SOME STATISTICAL EVALUATIONS OF NUMERICALLY OBTAINED ATMOSPHERIC COMPOSITION FIELDS IN BULGARIA

Georgi Gadzhev[1], Kostadin Ganev[1], Maria Prodanova[2], Dimiter Syrakov[2], Nikolay Miloshev[1]

1 National Institute of Geophysics, Geodesy and Geography, Bulgarian Academy of Sciences, Sofia, Bulgaria
2National Institute of Meteorology and Hydrology, Bulgarian Academy of Sciences, Sofia, Bulgaria

Abstract: Some extensive numerical simulations of the atmospheric composition fields in Bulgaria have been recently performed. The obtained ensemble of numerical simulation results is large enough to allow statistical treatment – calculating not only the mean concentrations and different source categories contribution mean fields, but also standard deviations, skewness, probability density functions, etc. with their dominant temporal modes (seasonal and/or diurnal variations).

Key words: *atmospheric composition numerical modelling, Models-3 system, ensemble of numerical simulation results.*

INTRODUCTION

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., 2013).

The simulations aimed at constructing of ensemble, comprehensive enough as to provide statistically reliable assessment of the atmospheric composition climate of Bulgaria – typical and extreme features of the special/temporal behavior, annual means and seasonal variations, etc.

The present paper will focus on two important characteristics of the atmospheric composition climate of Bulgaria – the concentrations of different compounds and the evaluation of the contribution of different emission categories to the overall air pollution in the country.

APPROACHES, TOOLS, DATA, DOMAINS AND NESTING

All the simulations are based on the US EPA Models-3 system. The system consists of three components: MM5 (Dudhia, 1993, Grell et al., 1994), used as meteorological pre-processor, CMAQ (Byun et al., 1998, Byun and Ching, 1999), the Chemical Transport Model of the system and SMOKE (CEP, 2003) – the emission pre-processor of Models-3 system.

The large scale (background) meteorological data used by the study is the NCEP Global Analysis Data with $1^o \times 1^o$ resolution. The MM5 and CMAQ nesting capabilities are used to downscale the problem to a 3 km horizontal resolution for the innermost domain (Bulgaria).

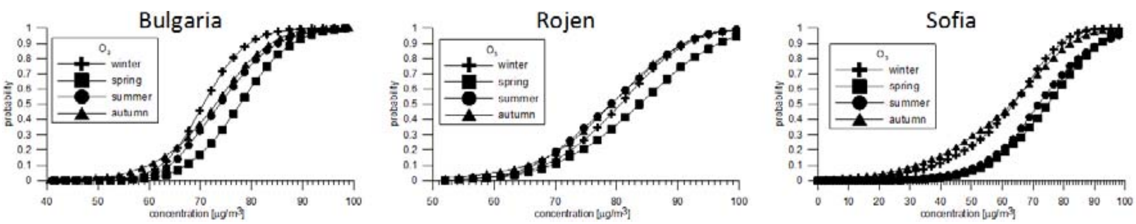

Figure 1. Seasonal variations of the cumulative distribution function of the surface ozone for Bulgaria, Rojen and Sofia

The TNO high resolution emission inventory (A. Visschedijk et all., 2007) is exploited. A more detailed description of the emission modeling is given in Gadzhev et al. (2013).

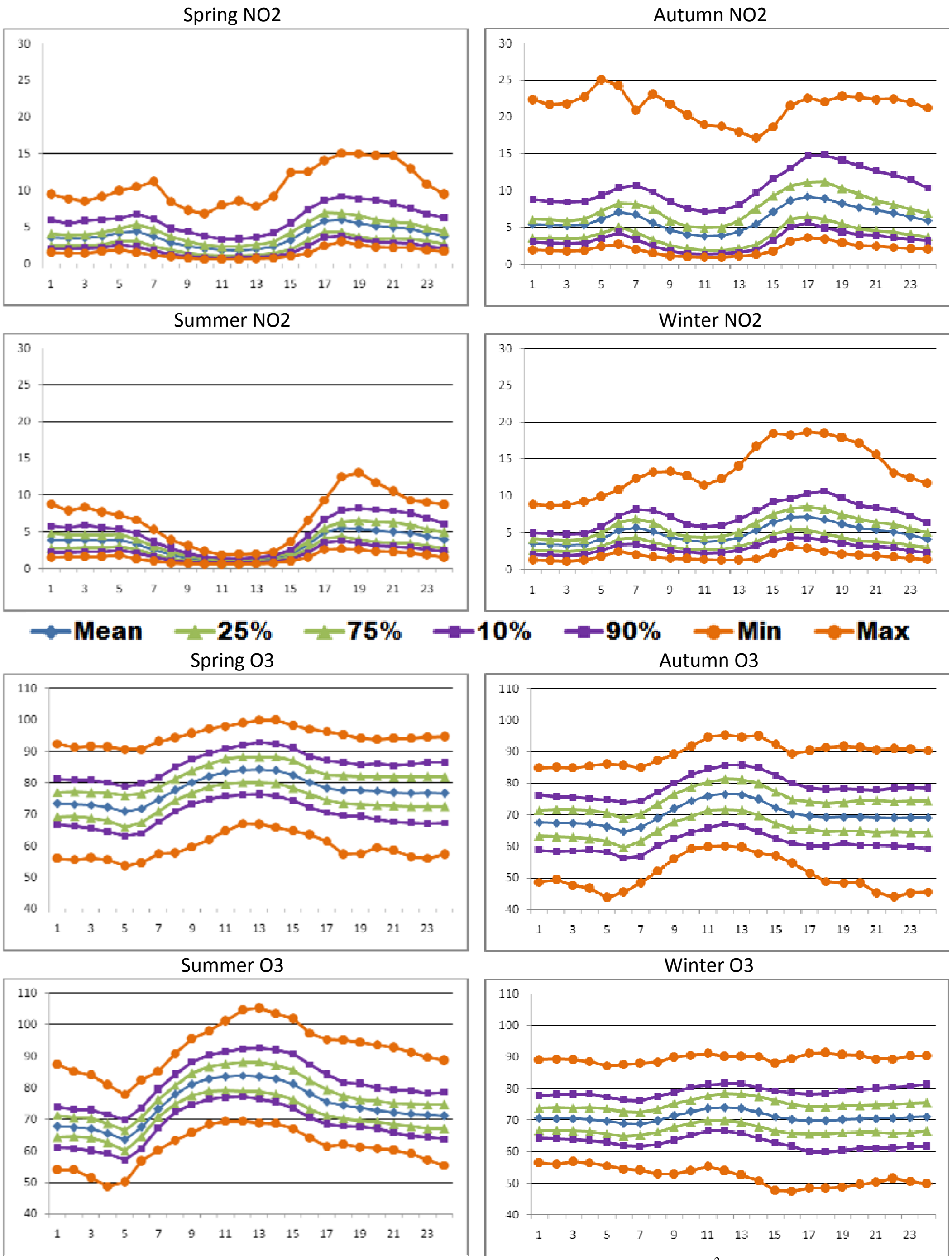

Figure 2. Seasonal/diurnal variations of the O3 and NO2 surface concentrations [μg/m^3], averaged for the territory of Bulgaria: curves of mean, maximal and minimal values as well as curves show the imaginary concentrations for which the probability of the simulated ones to be smaller is respectively 0.25, 0.75, 0.1 and 0.9.

The study is based on a large number of numerical simulations carried out day by day for years 2000-2007 and five emission scenarios – with all the emissions and with biogenic emissions, emissions from energetics (SNAP 1), road transport (SNAP 7) and none industrial combustion (SNAP 2) reduced. This makes it possible to evaluate the contribution of different emission categories to the formation of the overall atmospheric composition pattern.

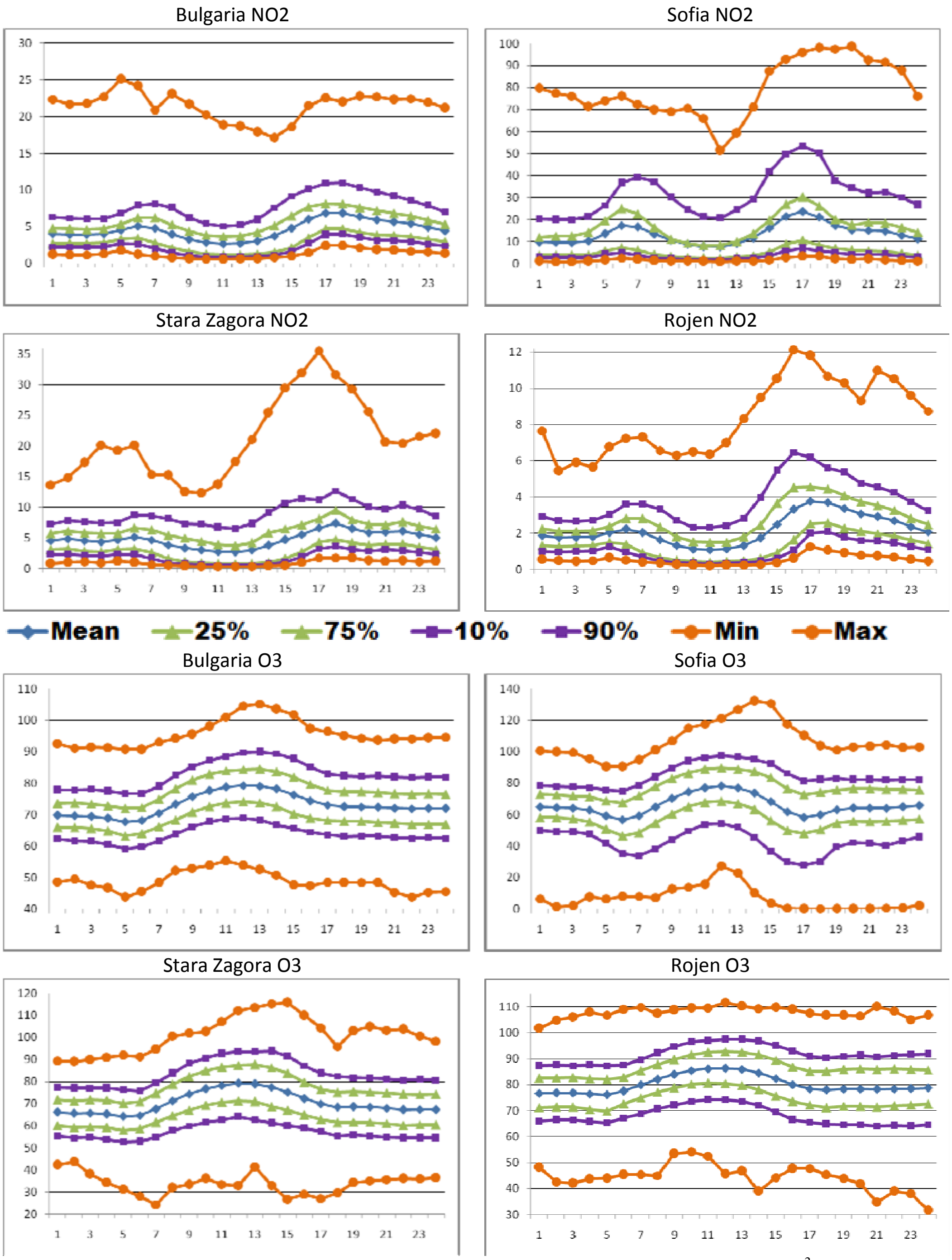

Figure 3. Geographical variations of the annual mean O_3 and NO_2 surface concentrations [μg/m^3] - averaged for the territory of Bulgaria and for Rojen, Sofia and Stara Zagora: curves of mean, maximal and minimal values as well as curves show the imaginary concentrations for which the probability of the simulated ones to be smaller is respectively 0.25, 0.75, 0.1 and 0.9.

SOME EXAMPLES OF THE NUMERICAL SIMULATION RESULTS

As already declared, the 8-year simulated fields ensemble is large enough to allow statistical treatment. In particular the probability density functions for each of the atmospheric compounds can be calculated, with the respective seasonal and diurnal variations, for each of the points of the simulation grid or averaged over the territory of the country. An example of the diurnally averaged cumulative distribution function of the surface ozone for Bulgaria, a typical mountain location (Rojen) and for the city of Sofia is given in Fig. 1. As it can be seen both the seasonal variation and local effects are well displayed.

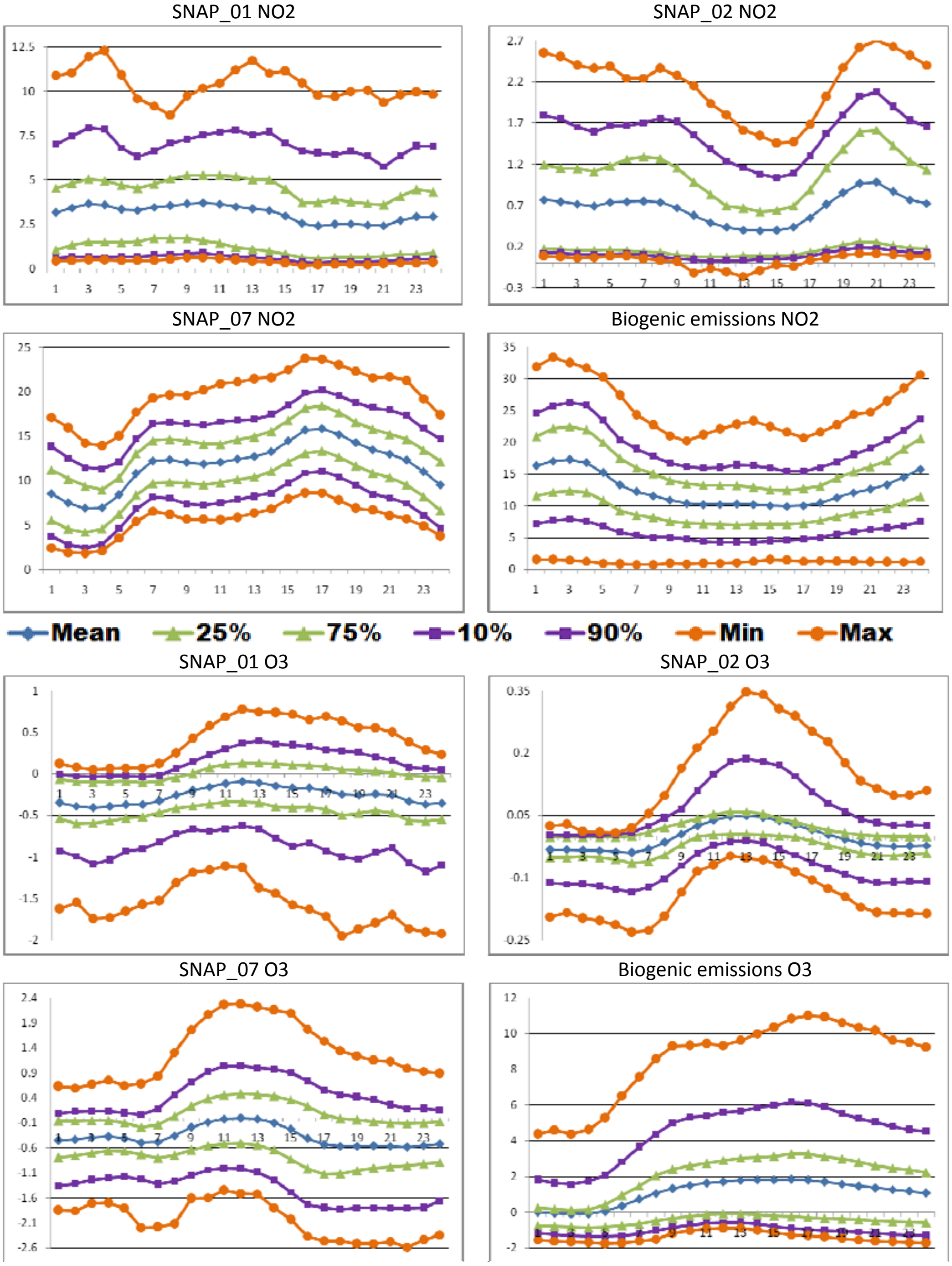

Figure 4. Diurnal variations of the annual contribution [%] of emissions from biogenic emissions, emissions from energetics, (SNAP_01) road transport (SNAP_07) and none industrial combustion (SNAP_02) O3 and NO2 surface concentrations, averaged for the territory of Bulgaria: curves of mean, maximal and minimal values as well as curves show the imaginary concentrations for which the probability of the simulated ones to be smaller is respectively 0.25, 0.75, 0.1 and 0.9.

The most simple atmospheric composition evaluations are, of course, the surface concentrations. The seasonal and diurnal variations of the averaged for the country surface O_3 and NO_2 are shown in Fig. 2. Together with the mean, maximal and minimal values there are also the curves denoted by 0.25, 0.75, 0.1

and 0.9. These curves show the imaginary concentrations for which the probability of the simulated ones to be smaller is respectively 0.25, 0.75, 0.1 and 0.9. Thus the band 0.25-0.75 contains 50% and the band 0.1-0.9 - 80% of the possible cases. The plots are self explanatory enough and demonstrate the seasonal and diurnal O_3 and NO_2 variations.

The local effects on the ensemble behaviour are demonstrated in Fig. 3, where the same characteristics are calculated for Bulgaria, Rojen and the cities of Sofia and Stara Zagora (smaller city). As it can be seen, the local effects are also very well displayed, in particular in the NO_2 fields, which for the different places simply can not be plotted with the same scale. The geographical variations in the O3 behaviour are much smaller.

Another important characteristic of the atmospheric composition climate is the contribution of different emission types (SNAP categories) to the atmospheric composition formation. Such an example is given in Fig. 4. The contribution of different emission categories is, of course, different. For all the studied emission categories the contributions vary within rather broad margins, for the ozone cases having negative, as well as positive values – a display of the nonlinearity of the ozone photochemistry. The contribution of biogenic emissions to surface ozone, though mostly positive, is rather small – effect discussed in Gadzhev et al. (2013). The fairly large contribution of the biogenic emissions to surface NO_2 is again manifestation of ozone photochemistry nonlinearity.

CONCLUSIONS

The mutual locations the "mean" and the bands 0.25-0.75 and 0.1-0.9 is quite an illustrative about the ensemble dispersion and asymmetry. The distribution could be significantly asymmetric, which means that the most probable value of given characteristic could be different from the mean one.

Statistical moments like but also standard deviations, skewness, etc. with their dominant temporal modes (seasonal and/or diurnal variations) are also calculated from the ensemble. Due to volume limitations examples of these characteristics will not be shown in the present paper.

ACKNOWLEDGMENTS

The present work is supported by the Bulgarian National Science Fund (grant ДЦВП-02/1/29.12.2009) and by the EU FP7 project PASODOBLE, grant № 241557. Deep gratitude is due to US EPA and US NCEP for providing free-of-charge data and software. Special thanks to the Netherlands Organization for Applied Scientific research (TNO) for providing the study with the high-resolution European anthropogenic emission inventory.

REFERENCES

Byun, D., Ching, J., 1999: Science Algorithms of the EPA Models-3 Community Multiscale Air Quality (CMAQ) Modeling System. EPA Report 600/R-99/030, Washington DC.

Byun, D., J. Young, G. Gipson, J. Godowitch, F.S. Binkowski, S. Roselle, B. Benjey, J. Pleim, J. Ching, J. Novak, C. Coats, T. Odman, A. Hanna, K. Alapaty, R. Mathur, J. McHenry, U. Shankar, S. Fine, A. Xiu, and C. Jang, 1998: Description of the Models-3 Community Multiscale Air Quality (CMAQ) Modeling System, 10th Joint Conference on the Applications of Air Pollution Meteorology with the A&WMA, 11-16 January 1998, Phoenix, Arizona, 264-268.

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

Dudhia, J. 1993: A non-hydrostatic version of the Penn State/NCAR Mesoscale Model: validation tests and simulation of an Atlantic cyclone and cold front. Mon. Wea. Rev. 121, 1493-1513.

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

Grell, G.A., Dudhia J., and Stauffer D.R., 1994: A description of the Fifth Generation Penn State/NCAR Mesoscale Model (MM5). NCAR Technical Note, NCAR TN-398-STR, 138 pp.

Visschedijk, A., Zandveld P., van der Gon, H., 2007: A high resolution gridded European emission database for the EU integrated project GEMS, TNO report 2007-A-R0233/B, The Netherlands