole Balkan region. This information, made available to the authorities and the public will help the formulation of long-term strategic measures and activities for abatement of the caused damages and gradual restoration of the environment.

The system is based on up-to date and complex meteorological and pollution transport models with proved high-quality simulation performance, high-spatial resolution and options for two way nesting. These requirements come from the very complex terrain of the Balkan Peninsula and will give the possibility to follow the accidentally released harmful gases from local to regional and to European scale, accounting for the mesoscale dynamic phenomena, to 'zoom-in' and obtain a very detailed air pollution evaluation in the particularly damaged regions.

Potential danger of major industrial accidents with the formation of highly toxic environmental contamination exists at textile, leather, pharmaceuticals and other sites, working with synthetic fibers, plastics, rubbers, dyes, explosive and flammable and combustible liquids. The sites of the chemical industry, where large ammounts of chlorine and/or ammonia are stored, are also potentially dangerous.Based on the information, provided by the operators of active enterprises,which fall under Chapter 7, Section I ("Prevention of major accidents") of the Law on Environmental Protection (LEP), about the quantities of hazardous substances that are stored on their territory, 56 enterprises are identified, which are subject to authorization in order to prevent major accidents involving dangerous substances and limiting their consequences. 28 of these are classified as having high risk potential. We have selected the following 11 sites (shown on Fig.1), which are most dangerous in terms of possible air pollution with toxic substances:

1. Devnya: POLIMERI AD – Production of chemical products based on chlor-alkali electrolysis - cleaning and disinfecting products for industrial and residential needs. Large amounts of chlorine are stored (~ 500 tons); AGROPOLIHIM AD – Production of nitrogen and phosphate fertilizers. Large quantities of the following substances are stored: ammonia (from 150 to 500 tons), nitric acid (1,500 tons), sulfuric acid (6,000 tons), ammonium nitrate (40,000 tons) and others.

2. Yambol, VEREYA HIM OOD, KONTINVEST OOD – Import of chlor-alkali products (hydrochloric acid, sodium hydroxide, methylene chloride) and production of chlorine coagulants, liquid and solid aluminium sulfate. Large amounts of

liquid chlorine are stored.

3. Dimitrovgrad, NEOHIM AD – Production of organic and inorganic chemicals - ammonia, nitric acid, ammonium nitrate, formalin, urea-formaldehyde resins, sodium nitrate, sodium nitrite, ammonium bicarbonate, liquid sulfur dioxide, nitrous oxide, polyethylene oxide, glass-thermoplastics and more.

4. Ruse: ORGAHIM AD – Production of resins, paints and adhesives; FIBRAN BULGARIA AD – Manufacture of insulation panels from XPS. Large amounts of polystyrene are stored. Polystyrene dust is explosive and during combustion it releases acids, styrene, aldehyde and carbon dioxide.

5. Dve Mogili, F+S AGRO OOD – Storage facilities for agricultural protection. Dry and liquid pesticides are stored, the most dangerous of which is carbofuran. Hazardous decomposition products: nitrogen oxides (NOx), carbon monoxide (CO), carbon dioxide (CO2), and methyl isocyanate

6. Velichkovo, municipality of Pazardzhik, AGROCHEMICAL EOOD – Storage facilities for pesticides

7. Burgas, NEFTOHIM AD – Oil refinery. Production and storage of various petrochemicals, some of which are highly toxic

8. Belozem, municipality of Rakovski, INSA OIL OOD – Oil refinery

9. Svishtov, SVILOCEL AD, SVILOZA YARN EOOD – production of bleached sulfate cellulose and cellulose products. Pollutants - nitrates, nitrites, ammonia, sulfates, phosphates, chlorides.

10. Sevlievo, PARALEL EOOD – production of polyurethane foams and products thereof (soft upholstered furniture). The burning of polyurethane foams releases isocyanates, hydrogen cyanide, carbon monoxide, etc.

11. Port Varna West, AGROPOLIHIM AD - The project of AGROPOLIHIM for construction of a new terminal at the port of Varna for import of ammonia. The new terminal is expected to provide import of 120-180 thousand tons of ammonia annually. The terminal for liquid dangerous goods will be equipped with facilities for processing of dichloromethane, sulfuric acid, hydrochloric acid and liquid fertilizer.

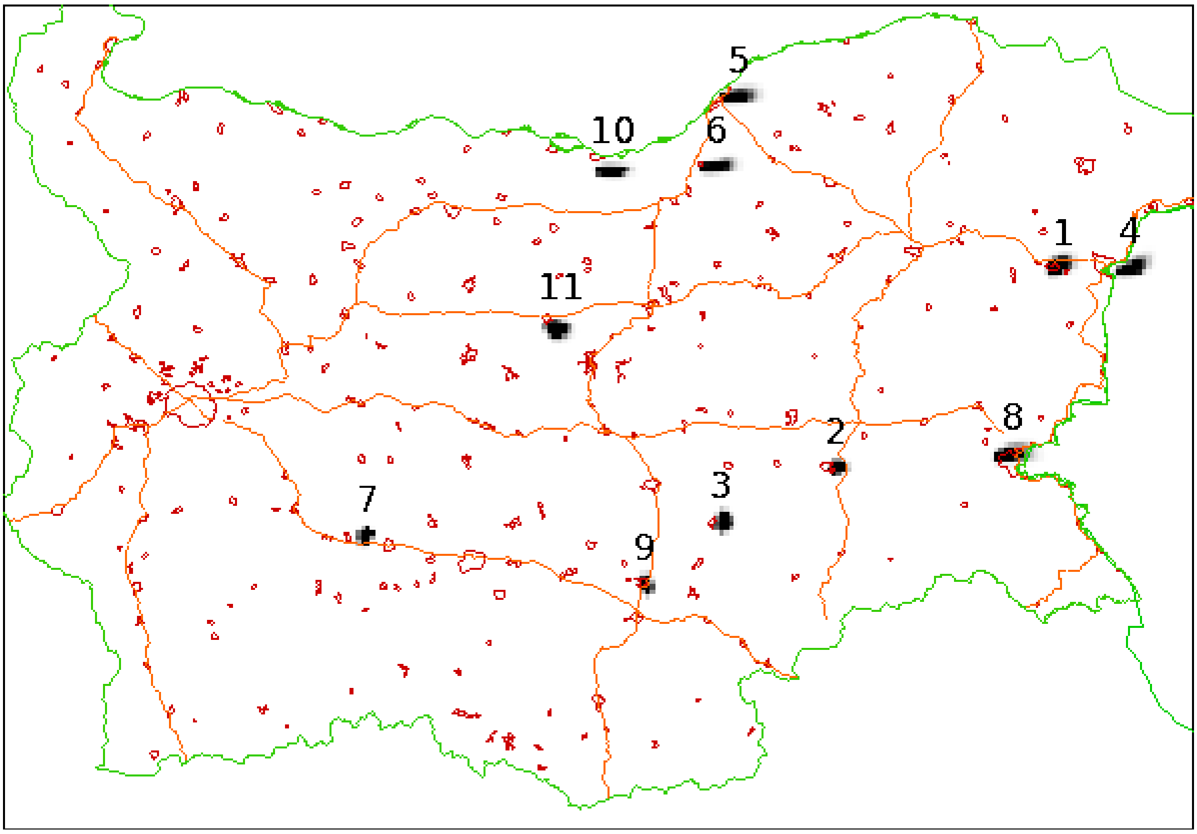

Figure 1. Locations of the potentially dangerous sites: 1. Devnq; 2. Yambol; 3. Belozem; 4. Port Varna Zapad; 5. Rousse; 6. Dve Mogili; 7. Velichkovo; 8. Burgas; 9. Dimitrovgrad; 10 Svishtov; 11. Sevlievo

MODELING TOOLS AND DESIGN OF THE "FAST DECISION MODE" OF THE SYSTEM

The modelling tool used for this study is US EPA Models-3 System: **WRF** - Meso-meteorological model (Shamarock et al., 2007), used as meteorological pre-processor. ; **CMAQ** - the Community Multiscale Air Quality System (Byun et al., 1998, Byun and Ching, 1999) - the Chemical Transport Model (CTM) of the system.; **SMOKE** - the Sparse Matrix Operator Kernel Emissions Modelling System (CEP, 2003) – the emission pre-processor of Models-3 system. SMOKE is run only once during the set-up of the system in order to produce landuse and OCEAN files, required by CMAQ. The actual emission files, used for the simulations, are prepared by a specially developed fortran program.

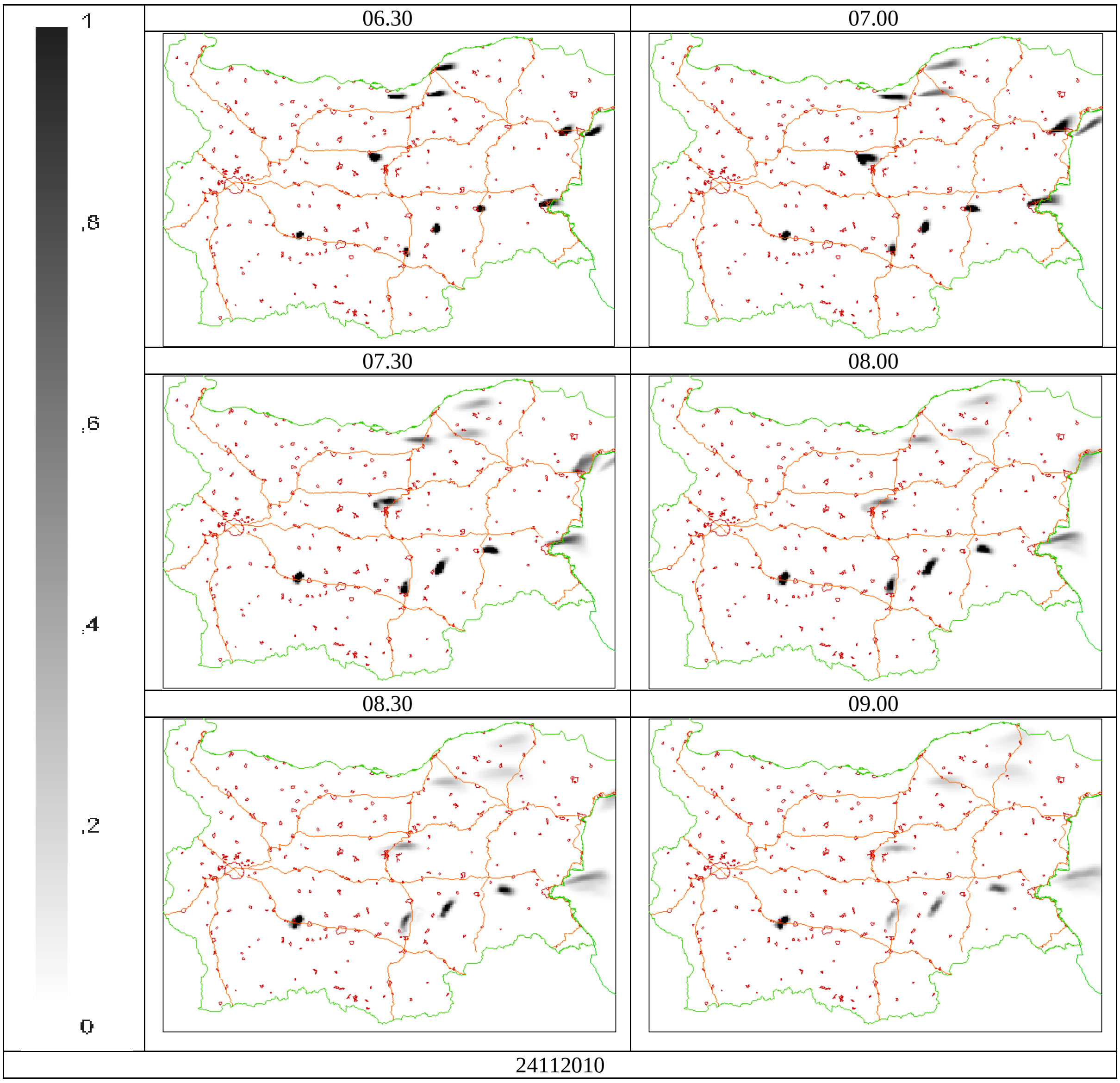

Figure 2. 3-hour tracer evolution for release at6 o'clock on 24.11.2010.

The NCEP Global Forecasting System (GFS) data with 1º×1º resolution is used as meteorological forcing and the WRF nesting capabilities are used for downscaling the problem to a horizontal resolution of 2 km. The meteorological simulations are carried out in four nested domains with resolutions 90, 30, 6, 2 km, downscaling from the region of South-Eastern Europe (90km) to Bulgaria (2km). The CMAQ simulations are carried out only in the innermost domain that consists of 256x181 points.

It is clear that the amount and nature of the accidental released gases will most probably not be known at the moment of the accident. That is why the concept of developing operational forecasting system, which follows the propagation of tracers, was accepted. The initial and boundary conditions for all pollutants, including tracers, are zero. The emissions of all pollutants, except for the tracers, are also zero. The corresponding emission files are produced by specially developed Fortran program, that produces tracer emissions for 11 locations (Fig. 1) in the domain of the chemical transport model. There are separate tracer species for each location and all of them have a hypothetical molar mass of 28 (the same as clean air). The emissions are area-source, assuming that 100 tons of pollutant are spilled in one grid cell and the pollutant evaporates in one hour. In the CMAQ chemical transport model the photolisis, chemistry, aerosol and cloud processes are switched off. The global mass-conserving scheme yamo is used for calculating the horizontal and vertical advection. The calculation of the horizontal diffusion coefficient is based on the local wind deformation, while for vertical diffusion the ACM2 scheme is used.

The system runs operatively at 00, 06, 12, 18 UTC every day and works in the following way: First, the meteorological input data is downloaded from NCEP and the WRF input files are prepared. Then the meteorological model is run for 15 hours, with 4 nested domains. The first 6 hours of the simulation are a spin-up and the next 9 hours are processed (by the CMAQ pre-processor MCIP) to become meteorological input for the chemical transport model. Then the CMAQ model is run for 9 hours and the output file with 15-min average surface concentrations is kept for archive in the OUTPUT folder. As an output of the system a series of images are produced, showing the sum of the 11 tracer concentrations at 15-min intervals for 9 hours. The units are relative, since the amount and the coverage of the toxic spill, as well as the molar mass of the pollutant and the evaporation rate, are hypothetical.

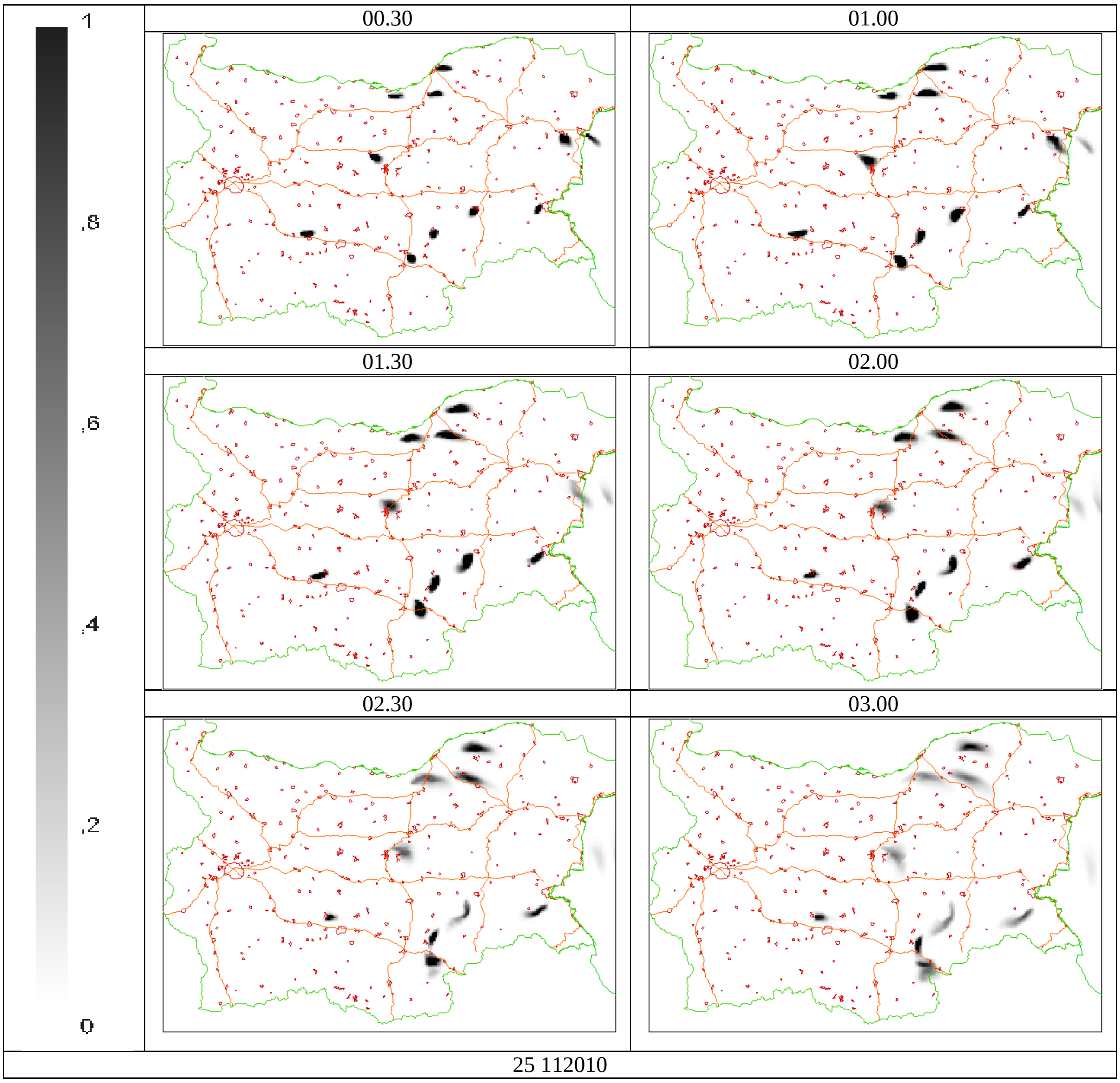

Figure 3. 3-hour tracer evolution for release at0 o'clock on 25.11.2010.

RESULTS AND DISCUSSION

Example of the simulated tracer evolution is shown in Fig. 3. The main characteristics of the plume propagation, which were outlined by the numerical experiments, carried out so fat are the following:

1. The shape of the plumes and the direction of their movement are governed by the meteorological conditions. Since there are no chemical reactions, the changes in the pollutant concentrations are only due to dispersion and deposition.

2. The local meteorological wind circulation can be very different than the mesoscale and this yet again confirms the need of high resolution. This is especially true for areas with complex terrain, like southern Bulgaria. The breeze circulation at the coast of the Black Sea during the warm months is also important – it can contribute to cleansing the air (when the wind is blowing from the west) or to high pollutant concentrations inland (when the wing is blowing from the east).

3. The simulations show, that if there are strong winds or the thermodynamic conditions are unstable, the surface concentrations drop 5 times in 2 hours, but this is a rare case. In most simulations the concentrations remain high at least 3 hours after the release. For some sites in some simulations the toxic plumes remain almost stationary and the surface concentrations remain high for more than 2 hours.

Some of the sites are very close to big cities (Varna, Burgas, Rousse) and major roads or railway lines, so the emergency simulations could be really useful, showing if the plume approaches a region with dense population. Even cities, which are more than 20km away from the source, can be under threat: on 24.11.2010, 18h release – the city of Plovdiv is threatened by the plume originating from “Velichkovo” site.

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