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Air pollution transport in the Balkan region and country-to-country pollution exchange between Romania, Bulgaria and Greece

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ABSTRACT

US EPA Models-3 system is used for calculating the exchange of ozone pollution between three countries in southeast Europe. For the purpose, three domains with resolution 90, 30 and 10 km are chosen in such a way that the most inner domain with dimensions 90×147 points covers entirely Romania, Bulgaria and Greece.

The ozone pollution levels are studied on the base of three indexes given in the EU Ozone Directive, mainly accumulated over threshold of 40 ppb for crops (AOT40C, period May–July), number of days with 8-h running average over 60 ppb (NOD60) and averaged daily maximum (ADM). These parameters are calculated for every scenario and the influence of each country emissions on the pollution of the region is estimated and commented.

Oxidized and reduced sulphur and nitrogen loads over the territories of the three countries are also determined. The application of all scenarios gave the possibility to estimate the contribution of every country to the S and N pollution of the others and detailed blame matrixes to be build.

Comparison of the ozone levels model estimates with data from the EMEP monitoring stations is made.

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1. Introduction

Regional studies of the air pollution over the Balkans, including country-to-country pollution exchange, had been carried out for quite a long time (see for example BG-EMEP (1994–1997), EMEP (1998), Syrakov et al. (2002), Ganev et al. (2002, 2003), Zerefos et al. (1998, 2000, 2004), Chervenkov et al. (2005a,b) and Chervenkov (2006)). These studies were focused on both studying some specific air pollution episodes and long-term simulations and produced valuable knowledge and experience about the regional to local processes that form the air pollution pattern over Southeast Europe.

The air pollution transport is subject to different scale phenomena, each characterized by specific atmospheric dynamics mechanisms, chemical transformations, typical time scales, etc. The specifics of each transport scale define a set of requirements for appropriate treatment of the pollutants transport and transformation processes, respectively for suitable modelling tools, data bases, scenarios and time scales for air pollution evaluation. The present study attempts to answer all these requirements by applying up-to date tools and facilities.

The present paper will focus on some results which give an impression on the country-to-country (CtC) regional scale pol-

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lution exchange (see also Prodanova et al. (2005a,b, 2006a,b)). The simulations performed are oriented towards solving two tasks—CtC study of ozone pollution levels in the region and CtC study of sulphur and nitrogen loads in the region.

2. Modelling tools

The US EPA Model-3 system was chosen as a modelling tool because it appears to be one of the most widely used models with proved simulation abilities. Important advantages of this software are that it is free downloadable and it can be run on contemporary PCs. In the same time, this is a modelling tool of large flexibility with a range of options and possibilities to be used for different applications/purposes. Many research groups in Europe already used the Model-3 system or some of its elements and this number are going to increase rapidly.

The system consists of three components:

- MM5 – the fifth generation PSU/NCAR Meso-meteorological Model MM5 – (Dudhia, 1993; Grell et al., 1994) used as meteorological pre-processor;
- CMAQ – the Community Multiscale Air Quality System CMAQ – (Byun and Ching, 1999; Byun and Schere, 2006);
- SMOKE – the Sparse Matrix Operator Kernel Emissions Modelling System – (CEP, 2003).

Each of these models consists of number of programs that can be run in different schedules depending on the task to be solved. The output of one module is input to others. Taking into account that they had to be run for multiple days it occurred that very complicated LINUX scripts were necessary to be created. The obtained results have been visualized by several graphical packages – GRAPH, GRADS, PAVE, SURFER – supplemented by meta-languages for automation of drawing. All this presumes high experience in Linux and other languages.

3. Model configuration and brief description of the simulations

3.1. Model domains

As far as the base meteorological data for 2000 is the NCEP global analysis data with 1° × 1° resolution, it was necessary to use MM5 and CMAQ nesting capabilities as to downscale to 10 km step for a domain over Balkans. The MM5 pre-processing program TERRAIN was used to define three domains with 90, 30 and 10 km horizontal resolution (51 × 45, 79 × 61 and 160 × 103 grid points, respectively). These three nested domains (referred as D3 domain set) were chosen in such a way that the finest resolution domain contain Bulgaria and two neighbouring Balkan countries—Romania and Greece, entirely. Lambert conformal conic projection, with true latitudes at 30°N and 60°N, and the central point with coordinates 41.5°N and 24°E were chosen. Together with grids definition TERRAIN specifies the raw topographic, vegetative, and soil-type data to all grid points.

The D3 model domains are shown in Fig. 1.

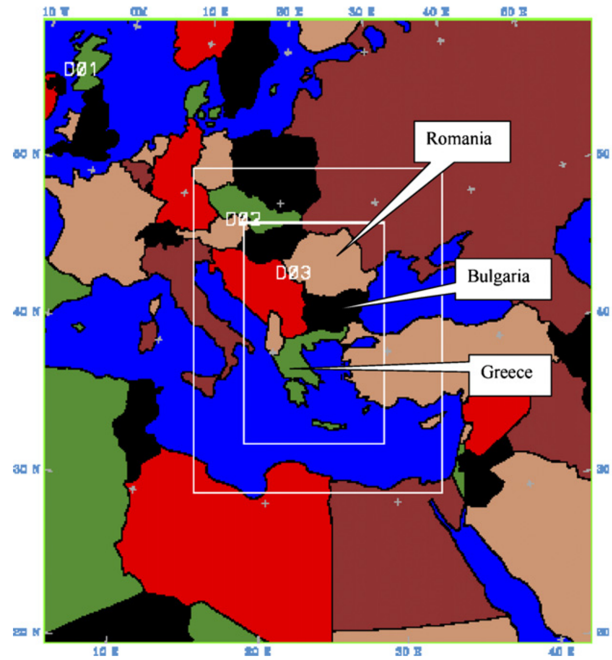

Fig. 1 – The three computational domains produced by TERRAIN.

3.2. MM5 simulations

First, MM5 was run on both outer grids of D3 (90 and 30 km resolution) simultaneously with "two-way" nesting mode on. Then, after extracting the initial and boundary conditions from the resulting fields for the 10-km domain, MM5 was run on the finer 10 km grid as a completely separate simulation with "one-way" nesting mode on. In this approach, information from the 30-km grid was transferred to the 10-km domain through boundary conditions during the simulation, but there is no feedback from the 10-km field up-scale to the 30-km domain. All simulations were made with 23 σ-levels going up to 10 hPa height.

The selected physical options of MM5 are shown in Table 1.

The model may be set to relax toward observed temperature, wind and humidity through four-dimensional data assimilation, known as FDDA (Stauffer and Seaman, 1990). FDDA amounts to adding an additional term to the prognostic equations that serves to "nudge" the model solution toward the individual observations. This significantly reduces

Table 1 – MM5 Parameterizations used in this study

Physics option	Parameterization
Cloud microphysics	Mixed-phase (Reisner)
Cumulus parameterization	Grell
Planetary boundary layer	MRF PBL
Radiation scheme	Cloud-radiation scheme
Shallow convection	None
Varying SST with time?	Yes
Soil temperature model	Five-layer soil model
Snow cover	With effect

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