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EVALUATION OF THE CONTRIBUTION OF DIFERENT SNAP CATEGORIES TO THE AIR POLLUTION OVER THE BALKAN PENNINSULA

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Abstract: Regional and local scale studies of the air pollution over the Balkans, including country-to-country pollution exchange, have been carried out for quite a long time. It seems, however, that the impact of the different SNAP categories to the air pollution of the Balkan Peninsula as a whole have never been comprehensively studied. Carrying out such a comprehensive study with up-to-date modelling tools detailed and reliable input data for long enough simulation periods and good resolution is the aim of the present work.
The simulations are carried out for several years for several emission scenarios. The obtained results make it possible to evaluate the contribution of different SNAP categories in many different terms – spatial pattern, averaged over the Balkans, typical and extreme impacts, seasonal behaviour.

Key words: *Regional scale modelling, emission scenarios, US EPA Model-3 system, SNAP category contribution*

INTRODUCTION

Regional studies of the air pollution over the Balkans, including country-to-country pollution exchange, have been carried out for quite a long time - for example BG-EMEP (1994, 1995, 1996, and 1997), Syrakov *et al.* (2002), Ganev *et al.* (2003, 2009), Zerefos *et al.* (2000), Chervenkov *et al.* (2006), Poupkou *et al.* (2008), Symeonidis *et al.* (2008), Zanis *et al.* (2007). 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 and local scale processes that form the air pollution pattern over Southeast Europe. It seems, however, that the impact of the different SNAP categories on the air pollution of the Balkan Peninsula as a whole had never been comprehensively studied. Carrying out such a comprehensive study with up-to-date modelling tools detailed and reliable input data for long enough simulation periods and good resolution is the aim of the present work.

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.

In order to obtain high quality scientifically robust assessments of the air quality and its origin, it is clear that extensive sensitivity studies have to be carried out. Performing extensive simulations of this kind with up to date highly sophisticated numerical models obviously requires computer resources in order of magnitude of those provided by the so-called supercomputers. Using supercomputers, however, is rather expensive and far beyond what most of the research groups can afford. Luckily an alternative technology – the grid computing (Atanassov *et al*., 2006, Foster and Kesselmann, 1998, Ganev *et al*., 2009), is recently developing intensively, which makes formulating and solving problems absolutely impossible several years ago, already quite relevant.

METHODOLOGY

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 systems with proved simulation abilities. Important advantages of this software are that it is downloadable free 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 use the Model-3 system or some of its elements and this number is going to increase.

The system consists of three components: **MM5** - the 5th 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 *et al.* (1998), Byun and Ching (1999); **SMOKE** - the Sparse Matrix Operator Kernel Emissions Modelling System.

Input data

The large scale (background) meteorological data used by the application is the NCEP Global Analysis Data with $1^{\circ}\times 1^{\circ}$ resolution. At the moment the created database contains all the necessary information since year 2000.

The TNO high resolution inventory (A. Visschedijk *et al*., 2007) is exploited. The inventory is produced by proper disaggregation of the EMEP 50-km inventory data base. The TNO inventory resolution is $0.125°\times 0.0625°$ longitude-latitude, that is on average about 14×7 km. GIS technology is applied as to produce area and large point source input from this data base. It must be mentioned that the TNO emissions are distributed over 10 SNAPs (Selected Nomenclature for Air Pollution) classifying pollution sources according the processes leading to harmful material release to the atmosphere. The inventory contains 8 pollutants: CH4, CO, NH3, NMVOC (VOC), NOx, SOx, PM10 and PM2.5.

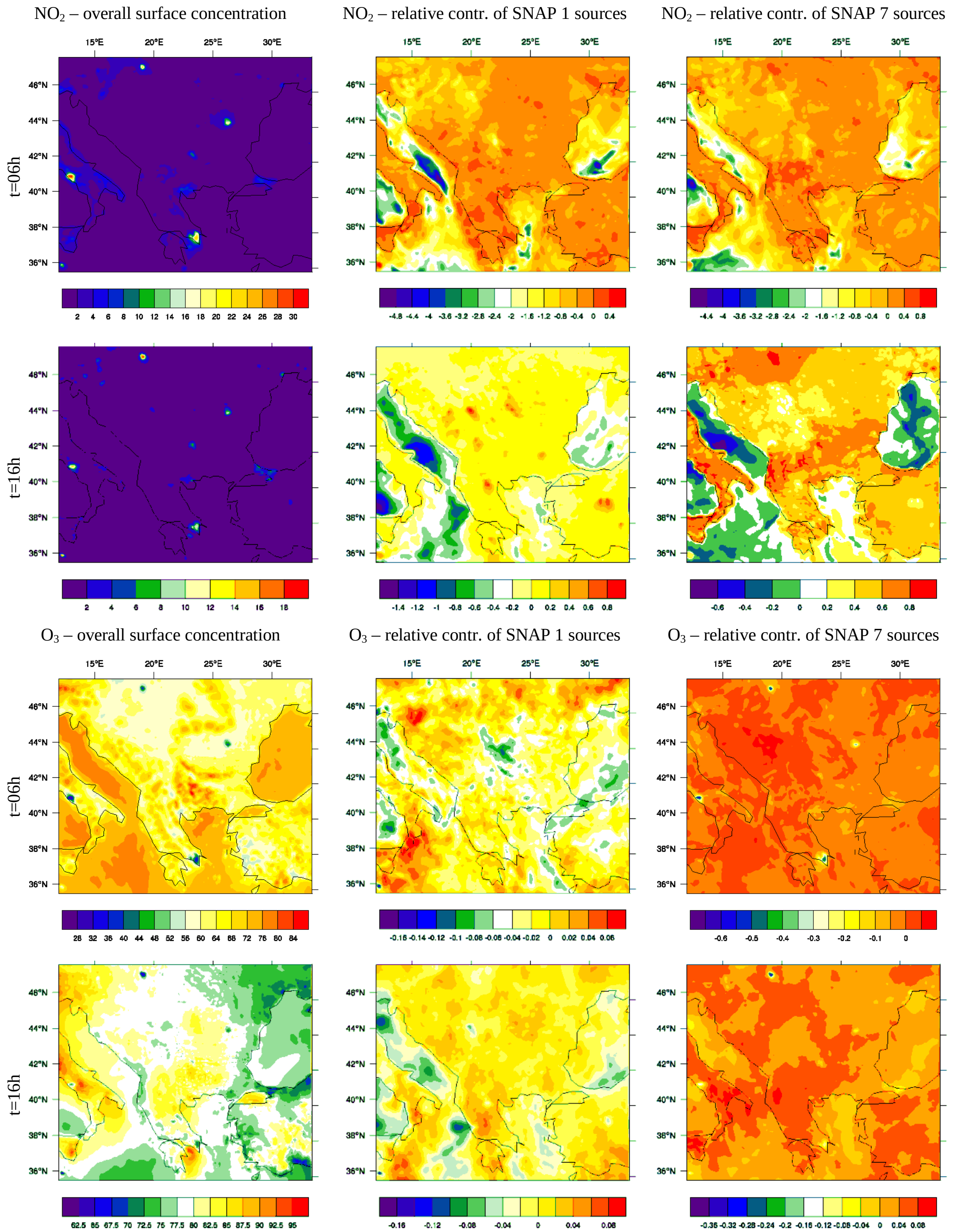

Figure 1. Plots of surface concentrations [μg/m^3] and relative contributions of SNAP 1 and 7 sources for NO_2 and O_3 for 06 and 16 UTC, “typical” day in July.

CMAQ demands its emission input in specific format reflecting the time evolution of all polluters accounted for the used chemical mechanism. A specific approach for obtaining speciation profiles is used here. The USA EPA data base is intensively exploited. A Bulgarian emission expert has found coincidence between main Bulgarian sources for every SNAP with similar source types from US EPA nomenclature. The weighted averages of the respective speciation profiles are accepted as SNAP-specific splitting factors, weights being the percentage of contribution of every source type in total Bulgarian emission in particular SNAP. In such a way VOC and PM2.5 speciation profiles are derived. It must be noted that the choice of source types and their contribution to the respective SNAP emissions are country specific, i.e. the obtained speciation profiles are applicable for Bulgarian territory, mainly.

Domains and nesting

As far as the background meteorological data is the NCEP Global Analysis Dat**a** with 1º×1º resolution, it is necessary to use MM5 and CMAQ nesting capabilities so as to downscale to 3 km step for the innermost domain. The MM5 pre-processing program TERRAIN was used to define four domains with 81 (D1), 27 (D2), 9 (D3) and 3 (D4) *km* horizontal resolution. These four nested domains were chosen in such a way that the domain with a horizontal resolution of 9 *km* covers the whole Balkan Peninsula.

Emission scenarios

Let in the chosen domain there are N countries and the total number of source categories is M (generally $M=12$ if maritime and biogenic emissions are accounted for). Let an arbitrary (concentration, deposition, columnar value, process contribution, etc.) pollution characteristic, obtained with all the emissions accounted for is denoted by φ . Let φ_{nm} is the respective characteristic obtained when the emissions form source category m in country n are reduced by a factor of α . In such a case the quantity φ_{nm}:

$$\varphi_{nm} = \frac{1}{1-\alpha}\frac{\phi-\phi_{nm}}{\phi}.100 \qquad (1)$$

can be interpreted as the relative (in %) contributions of emission category m in country n to the formation of the characteristic φ .

It is obvious that more than one SNAP category emissions in more than one country can be reduced by a factor of α and so the quantities $\varphi_{n1m1,n2m2,\dots,nLmL}$ ($n1, n2, \dots, nL \leq N$, $m1, m2, \dots, mL \leq M$) can be simulated and the respective estimations $\varphi_{n1m1,n2m2,\dots,nLmL}$ of the joint influence of the L pairs of chosen SNAP categories in chosen countries in the formation of the pollution characteristic φ can be evaluated. It is possible, in particular, to evaluate the contribution of all the emissions from a chosen country, or of the emissions from a chosen SNAP category in the whole domain, which are actually the emission scenarios that will be considered in the present paper.

SOME EXAMPLES OF THE SNAP CATEGORY CONTRIBUTION SIMULATIONS

The modelling infrastructure (models and input data, Grid simulation practices) has been well validated (see for example Ganev, 2009) which allows applying it for air pollution studies for the Balkan region with trust in the obtained results.

Following the methodology described above, with emission reduction factor $\alpha = 0.8$, MM5 and CMAQ simulations were carried out for the years 2003- 2009. The SNAP categories considered are 1 – combustion in energy and 7 – road transport. Averaging the fields over the whole ensemble of results for the respective month produces a diurnal behaviour of given pollution characteristic, which can be interpreted as “typical” for the month (respectively season). The characteristic, which will be demonstrated and discussed as an example further in this paper is the surface concentration c for months January and July. Analysing the results one should keep in mind that the contribution of a SNAP category in a given point (or sub-domain) reflects the respective SNAP sources in the whole integration domain.

Plots of surface concentrations of O_3 and NO_2, typical for July, for 06 and 16 UTC are shown in Figure 1, together with the relative contribution of the emissions from SNAP categories 1 and 7. One can not help, but notice how the big industrial sites, big cities, roads are manifested as sources in the NO_2 plots and as sinks in the O_3 plots. The plot of the SNAP 7 relative contribution to NO_2 pollution for 16 UTC can almost be used as a map of the roads in the region.

Plots of this kind are rather spectacular and can give a good qualitative impression of the spatial complexity of the different SNAP categories contribution. In order to demonstrate the pollution and SNAP code contribution behaviour in a more simple and easy to comprehend way, the respective fields can be averaged over some domain (in this case the territory of Bulgaria), which makes it possible to jointly follow and compare the diurnal behaviour of the overall pollution and the pollution from the respective SNAP categories (obtained by multiplying the relative contribution (1) by the concentration from all the sources).

Such plots for some of the compounds are given in Figures 2 and 3 for January and July respectively. There are several things in these plots which should be mentioned. First of all the contribution of both SNAP categories to the NO_2, PM2.5 and PM-coarse is quite significant for both January and July (the SNAP 7 contribution for NO_2 is definitely bigger than the SNAP 1 one). The diurnal courses of the PM2.5 and PM-coarse overall concentrations, as well as the concentrations from Snap categories 1 and 7 for January and July are very similar.

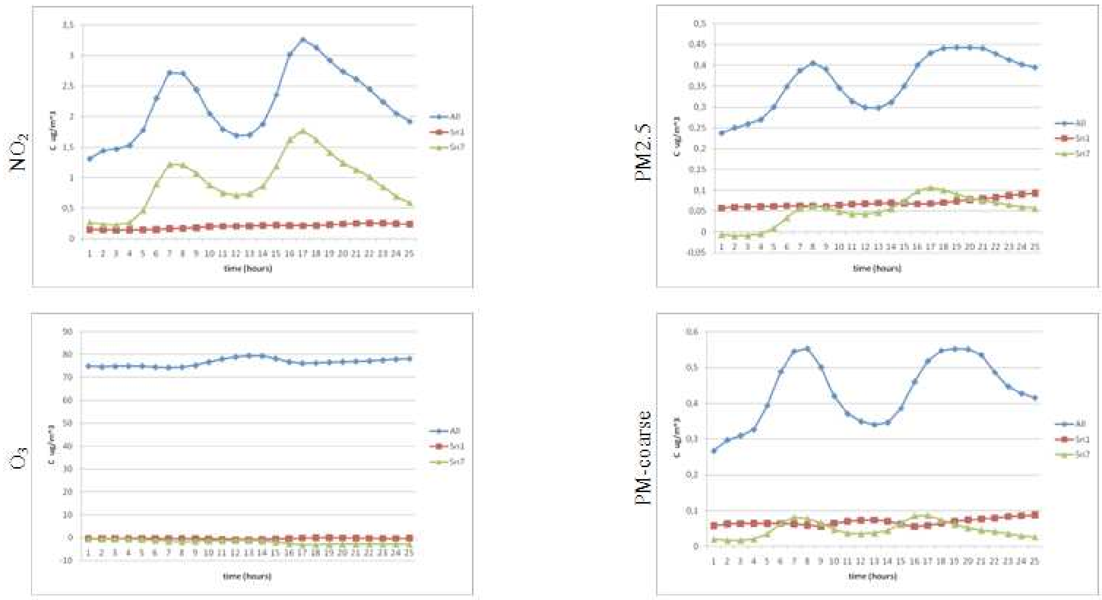

Figure 2. Plots of the diurnal course of surface concentrations [μg/m^3] from all the sources and from the sources from SNAP 1 and 7 sources for NO_2, O_3, PM2.5 and PM-coarse for a "typical" day in January.

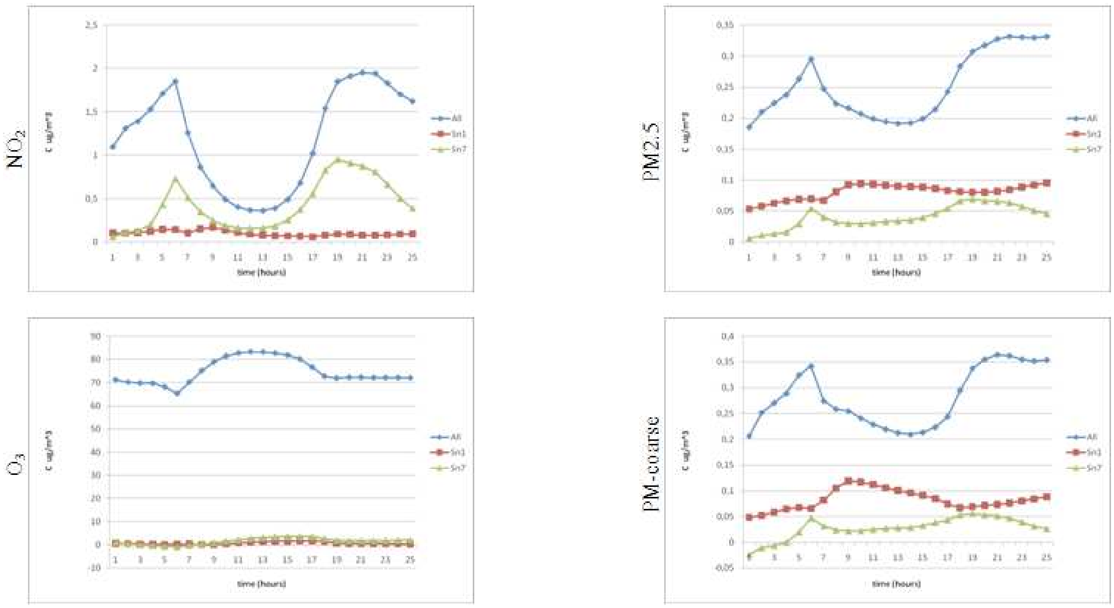

Figure 3. Plots of the diurnal course of surface concentrations [μg/m^3] from all the sources and from the sources from SNAP 1 and 7 sources for NO_2, O_3, PM2.5 and PM-coarse for a "typical" day in July.

The overall surface concentrations of NO_2, PM2.5 and PM-coarse have similar specifics for the overall concentration and the part of the concentration due to SNAP 7 emissions – peaks in the morning and late afternoon, early evening hours and a minimum around noon. This obviously is due partially to the specific diurnal course of the road transport (SNAP 7) emissions, but probably also to the meteorological conditions – a tendency for predominant unstable conditions during the day, which causes more intensive vertical mixing, thus transporting some of the surface pollution aloft. The last effect can be followed also in the diurnal course of the concentrations due to SNAP 1 emissions (elevated sources) – slight peaks around noon can be observed for NO_2, PM2.5 and PM-coarse in July.

The O_3 diurnal course manifests the expected maximum in daytime. Surprisingly the contribution of both SNAP categories to the overall O_3 concentration is small. This probably means that the O_3 in Bulgaria is mostly "imported", while the Bulgarian sources cause O_3 formation somewhere else. This is not such a revolutionary conclusion, bearing in mind that the O_3 is a secondary pollutant and can be formed away from the O_3 precursor sources.

CONCLUSIONS

Studying the air pollution fields response to emission changes (model sensitivity to emission input) is obviously a task of great practical importance, obviously connected with formulating short-term (current) pollution mitigating decisions and long-term pollution abatement strategies.

The numerical experiments performed produced a huge volume of information, which have to be carefully analyzed and generalized so that some final conclusions could be made. The obtained ensemble of numerical simulation results is extensive enough to allow statistical treatment – calculating not only the mean concentrations and different SNAP categories contribution mean fields, but also standard deviations, skewness, etc. with their seasonal and diurnal variations.

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