Proceedings of the Third International Symposium on Air Quality Management at Urban, Regional and Global Scales. pp. 681-685, 26-30 September 2005, Istanbul – Turkey

EVOLUTION OF THE TROPOSPHERIC COMPOSITION IN 2030: IMPACT ON EUROPEAN AIR QUALITY

Szopa Sophie, Didier A. Hauglustaine and Robert Vautard*

Laboratoire des Sciences du Climat et de l'Environnement, CEN Saclay, Orme des Merisiers, Bat. 712, F-91191 Gif-sur-Yvette CEDEX, France, szopa@cea.fr, hauglustaine@cea.fr
*Laboratoire de Météorologie Dynamique, Ecole Polytechnique, F-91128 Palaiseau CEDEX, France, Robert.Vautard@lmd.polytechnique.fr

ABSTRACT

Over the next decades, the atmospheric composition will be affected by major changes in anthropogenic emissions and in particular by an increasing number of megacities and by climate change. In order to investigate and discriminate the impacts of these changes on the tropospheric composition, several simulations were performed in the framework of the ACCENT network modeling activities. This activity relies on the recent availability of new global emission scenarios developed by the IIASA institute. The LMDz-INCA general circulation model is involved in this activity among 25 global models. Furthermore, additional simulations were performed using the LMDz-INCA results as boundary conditions for the CHIMERE regional model and the IIASA emissions datasets in order to better analyse future air quality trends in Europe. In addition, several model simulations considering separately the emission changes and the global boundary condition changes were carried out. We discuss in particular a possible compensation between European emission reductions and the effects, in Europe, of the global emission increase.

Keywords : Air Quality, Global and Regional Modeling, Evolution of Atmospheric Composition

1. INTRODUCTION

Ozone is a trace gas species resulting, in the troposphere, from the oxidation of carbonaceous compounds (methane, carbon monoxide, volatile organic compounds) in the presence of nitrogen oxides both emitted by anthropogenic and natural processes. Attention is paid to this molecule for its role as a greenhouse gas impacting global climate as well as for its impact on air quality closed to inhabited areas during smog events causing both human health and vegetation damages. The emissions of ozone precursors (nitrogen oxides and volatile organic compounds) are expected to decline in the European Union (EU-25) until 2020 even under the assumption of accelerated economic growth. However, ozone and its precursors are subject to long-range transport in the atmosphere. Therefore, the future air quality in Europe will not only be a result of local emissions but will also be affected by the global distribution of ozone and its precursors. The future evolution of ozone and associated radiative forcing was recently investigated by 25 state-of-the-art global atmospheric chemistry models in the framework of the Photocomp experiment (Stevenson et al., 2005; Dentener et al., 2005). In this study, we apply a global climate-chemistry model and a regional chemistry-transport model dedicated to air quality studies to refine these results and investigate the relative impact of anthropogenic emission changes on Western European surface ozone levels in 2030. The relative contribution of the global ozone background modification with respect to the European emission control strategy is subsequently investigated.

2. MODELS AND PERFORMED SIMULATIONS

The global simulations were performed using the three-dimensional (3D) LMDz-INCA chemistry-climate model. LMDz (Laboratoire de Meteorologie Dynamique, zoom) is a grid point General Circulation Model (GCM) initially developed for climate studies. LMDz (version 3.3) has a horizontal resolution of 3.75 degrees in longitude and 2.5 degrees in latitude and uses 19 vertical *sigma*-p levels extending from the surface to 3 hPa. The INteractive Chemistry and Aerosols (INCA) model has been integrated into LMDz and simulates tropospheric chemistry, emissions and deposition of primary tropospheric trace species including non-methane hydrocarbons. The INCA chemical scheme used in this study describes the tropospheric photochemistry (O_3-NO_x-CO-VOC) through 85 chemical species and 303 chemical reactions. A detailed description and evaluation of LMDz-INCA are given in Hauglustaine et al. (2004) and Folberth et al. (2005). For the global scale simulations, the emission scenarios, recently described by Dentener et al. (2004) are used. For each scenario, the simulations were spun up for 3 months and performed over one year, using the nudged meteorology (i.e. meteorological fields are relaxed toward the ECMWF ERA40 reanalysis). Additional simulations were performed using the LMDz-INCA results as boundary conditions for a regional chemistry-transport model: CHIMERE. The CHIMERE model calculates gaseous chemical concentrations over Europe within an horizontal domain, ranging from 10.5°W to 22.5°E in longitude and from 35°N to 57.5°N in latitude. The horizontal resolution ($50x50km^2$) allows to capture the local O_3 maxima which is determinant regarding the population exposure to photochemical pollution and thus to determine compliance with the European O_3 standard (Schmidt et al., 2001). On the vertical, eight vertical hybrid sigma-p levels represent the atmospheric column from the surface to 500 hPa. The chemical mechanism is adapted from the EMEP chemical mechanism. The dynamical fields are computed using the MM5 model driven by the ECMWF ERA40 reanalysis. For both global and European simulations, the meteorology corresponds to the year 2001.

Three scenarios were tested representing respectively the implementation of current air quality legislation in each individual country around the world (CLE scenario), the maximum reduction of emissions currently technically feasible (MFR scenario) and the scenario SRES-A2 developed for the last Intergovernmental Panel for Climate Change report. For the three 2030 scenarios we applied LMDz-INCA coupled with CHIMERE to investigate the response of European summer pollution episodes relative to present day pollution level to (1) global and European modifications of the anthropogenic ozone precursors emissions; (2) modifications of global scale chemical composition due to anthropogenic emission changes all around the world except Europe; (3) projected 2030 anthropogenic emissions in Europe considering the current anthropogenic emissions in the rest of the world.

3. RESULTS

In this paper we focus on the “current legislation” (CLE) scenario which assumes current perspectives of individual countries on future economic development and anticipated effects of presently decided emission control legislation in the individual countries. Figure 1 shows the ozone change calculated with the global model for the whole world and those obtained with the regional model using the results coming from the global model as boundary conditions. At the global scale, a general increase of ozone concentrations, reaching up to 5-10 ppb over Asia, is observed except for the south of USA and Mexico and southern Europe (also shown by the simulation using the regional model) where an ozone decrease is predicted.

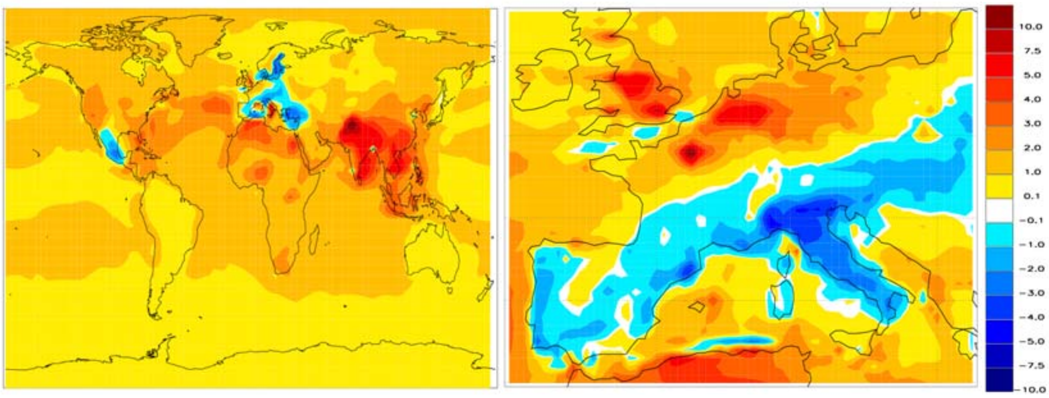

Figure 1 : Future surface ozone changes, averaged over July (in ppb), considering the “Current Legislation” (CLE) scenario: (right) ozone computed by LMDz-INCA and (right) daily maximum surface ozone computed by CHIMERE (coupled with LMDz-INCA) over Europe.

In order to refine the study over Europe and to discriminate the role of European emission changes and global emission changes, two additional simulations were carried out. The changes of the daily maximum surface ozone mixing ratio are shown in Figure 2 for July conditions. The main conclusions are that the European emission reduction policy would lead to a decrease of maximum ozone daily values for almost all European locations except the main north European towns and suburbs. The global emission modifications have an opposite effect increasing the averaged of the maximum daily ozone values all over Europe from 1 to 3 ppb. This study shows how political decisions could be counterbalanced by the global emission changes and underlines the importance of taking into account the global scale changed to assess the relevance of such policy.

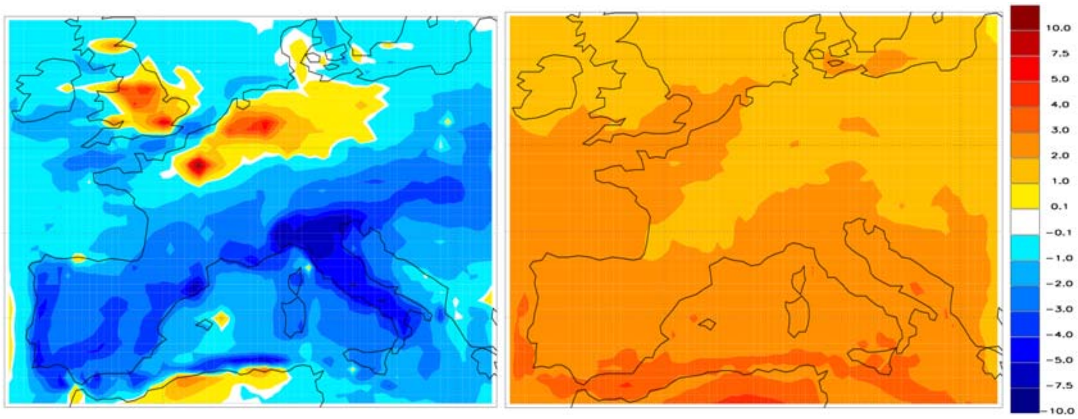

Figure 2 : Future changes of daily maximum surface ozone averaged over July (in ppb) computed by CHIMERE (left) considering the 2030 changes in emissions such as in the CLE scenario over Europe but without any changes of emissions over the rest of the world and (right) considering no emission modification over Europe but taking into account the 2030 changes of emissions over the rest of the world.

4. CONCLUSION

This 3D model analysis coupling a global model with a sub-continental model shows that realistic future emission modifications would lead to heterogeneous repartition of the effects on summertime Western European ozone air quality in 2030. The northern part of Europe, essentially highly inhabited areas, would see an increase of the mean level of surface ozone due to combined effects of both local and global emission changes. On the contrary, the air quality in south part of Western Europe would benefit from the reduction of emission policy managed in Europe despite of the global emission modifications which tend to increase the background ozone level and thus reduce the benefit of European policy. The simulation separating the role of worldwide emission changes and that of European emission control underlines the need of taking into account both global and regional scales to design relevant legislation for air quality management in the next decades.

5. ACKNOWLEDGEMENTS

The authors would like to acknowledge EMEP, IER (University of Stuttgart) and UK Dept of Environment for providing present day emissions data for Europe. The global emissions were provided by IIASA and reprocessing by Frank Dentener who made it available for the Photocomp experiment (managed under the umbrella of the European ACCENT network). The study was supported by the RETRO European project under contract EVK2-CT-2002-00170.

REFERENCES

Dentener, F., D. Stevenson, J. Cofala, R. Mechler, M. Amann, P. Bergamaschi, F. Raes, and R. Derwent, 2004. The impact of air pollutant and methane emission controls on tropospheric ozone and radiative forcing: CTM calculations for the period 1990-2030, Atmos. Chem. Phys., 4, 8471-8538.

Dentener, F., et al., 2005. Global air quality for the next generation, *Geophys. Res. Lett*., submitted for publication.

Folberth, G., D. A. Hauglustaine, J. Lathière, and F. Brocheton, 2005. Impact of biogenic hydrocarbons on tropospheric ozone ; results from a global chemistry-climate model, *Atmos. Chem. Phys*., submitted for publication.

Hauglustaine, D. A., F. Hourdin, S. Walters, L. Jourdain, M.-A. Filiberti, J.-F. Larmarque, and E. A. Holland, 2004. Interactive chemistry in the Laboratoire de Météorologie Dynamique general circulation model : description and background tropospheric chemistry evaluation, *J. Geophys. Res.*, 109, D04314, doi:10.1029/2003JD003957.

Schmidt, H., C. Derognat, R. Vautard, and M. Beekmann, 2001. A comparison of simulated and observed ozone mixing ratios for the summer of 1998 in Western Europe, *Atmos. Environ.*, 35, 6277-6207.

Stevenson, D., et al., 2005. Multi-model ensemble simulations of present-day and near future tropospheric ozone, Atmos. Chem. Phys., submitted for publication.