5.4 ON THE AIR-POLLUTION MODELLING AND PREDICTION IN THE CZECH REPUBLIC

Tomáš Halenka[1,3], Kryštof Eben[2], Pavel Juruš[2], Michal Belda[1,2], Josef Brechler[1], Jan Bednář[1], Rita Cesari[4],Emil Pelikán[2]

[1] Dept. of Meteorology and Environment Protection, Charles University, Prague, Czech Republic
[2] Institute of Computer Science, Academy of Science, Prague, Czech Republic
[3] Regular associate of the Abdus Salam ICTP, Trieste, Italy
[4] Institute of Atmospheric Sciences and Climate (ISAC), CNR , Lecce, Italy

1. INTRODUCTION

A common problem of almost all urban areas in Europe is air-pollution due to photooxidation (summer photochemical smog). The episodes of this smog occur in summer months as consequences of high production of ozone precursors from anthropogeneous emissions in urban and industrial areas as well as from biogenic emissions in remote areas. These compounds under specific meteorological conditions with main impact of solar radiation and high temperature produce this type of air-pollution, which especially in urban and industrial areas significantly aggravates the air quality.

Tropospheric ozone, the main part of the summer photochemical smog, is a result of a cycle of the photochemical reactions. To assess the air-quality on daily basis with the possibility to predict the situation and, consequently, to adopt some measures in case of high concentration episodes, many couples of chemical transport models (CTM) with meteorological preprocessors – numerical weather prediction (NWP) models are used operationally both in meteorological services and other institutes. Example of such a couple in use in the Czech Republic will be described in Sec. 2.

To accept some appropriate measures that can prevent the high O3 concentration episodes it is necessary to know appropriate contribution of different sources, with respect to their type, height, distance etc. With respect to nonlinearity of the reactions and complexity of the problem this is not so easy as for sulphur problem. To estimate role of emission intensity of individual sources, chemistry along the trajectory from the sources and mixing of pollutants from individual sources as well it is essential to study the contribution of individual parts of emission plumes – so called “puffs” – to the places of interest. The introduction into this kind of analysis will be presented in Sec. 3.

Another possible way to study the contribution of individual sources or their groups are scenarios run with appropriate emissions switched on and off and comparative analysis of the results. The main goal of the model study presented in Sec. 4 is to show how the different types and individual emission sources in particular can affect the O3 ground concentration. This study is concerning with the role of biogenic emissions in photochemical processes producing ozone in remote areas with main impact of forests.

2. MM5 - CAMx

In framework of the national project the couple MM5-CAMx is used as a tool for evaluation and analysis of ozone high concentration episodes as well as for experimental air-quality prediction. This tool was finally used as a basis for further development of data assimilation technique. It is Eulerian CTM CAMx model coupled with NWP model MM5, both the models have nested higher resolution version. There are measured data from field campaigns for some episodes as well as air-quality monitoring station data available for comparison of model results with reality and for assimilation technique.

Usually, there is a problem with emission data for the simulations and definitely they are far to be actual instantaneous data. Both the couples have rather older database of emissions available with many uncertainities, for CAMx-MM5 with some problems in resolution and proper description of significant point sources and to avoid the problem with these emission uncertainities assimilation techniques are adopted in CAMx-MM5 system.

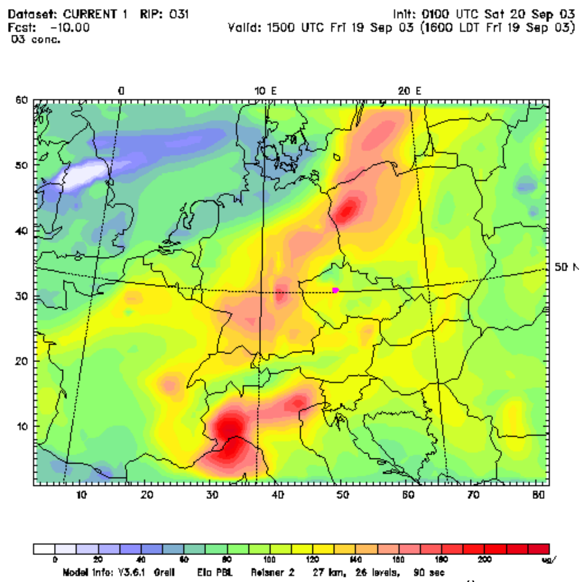

Figure 1. Surface concentration of O3 (μg.m^{-3}) simulated with CAMx-MM5 for 19 September 2003.

The model simulation of photochemical smog episode in September 2003 using MM5-CAMx couple on regional and local scale with sample of results is presented in Fig. 1. Assimilation techniques are tested now to improve the results which is presented in Fig. 2 at local scale.

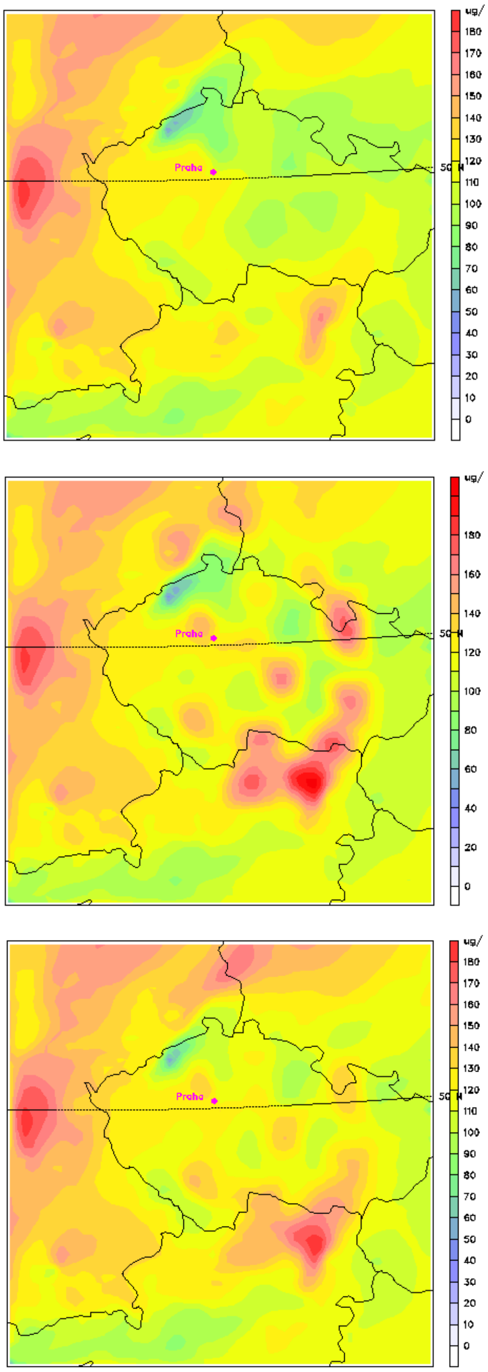

Figure 2. Surface concentration of O3 (μg.m^{-3}) simulated with CAMx-MM5 for 18 September 2003, and Czech Republic. No assimilation (upper panel), optimum interpolation in 2D (middle),optimum interpolation in 3D (bottom panel)

The sparse approximation of background error covariance matrix is used, based on isotropic Balgovind correlation function (cf. Hoelzemann, 2000) for optimum interpolation in 2D, in 3D it is the sparse approximation of background error covariance matrix used, based on Balgovind correlation function with different decorrelation length in vertical dimension.

3. SOURCES APPORTIONMENT IN URBAN PLUME

The sources apportionment routines are involved in most contemporary Eulerian models as CAMx or CMAQ (see, for example, appropriate web pages). As it was necessary to carry out studies where the eulerian approach has not been too advantageous (changing resolution or irregular mesh of receptory points, for example), lagrangian photochemical puff model SMOG has been developed at the Department of Meteorology and Environment Protection, Faculty of Mathematics and Physics, Charles University, Prague (see Bednar, 2001, 2002).

The lagrangian photochemical model SMOG has been used in this study. The model is based on spreading of puffs along the trajectories, with summer daily photochemistry in individual puffs and mixing between the puffs. The model is driven by meteorological conditions from ETA model (Black, 1988) and it is used for ozone episode near Prague. Trajectories are evaluated on the level of individual sources from the ETA wind fields. There are emission sources included both as point sources (significant sources in terms of emission intensity in NOx or VOC, height of the source) or area sources (grouping of less important, smaller emission sources and sources from transportation). The chemistry involved is simplified by lumping of the compounds, mainly VOC's due to efficiency of the computation and due to availability exact information on chemical parameters of individual compounds as well as individual compounds emission intensity.

When this task has to be performed and contributions of individual sources and groups of sources of a given kind have to be estimated it is necessary to organize a file with information about emission sources and to lump all the sources of one kind together (for example traffic sources, technologies etc.). Then it is possible to get desired information about individual source contribution in a point of interest and also information about contribution of a group of a given type of sources as each puff carry information about its origin (from which source it has been emitted) and which type of sources it belongs to. The contributions of the puffs on the trajectories from the sources are evaluated providing the information not only about individual sources but giving some information about influence of progress of chemistry between and/or in puffs along the trajectories as well. Results show great importance of local sources including traffic as well as point sources, with significant influence of remote strong emission sources. As the puffs follow trajectories from the individual emission sources it is necessary to know the wind field in a model area. Trajectories are then constructed from all the involved emission sources that are used in two forms as it has been mentioned – point emission sources and those lumped into emission grid of squares of desired resolution. In the study the results of which are presented here, the resolution of emission grid was equal to 5 × 5 km

Examples of emission sources are given in Figure 3 – point sources and Figure 4 – gridded sources with lumping into squares 10 ×10 km. In both figures emission sources from the area of the middle Bohemia are shown.

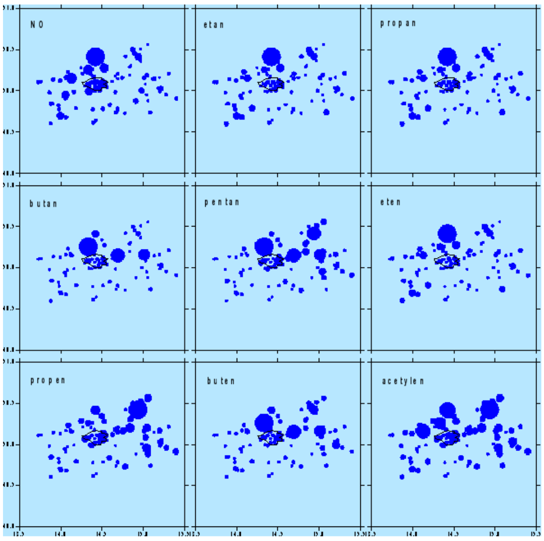

Figure 3. Point emission sources in the area of the middle Bohemia.

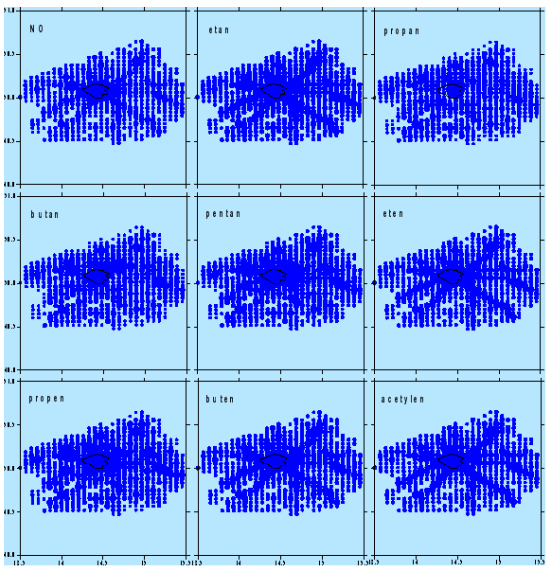

Figure 4. Small emission sources (e.g. local heating, transportation) given in gridded form. Area of source corresponds to an emission rate.

Figure 5 shows the ground ozone concentration in μg.m^{-3} in the central Bohemia region (surroundings of Prague). Prague city is shown by the bold line. The situation shows the field of concentration corresponding to meteorological conditions advantageous for high tropospheric ozone concentration. Contributions from individual categories of emission sources were estimated for the area of ozone maximum concentration (point 50.5° N and 14.5° E). All emission sources were divided into 9 groups (for example group 1 – large point sources as power plants, group - 2 large point sources as technologies, group 9 – traffic). The largest contribution came from traffic (group 9) - more than 64%), large point sources (group 1) contributed only with 6.7% to the resulting value of ground ozone concentration.

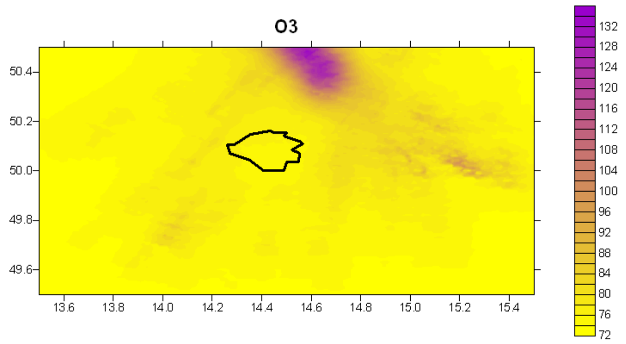

Figure 5. Ozone ground concentration (μg.m^{-3}) in the surroundings of Prague.

In this part some results of the apportionment methodology are shown. In Fig. 6 the positions of all the puffs from all the emission sources that could contribute to above mentioned point of interest. It is necessary to have in mind that contribution from some puffs are close to zero. If the contribution that differed from zero was taken into account the resulting situation is limited to the puffs located in the surroundings in the closes neighbourhood of the point 50.5° North and 14.5° East. Fig. 7 shows contributing puffs that originated in the emission sources of the group 9 (traffic sources).

For complete analysis it would be necessary to have information from which emission source each puff originates. However, this is only technical problem as this information is saved in the code. Thus it would be possible to create scenarios how changes in emission productions of some important source (oil refiners, for example) could result in the ozone ground concentration in some area or how the changes in traffic infrastructure could change the concentration pattern.

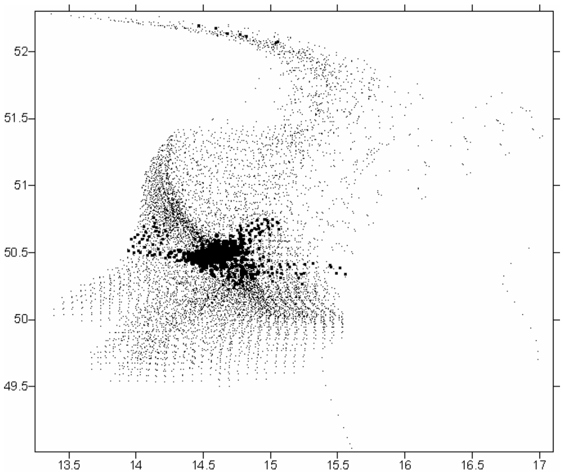

Figure 6. Position of all the puffs contributing to the concentration of O3 in the point 50.5° N and 14.5° E.

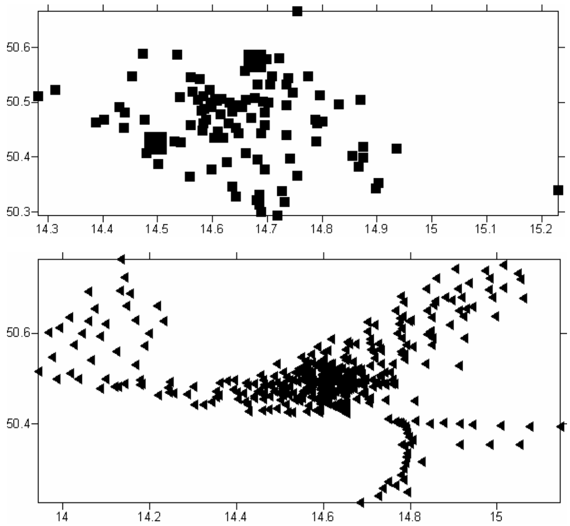

Figure 7. Position of individual puffs contributing in the area of ozone maximum concentration (50.48N, 14.58E) of Prague ozone plume, September, 19, 2003, from the important point sources (left panel, 7% of total contribution) and from the traffic sources (right panel, 64% of total contribution). Size of symbols proportional to the relative contribution to the total concentration.

4. BIOGENIC EMISSIONS

In "remote" experiment we examined the influence of biogenic emissions on ground concentration of ozone. We used another possibility of studying the impact of some compounds, i.e. comparing the simulation switching the inclusion of the compound on and off. Information about the biogenic sources comes from land-use. For selected remote area appropriate categories can be found in Fig. 8 with calculated emissions under typical conditions of photochemical smog episodes presented in Fig. 9. Significant increase of ozone concentration with biogenic emission involved can be seen in Fig. 10 estimated under typical conditions for summer photochemical smog formation. For remote mountain location Cervenohorske sedlo with available measurement we provide the comparison for June 2002 in Fig. 11. It can be clearly seen much better performance of the model with the biogenic emissions involved.

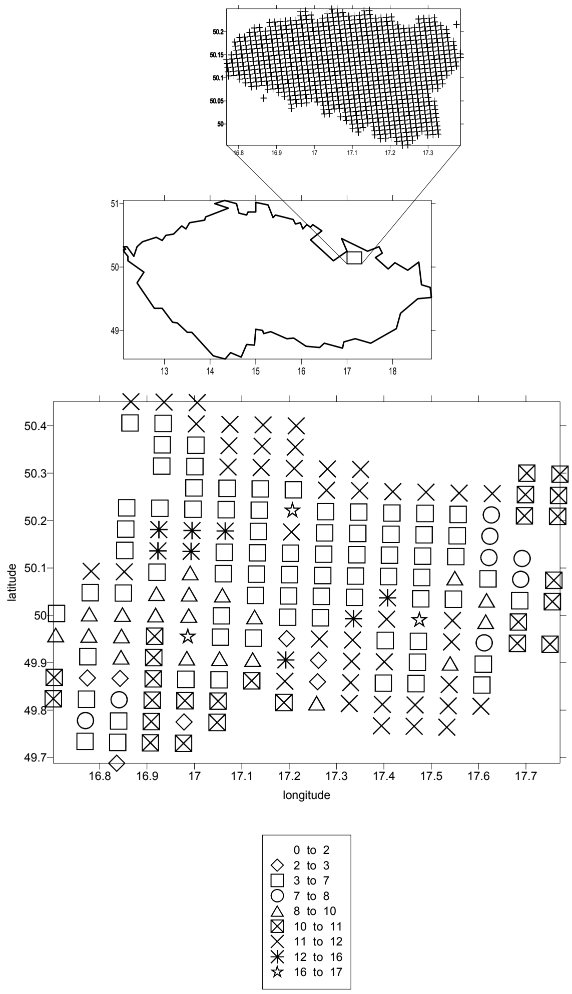

Figure 8. Location of selected remote area with land use categories. 0-without data, 2-mixed forest, 3-coniferous forest, 7-forest and cultivated areas (fields), 8-forest and meadows, 10-agricultural area with prevailing arable land, 11-mixed agricultural area with arable land and meadows, 12-agricultural area with prevailing meadows, 16-built-up areas (industrial areas or settlement)

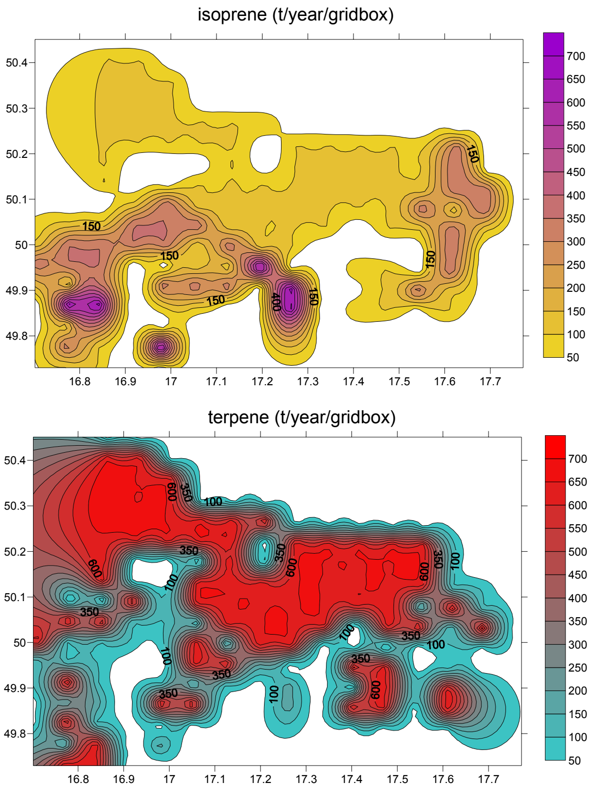

Figure 9. Biogenic emission intensities under photochemical smog formation conditions.

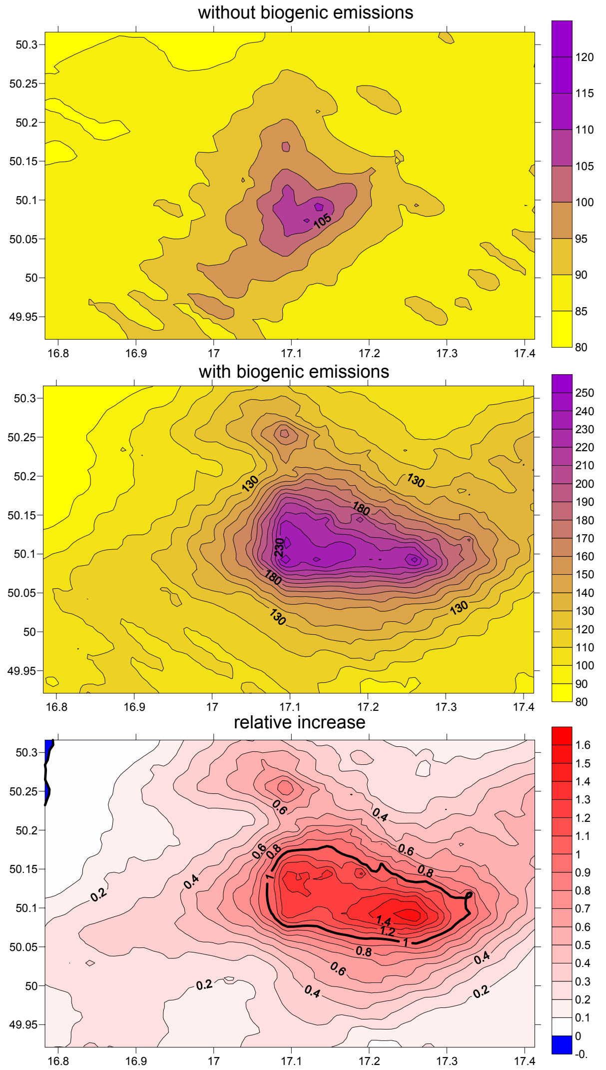

Figure 10. Comparison of ground concentration of ozone in μg.m^{-3} for model experiment with biogenic emission switched off (upper panel) and on (middle) for typical conditions of summer photochemical smog formation - relative change in bottom.

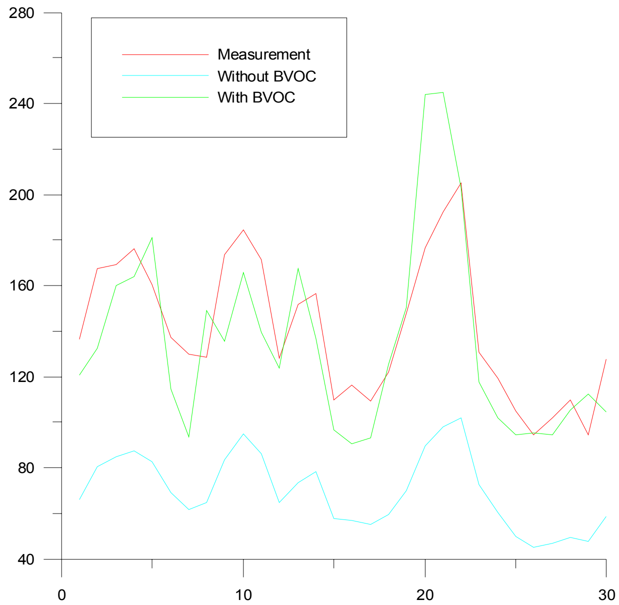

Figure 11. Comparison of model experiment with biogenic emission switched on and off with measurement for daily ground concentration of ozone (µg/m^3) for Cervenohorske sedlo in June 2002.

5. CONCLUSIONS

Results show feasibility of the proposed techniques to study the influence of emissions, chemistry and transport on ground concentration of ozone under photochemical smog conditions. It can be seen significant impact of biogenic emissions as well as the influence of traffic emissions on photochemical smog formation.

ACKNOWLEDGEMENTS

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