UDK 681.3

ON SOME OZONE STUDIES: COMPARISON OF MODEL RESULTS AND MEASUREMENTS OVER THE TERRITORY OF BULGARIA

K. Georgiev, E. Donev

Institute for Parallel Processing of Bulgarian Academy of Sciences, Acad. G. Bonchev str., Bl. 25-A, 1113 Sofia, Bulgaria

Faculty of Physics of Sofia University, 5, J. Bourchier Blvd., 1126 Sofia, Bulgaria

Introduction

TM5 model is used to estimate the ozone pollution over the territory of Bulgaria and surrounding countries for year 2000. The model output results are compared with measurements done by two stations in Bulgaria. The rest of the paper is organized as follows. In section 2 some basic principles and description of the TM5 model are presented. Section 3 is devoted to the short description of the measurement stations and their parameters. TM5 output results and comparisons with the measurements can be found in section 4.

1. TM5 model

TM5 is a three dimensional global chemistry Transport Model. It allows two-way nested zooming which leads to possibility to run the model on relatively very fine space grid (1°×1°) (longitude × latitude) over selected regions (Europe is most often used in up to now experiments but North America, South America, Africa and Asia can be treated separately or in combinations) while the coarsest space resolution is (6°×4°). The boundary conditions for the zoomed subdomains are provided consistently from the global model. The model consists of 25 vertical layers: five layers in the boundary layer, ten layers in the free troposphere and ten layers in the stratosphere. There is no zooming in the vertical direction and all regions use the same vertical layer structure (hybrid sigma-pressure coordinate system). TM5 is an *offline* model which uses preprocessed meteorological fields from ECMWF (European Center for Medium-Range Weather Forecast), Reading, UK. The model is a good tool for studying some effects due to the grid refinement on global atmospheric chemistry issues (intercontinental transport of air pollutants, interhemisphere exchange, effects of the grid refinement on the budgets of the chemically active compounds, etc. (Krol et al., 2005).

The first of this row TM models was developed by Heinman et al. (1988). Like in its predecessor, the TM3 model, the ***symmetrical operating splitting*** is used in TM5 model. Therefore, separate solution of the following subproblems: transport, emissions, depositions and chemistry are performed. This approach combining with ***tailored implicit schemes*** (Verver et al., 1999) leads to avoiding the small time steps due to the stiff problems in chemistry and the vertical mixing operators. Unfortunately, the symmetrical splitting can not always be presented in a zooming algorithm. It can be seen that in the subdomains with mesh refinement the algorithm is only partly symmetrical (see e.g. Krol et al., 2005, p. 421, Tabl. 1). The advection numerical scheme is based on the slope scheme (Russel and Lerner, 1981) and is mass–conserving. The convection parameterization is based on the algorithm which can be found in Tiedke, 1989.

TM5 model is coded in Fortran 90. The model has implemented and tested on different high-performance computer platforms (IBM p690+, SGI Origin 3800, MAC OSX, Sun clusters, etc.). Message Passing Interface (MPI) is used as a communication tool. The parallel version of the model is run parallel over tracers as well as over vertical layers. The first one leads to good speedup in transport while the second leads to good speedup in chemistry (Peters, 2003). During the single run, each processor is responsible for one or more tracers during the transport, and the same processor is responsible for one or more vertical layers during the chemical part of the mode. Between these two main part of the numerical algorithm big amount of data are swapped between processors. The last one is the bottleneck of the parallel version of TM5 model. Each time step for the three regions (European focused model) proceeds according to the following diagram (Peters, 2003):

t → → → → → → → → → → → → → → → → → t + ΔT/2
xyz -- vsc
↓↓↓ xyz------------------------------ vsc --- csv --- zyx ----------------------------⇑
↓↓↓ xyz vsc csv zyx ↑ ↓↓↓ csv zyx xyz vsc ⇑
t + ΔT/2 → → → → → → → → → → → → → → t+ΔT
csv zyx ---
⇓ xyzvsc --------------------------- csv zyx ------------------------ ↑
⇓ csv zyx xyz vsc ⇑ ⇓ xyz vsc csv zyx ↑

where

↑ – update parent, no swap needed;
⇑ – update parent, swap parent to levels needed;
↓↓↓ – write boundary conditions before advection, no swap needed;
⇑ – write boundary conditions before advection, swap child to tracer needed;
c – chemistry with swap to levels needed
s – sources with swap to tracer needed.

2. Measurement stations

Measurements from two measurement stations are used for the comparisons reported in this paper. First station is located almost on the see level (at an altitude of 5 m. above see level) on the Black See cost, near the town of Ahtopol. This station is far from the industrial zones but at the same time is very much depend on the breeze circulations of the wind. As is reported in some papers the breeze circulations lead to recirculation of the air which is reach of ozone of the previous days. The last process can lead to dangerous concentrations of ozone in the areas closed to the see.

The second station is located in the mountain (Rodopi mountain; at an altitude of 1570 m above see level). The location of this station gives the possibility to make estimation of the background values of the ozone in this part of Europe. Like the first station, it is far from anthropogenic precursors of ozone. At most time there are winds from the north and the west directions at the location of the station.

3. TM5 output results and comparisons with the measurements

The TM5 model setup is ideally suited for measurements campaigns (Krol et al., 2005). We analyze the ozone measurements that were made in the both Bulgarian stations mentioned above for the year 2000 on monthly mean base. *Ahtopol station* (see Tabl. 1 and the corresponding figure)

The comparisons between measurements done at this stations and the TM5 output show that the model results underestimate the measurements during the winter, spring and autumn, and overestimate the measurements during the summer period. The model results follow well the tendency in the increasing and decreasing of the values of the ozone concentrations but the differences in percent are relatively high for some months. It seems that use of the wind data measurements and other meteorological parameters as boundary heights, etc. (not used in this study) are very important for the validation of the model results. *Rojen station* (see Tabl. 2 and the corresponding figure)

Comparisons between measurements done at this station and the TM5 output, show, that the model results underestimate the measurements during the whole year. The underestimate is essential during the winter months, is decrease during the spring and autumn, and it is negligible during the summer period. The model results follow well the tendency in the increasing and decreasing of the values of the ozone concentrations. The conclusions made above about the influence of some meteorological parameters which are not taken into account in this study seem to be true for this station too. Nevertheless there are some differences between the measurements and the model results it can be concluded that the obtained critical levels of the ozone concentrations for the area of the Rojen station are dangerous for trees. The calculated AOT40 indexes are more than two times more than the limit values for forests.

Table.1. Comparisons between measurements and TM5 output results for Ahtopol station

	January	***February***	***March***	***April***	***May***	***June***
Measurements in ppb	37.3	41.1	44.8	42.3	40.7	41.2
TM5 output in ppb	26.5	31.5	36.0	41.5	47.5	56.5
(meas – TM5)/meas (in %)	29%	23%	20%	2%	-17%	-37%

	July	***August***	***September***	***October***	***November***	***December***
Measurements in ppb	47.8	45.1	40.9	39.5	28.9	29.2
TM5 output in ppb	62.5	57.5	42.5	33.5	25.5	23.5
(meas – TM5)/meas (in %)	-31%	-27%	-4%	15%	12%	20%

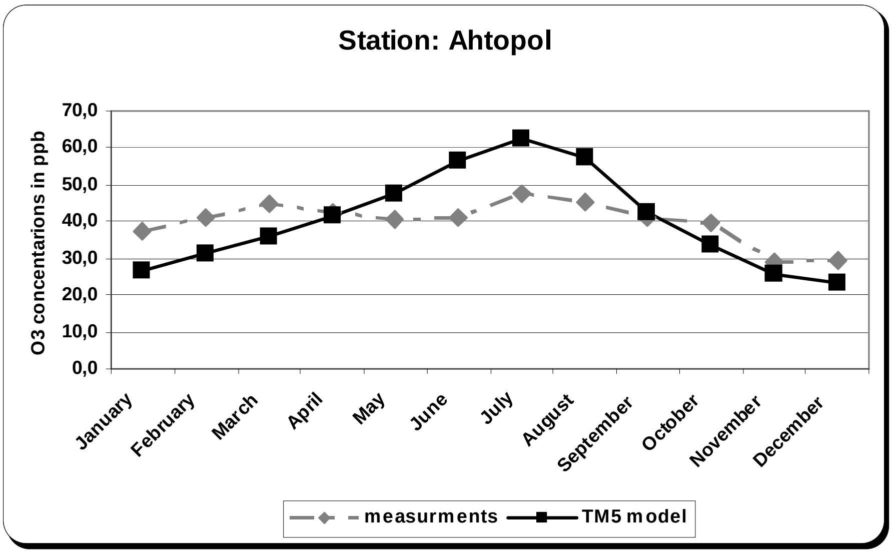
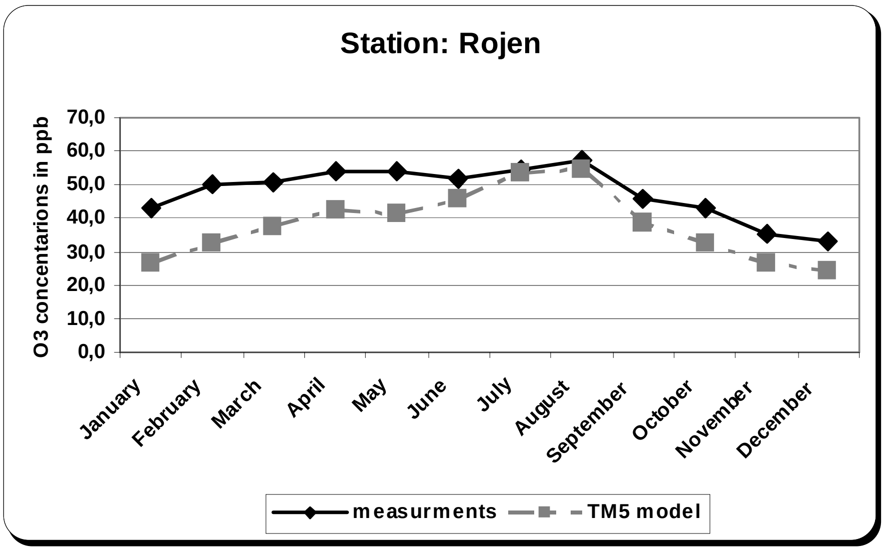


Table.2. Comparisons between measurements and TM5 output results for Rojen station

	January	*February*	*March*	*April*	*May*	*June*
Measurements in ppb	43.2	50.0	50.8	54.0	53.9	52.0
TM5 output in ppb	26.5	32.5	37.5	42.5	41.5	45.5
(meas – TM5)/meas (in %)	39%	35%	26%	21%	23%	13%

	July	*August*	*September*	*October*	*November*	*December*
Measurements in ppb	54.4	57.5	46.0	42.9	35.3	33.3
TM5 output in ppb	53.5	54.5	38.5	32.5	26.5	24.5
(meas – TM5)/meas (in %)	2%	5%	16%	24%	25%	26%



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