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CONTRIBUTION OF DIFFERENT EMISSION SOURCES TO THE ATMOSPHERIC COMPOSITION FORMATION IN CITY OF SOFIA

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Abstract:
Some extensive numerical simulations of the atmospheric composition fields in the city of Sofia have been recently performed and an ensemble, comprehensive enough as to provide statistically reliable assessment of the atmospheric composition climate of Sofia – typical and extreme features of the special/temporal behaviour, annual means and seasonal variations, etc. has been constructed.
The US EPA Models-3 system (WRF, CMAQ, SMOKE) is chosen as a modeling tool. As the NCEP Global Analysis Data with 1 degree resolution is used as meteorological background, the system nesting capabilities were applied for downscaling the simulations to a 1 km resolution over Sofia. The national emission inventory was used as an emission input for Bulgaria, while outside the country the emissions were taken from the TNO inventory. Special pre-processing procedures are created for introducing temporal profiles and speciation of the emissions. The biogenic emissions of VOC are estimated by the model SMOKE.
The present work aims at studying the contribution of different emission sources to the atmospheric composition formation in the region.
The study is based on a large number of numerical simulations carried out day by day for years 2008-2014 and 5 emission scenarios – with all the emissions (SNAP_ALL), with the emissions from energetics (SNAP_01), emissions from non-industrial (SNAP_02) and industrial combustions (SNAP_03) and road transport (SNAP_07) excluded. Results from the numerical simulations concerning the contribution of the different emission categories are demonstrated in the paper.

Key words: *urban air pollution, computer simulations, SNAP categories, contribution of different emission sources*

INTRODUCTION

The atmospheric composition in urban areas is one of the primary tasks in air pollution studies. The seasonal air pollution climate in urban areas have not been systematically studied yet, but some air pollution modeling for the city of Sofia had been performed and even air pollution forecast for the city is operationally going on (Syrakov et al., 2012), (Georgieva, 2014) and (Georgieva et al., 2015). Recently extensive studies for long enough simulation periods and good resolution of the atmospheric composition status in Bulgaria have been carried out using up-to-date modeling tools and detailed and reliable input data (Gadzhev et al., 2011a, b), but next step in studying the atmospheric composition climate is performing simulations in urban scale. The simulations aim at constructing of ensemble, comprehensive enough as to provide statistically reliable assessment of the atmospheric composition climate of the city of Sofia – typical and extreme features of the special/temporal behaviour, annual means, seasonal variations, etc. Some evaluations of the the contribution of different pollution sources to the atmospheric composition of the city of Sofia will be presented in the present paper.

METHODOLOGY

The simulations were carried out using the US EPA Models-3 system: WRF (Shamarock et al., 2007) used as meteorological pre-processor, CMAQ - the Community Multiscale Air Quality System (Byun, 1998), (Byun and Ching, 1999), being the Chemical Transport Model (CTM) of the system, and SMOKE - the Sparse Matrix Operator Kernel Emissions Modelling System (CEP, 2003) – the emission pre-processor of Models-3 system.

The large scale (background) meteorological data used is the NCEP Global Analysis Data with 1˚x1˚resolution. WRF and CMAQ nesting capabilities are applied for downscaling the simulations to a 1 km step for the innermost domain (Sofia). The national emission inventory is used as an emission input for Bulgaria, while outside the country the emissions are taken from the TNO inventory (Vestreng, 2001), (Vestreng et al., 2005) and (Visschedijk et al., 2007). The simulations are performed for 7 years (2008 to 2014) with Two-Way Nesting mod on. Special pre-processing procedures are created for introducing temporal profiles and speciation of the emissions. The biogenic emissions of VOC are estimated by the model SMOKE (Schwede et al., 2015), (Gadzhev et al., 2012), (Syrakov et al., 2013) and (Georgieva and Ivanov, 2017).

RESULTS

Six emission scenarios will be considered in the present paper: Simulations with all the emissions and with the emissions from all the SNAP categories (SNALL), SNAP categories 1 (energetic – SN1), 2 (non-industrial combustions 2– SN2), 3 (industrial combustions – SN3) and 7 (road transport – SN7) for Sofia reduced by a factor of 0.8. This makes it possible to evaluate the contribution of all the emissions, as well as the emissions from road transport, energetic, industrial and non-industrial combustions to the atmospheric composition in the city. The relative contribution of the emissions for each scenario was calculated for each day of this 7 year period and then by averaging over the ensemble, the typical fields of relative contributions of these emissions for each of the compound surface concentrations were calculated for the 4 seasons and annually. Some illustrations of the emission impact evaluations will be given in the present paper.

Plots of some of these typical seasonal (summer and winter) surface relative contribution of SN7 to the formation of pollutants NO_2, O_3 and FPRM (12:00 GMT) are presented in Figure 1. The spatial and seasonal variability in NO_2, O_3 and FPRM emission contribution fields is very well manifested.

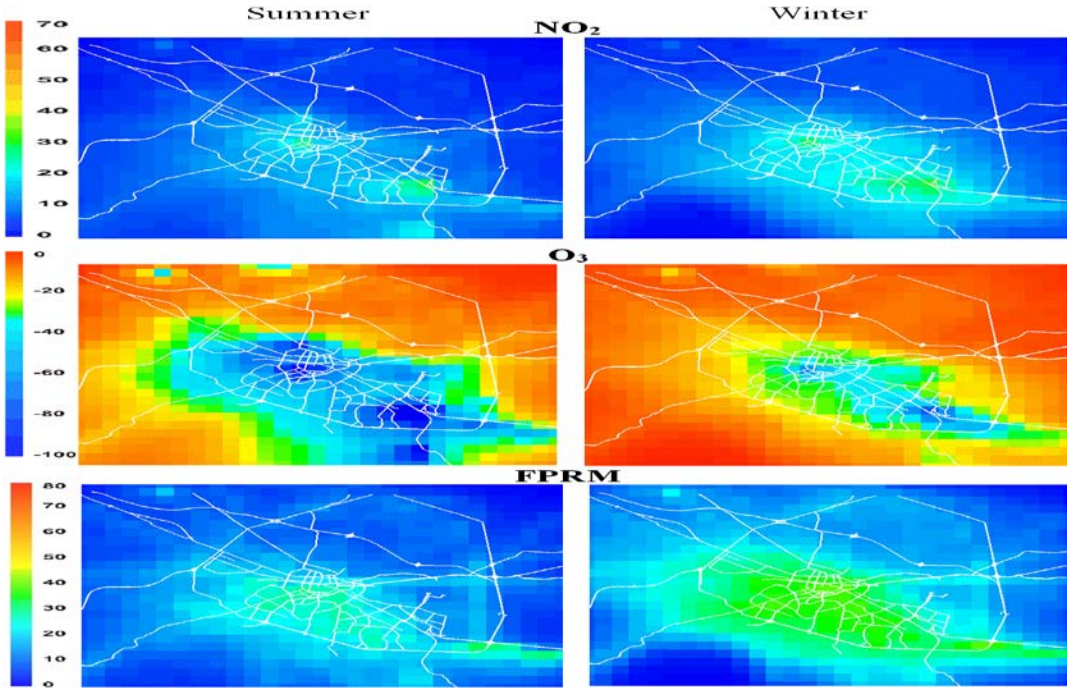

Figure 1. Seasonal (summer and winter) surface relative contribution of the emissions from SN7 to the formation of surface NO_2, O_3 and FPRM [%] at 12:00 GMT

The average summer and winter contribution of the emissions from SN7 to the formation of NO_2 is positive. The places with high relative contribution are mainly in the city centre and road network.

On the plots for the average summer and winter contribution of the emissions from SN7 to the formation of Ozone it can be seen that the contribution is strictly negative, and the places with high negative values are the same as NO_2 maximums. That is not so strange having in mind the role of NO_2 in the O_3photochemistry and also that the ozone in Bulgaria is to a great extent due to transport from abroad (Gadzhev et al., 2013a, b, c and 2014)

The surface FPRM relative contributions are positive and bigger during the winter months than in summer and are larger in the city centre and over the most busy roads (places with most intensive road transport). For both NO_2 and FPRM the SN 7 emission contributions are larger for the winter. The main reason is probably the atmosphere stability and hampered transport of pollutants aloft.

For all the emission categories the pattern of the contribution fields is rather complex, which reflects the emission source configuration, the heterogeneity of topography, land use and meteorological conditions.

Plots of this kind can give a good qualitative impression of the spatial complexity of the emission contribution. In order to demonstrate the emission contribution behaviour in a more simple and easy to comprehend way, the respective fields can be averaged over some domain, which makes it possible to follow and compare the diurnal behaviour of the respective contributions for different species. Graphics of the diurnal evolution of the "typical" relative contribution of summer and winter emissions of SNAP categories 1, 2, 3, 7 and all the emissions to the surface concentrations of NO_2, FPRM and CPRM, averaged for the territory of Sofia city, are shown in Figure 2.

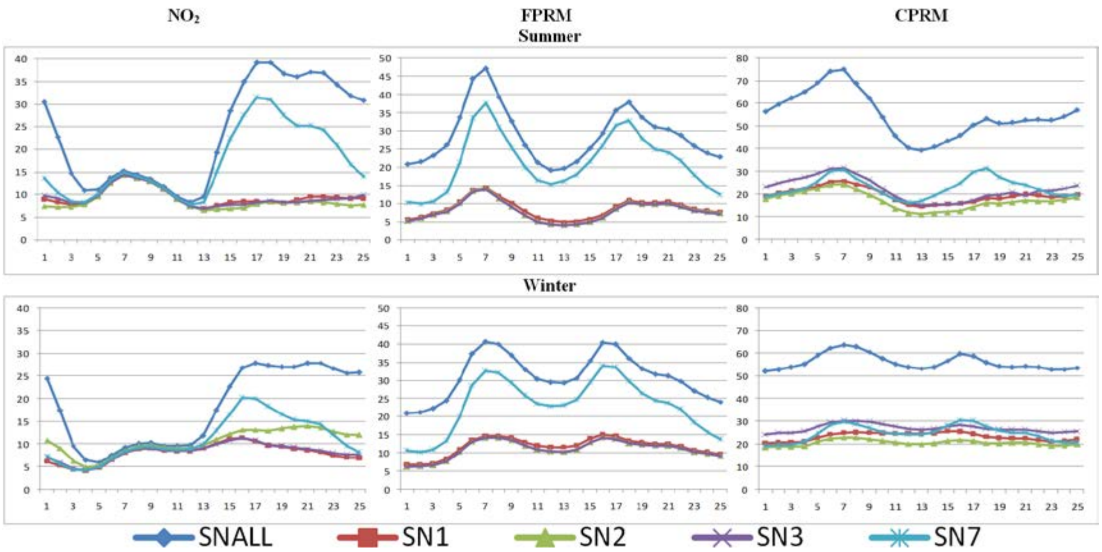

Figure 2. Seasonal (summer and winter) averaged relative contribution of all the emissions and the emissions from different SNAP categories [%] to the formation of NO_2, FPRM and CPRM for Sofia

In first place it should be noted that the contributions of the emissions from all the SNAP's to the formation of surface concentrations of NO_2, FPRM and CPRM are positive. Quite natural the relative contribution of all the emissions is the biggest. Generally all the contributions for all the compounds have well displayed seasonal and diurnal course. It should be noted that for a given season the contributions from different SNAP categories are different, but have qualitatively quite similar diurnal course in spite that the emissions from the different SNAP categories have different diurnal courses. This means that the main factor, which determines the emission contributions are the meteorological conditions. Yet some pics in the contribution of the emissions from SN7 during the hours with most busy road traffic can be observed.

From the plots for the summer and winter contributions of the different sources that lead to the formation of surface NO_2 in Sofia it could be seen that the dominant emissions are mostly from SN7. Exception could be seeing in the winter for NO_2 plots during the night time when the contribution of SN2 is bigger than SN7.

From the plots for the summer and winter contributions of the different sources that lead to the formation of surface FPRM, it can be seen that the emissions from SN7 are strictly dominant (up to about 30%). The diurnal distribution shows that for all the SNAPs there local maximums of the contribution in the morning and afternoon, and minimum around noon and during the night.

In the case of surface CPRM it can be seen that there is not a clearly dominant SNAP category, except for the afternoon hours in summer, when the contribution of SN7 emissions rises to 30% and becomes significantly larger than the contribution of the other SNAP categories, but generally the emissions from SN3 have the biggest contribution. The smallest contributions have the emissions from energetic and non-industrial combustion - about 20% each.

The contribution of emissions from all categories (SNALL) is less than 100%, which means that part of the concentrations are formed from sources external to the domain and are result of transport from outside the Sofia city.

CONCLUSION

The results, presented in the paper are just a first glance on the atmospheric composition status in urban areas, so very few decisive conclusions can be made at this stage of the study. Nevertheless, some of the major findings so far will be listed below:

- Different emissions relative contribution to the concentration of different species could be rather different, varying from almost 80% to several %. The contributions of different emission categories to different species surface concentrations have different diurnal course.
- For all of the pollutants the contribution of SNALL is dominant, but this contribution of emissions is less than 100%, which means that part of the concentrations are formed from sources outside the Sofia city, due to transport into the domain.
- The contribution of emissions of all SNAPs to ozone levels in Sofia is rather small and strictly negative. This is probably due to the fact that the NO_x concentrations are relatively small and they are the limitation factor for ozone formation. That means that the surface O_3 in Sofia mostly originates from outside the city.
- The contribution of all SN7 (road transport) to NO_2 surface concentrations is positive and reaches 50% around the most busy traffic roads. The SN7 emissions have dominant contributions to the NO_2 and FPRM surface concentrations.
- Dominant contribution to the surface CPRM concentrations have emissions of SNAP7 (road transport) and SNAP3 (industrial combustions).

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REFERENCES

Byun, D., 1998: Dynamically Consistent Formulation in Meteorological and Air Quality Models for Multi-scale Atmospheric Studies, *J. Atm.Sci.*, in review.

Byun, D., and J.K.S. Ching, 1999: Science Algorithms of the EPA Models-3 Community Multiscale Air Quality (CMAQ) Modeling System, United States Environmental Protection Agency, Office of Research and Development, Washington, DC 20460, EPA-600/ R-99/030.

CEP, 2003: Sparse Matrix Operator Kernel Emission (SMOKE) Modeling System, University of Carolina, Carolina Environmental Programs, Research Triangle Park, North Carolina.

Gadzhev G., G. Jordanov, K. Ganev, M. Prodanova, D. Syrakov, N. Miloshev, 2011a: Atmospheric Composition Studies for the Balkan Region, *Lecture Notes in Computer Sciences, LNCS 6046, c. Springer-Verlag Berlin Heidelberg,* 150-157.

Gadzhev, G., Syrakov, D., Ganev, K., Brandiyska, A., Miloshev, N., Georgiev, G., Prodanova, M., 2011b: Atmospheric composition of the Balkan region and Bulgaria. Study of the contribution of biogenic emissions, *AIP Conference Proceedings*, **1404**, 200-209.

Gadzhev, G., Ganev, K., Syrakov, D., Miloshev, N., Prodanova, M., 2012: Contribution of Biogenic Emissions to the Atmospheric Composition of the Balkan Region and Bulgaria, *Int. J. Environment and Pollution*, **Vol. 50**, Nos. 1/2/3/4, 2012, 130-139.

Gadzhev, G., Ganev, K., Miloshev, N., Syrakov, D., Prodanova, M., 2013a: Numerical Study of the Atmospheric Composition in Bulgaria, *Comp. and Mathematics with Applications*, **65**, 402-422.

Gadzhev G., K. Ganev, D. Syrakov, M. Prodanova and N. Miloshev, 2013b: Some Statistical Evaluations of Numerically Obtained Atmospheric Composition Fields in Bulgaria, *Proc. of 15th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes*. 6-9 May 2013, Madrid, Spain, 373-377.

Gadzhev, G., Ganev, K., Prodanova, M., Syrakov, D., Atanasov, E., Miloshev, N., 2013c: Multi-scale Atmospheric Composition Modelling for Bulgaria, *NATO Science for Peace and Security Series C: Environmental Security*, **137**, 381-385.

Gadzhev, G., Ganev, K., Miloshev, N., Syrakov, D., Prodanova, M., 2014: Calculation Of Some Ozone Pollution Indeces For Bulgaria, *Ecology and Safety*, **Vol. 8**, ISSN 1314-7234, pp: 384- 392

Georgieva, I., 2014: Study of the air quality index climate for Bulgaria, *Proc. of the international conference on numerical methods for scientific computations and advanced applications*, May 19-22, 2014, Bansko, ISBN978-954-91700-7-8, p. 39-42.

Georgieva I., G.Gadzhev, K. Ganev, M. Prodanova, D. Syrakov, N. Miloshev, 2015: Numerical study of the air quality in the city of Sofia – some preliminary results, *International Journal of Environment and pollution*, Vol. **57,** Nos. 3/4, 162-174.

Georgieva I and Ivanov V., 2017: Air Quality Index Evaluations for Sofia city *Proc. of the 17th IEEE International Conf. on Smart Technologies IEEE EUROCON* 2017, 6 - 8 July 2017, 920-925

Shamarock et al., 2007: A description of the Advanced Research WRF Version 2.

Schwede, D., G. Pouliot, and T. Pierce, 2005: Changes to the Biogenic Emissions Invenory System Version 3 (BEIS3), *Proc. of 4th Annual CMAS Models-3 Users's Conference*, September 26-28, 2005, Chapel Hill, NC.

Syrakov, D., Etropolska, I., Prodanova, M., Ganev, K., Miloshev, N., Slavov, K., 2012: Operational Pollution Forecast for the Region of Bulgaria, *American Institute of Physics*, Conf. Proc. 1487, p. 88 - 94

Syrakov, D., Etropolska, I., Prodanova, M., Slavov, K., Ganev, K., Miloshev, N., Ljubenov T., 2013: Downscaling of Bulgarian Chemical Weather Forecast from Bulgaria region to Sofia city, *American Institute of Physics*, Conf. Proc. **1561**, 120-132.

Vestreng V., 2001: Emission data reported to UNECE/EMEP: Evaluation of the spatial distribution of emissions. Meteorological Synthesizing Centre - West, The Norwegian Meteorological Institute, Oslo, Norway, Research Note 56, EMEP/MSC-W Note 1/2001.

Vestreng V., K. Breivik, M. Adams, A. Wagner, J. Goodwin, O. Rozovskaya, J.M. Pacyna, 2005: Inventory Review 2005 (Emission Data reported to LRTAP Convention and NEC Directive), Technical Report MSC-W 1/2005, EMEP.

Visschedijk A. J. H., P.Y.J. Zandveld and H.A.C. Denier van der Gon, 2007: A High Resolution Gridded European Emission Database for the EU Integrate Project GEMS, TNO-report 2007-A-R0233/B, Apeldoorn, The Netherlands.