MODELLING OF VARIOUS EMISSION SCENARIOS FOR 1985-2010 IN SWITZERLAND

Sebnem Andreani-Aksoyoglu[1], *Johannes Keller*[1], *Andre S.H. Prevot*[1] *and Martin Schultz*[2]
[1]Laboratory of Atmospheric Chemistry, Paul Scherrer Institute (PSI), Switzerland
[2]Max Planck Institute, Hamburg, Germany

INTRODUCTION

Ozone levels during persistent periods of hot and sunny weather frequently exceed the legal threshold of 120 μg m^{-3}. Since 1981 numerous regulations have been enforced or proposed in Switzerland (BUWAL, 2004). They should have caused a clear improvement of the air quality in Switzerland. However, near-surface ozone concentrations have apparently not decreased except in the region of Zurich. A recent study suggested that the decrease in the local production due to the reductions of the precursor emissions might have been compensated by a background increase (Ordonez *et al.*, 2005). In order to assess the effect of emission reductions measures on a scientific basis, a project was launched, in which the following questions were addressed:

- What was the ozone level in 1985 (no catalytic converters available) compared to 2000?
- What would the ozone level have been in 2000, if no mitigation measures were enforced ("no control" scenario)?
- What will the ozone level be in 2010 if the emission reductions specified in the Gothenburg Protocol are in force? What happens if only half of the Gothenburg ceiling emissions are allowed?
- What will the ozone level be in 2010 assuming a current legislation (CLE) emission scenario?
- What would the ozone level have been in 2000 if anthropogenic emissions in Switzerland were 0?

In this paper the results of these scenarios are discussed.

MODELLING METHOD

In this study, the CAMx model (Comprehensive Air Quality Model with Extensions) was used (ENVIRON, 2004). The two model domains were defined according to the requirements of the photochemical and meteorological models. The coarse domain has 95 grid cells in the east-west direction and 79 grid cells in the north-south direction with a resolution of 27 km x 27 km. The fine domain contains 74 and 56 grid cells in the east-west and north-south direction, respectively, with a resolution of 9 km x 9 km and covers Switzerland and partly also the surrounding countries. There are 10 σ-layers in a terrain-following Lambert Conic Conformal coordinate system. Meteorological input files were prepared using the MM5 mesoscale model (PSU/NCAR, 2004). MM5 is initialized by data of the "alpine model" (aLMo) of MeteoSwiss. In this study assimilated data were used as first guess data. The simulations were nudged towards aLMo data using the 4-dimensional data assimilation (FDDA) option of MM5 to obtain as realistic meteorological fields as possible. After some sensitivity tests, 1-way nesting, the MRF (Medium Range Forecast) PBL scheme, and FDDA in the coarse domain were used. The initial and boundary conditions for CAMx were obtained from the output of the global model MOZART that covers the same time period (Horowitz et al., 2003). The chemical mechanism used in this study is the CBM-IV gas-phase mechanism 3 without aerosols (Gery, 1989). Simulations started on 4 August 2003 at 0000 UTC and ended on 7 August at 2400 UTC. Calculations were performed using the base case and the scenario emissions.

EMISSIONS

The annual emissions and time functions for Europe were kindly provided by the Freie Universitaet Berlin (FUB). Reference year is 1995. Annual road traffic emissions in Switzerland were prepared by INFRAS. Reference year is 2000. For the present study the inventory valid for the current legislation was used. Annual NO_x emissions from residential activities, heating, industry, off-road traffic and agriculture / forestry on a 200 m resolution were provided by Meteotest. Reference year is 2000. Gridded biogenic emissions were calculated directly for the CAMx domains (Andreani-Aksoyoglu, 1995). In order to answer the questions raised in the introduction we defined the following emission scenarios:

Scenario 0 : base case, 2000, CLE, reference year 2000, current legislation (CLE).
Scenario 1 : 1985, CLE, reference year 1985, current legislation (CLE).
Scenario 2 : 2000, NC, reference year 2000, economic development in 2000 as projected in 1985. No further legal limits of the emissions.
Scenario 3 : 2010, GOTH, reference year 2010, emissions reductions as agreed in the Gothenburg Protocol.
Scenario 4 : 2010, CLE, reference year 2010, current legislation (CLE).
Scenario 5 : 2010, GOTH, 100 / 50, reference year 2010, emissions: Europe: Gothenburg target emissions, Switzerland: 50% of the Gothenburg target emissions.
Scenario 6 : 2010, GOTH, 50 / 50, reference year 2010, emissions: Europe: 50% of the Gothenburg target emissions, Switzerland: 50% of the Gothenburg target emissions.
Scenario 7 : 2000, CLE, 100 / 0, reference year 2000, current legislation (CLE) for Europe, zero anthropogenic emissions for Switzerland.

RESULTS AND DISCUSSION

Scenario 0 : 2000, CLE (base case)

Results of the base case are given elsewhere in detail (Keller, 2005). Highest ozone concentrations were predicted in southern Switzerland. Comparison of model results with the measurements at some NABEL stations indicate the strong effect of initial values during the first day (Keller, 2005). The best agreement between the predicted peak ozone concentrations and measurements was obtained for 5 August. The second day therefore, was chosen to be used for the evaluation of scenario cases in the following section.

Scenario 1 : 1985, CLE

In general, emissions decreased between 1985 and 2000, especially in the northern part of the model domain. The relative difference between predicted ozone mixing ratios in 1985 and 2000 is shown in Figure 1. Peak ozone concentrations in 2000 are lower by typically around 5 -10% in the Swiss Plateau. The largest difference is in the northeast of Switzerland where peak ozone levels decreased by up to 15 % compared to 1985. The change in the southern part of Switzerland is less than 5 %. In northern Italy around Bologna where there are large combustion point sources, an increase in peak ozone concentrations since 1985 is predicted. This is most probably due to the change in NO_x-VOC sensitivity of ozone which was much more VOC-sensitive with 1985 emissions. Results of this scenario suggest that reductions of the precursor emissions during the last two decades were effective to decrease the local ozone production although this effect cannot be seen by the measurements at most stations except in the region of Zurich, probably due to an increase in the background ozone (Ordonez et al., 2005). The increase at Jungfraujoch, which might be regarded as a proxy for the background increase, has approximately the same magnitude as the decrease of ozone predicted from the emission reductions in Europe since 1985.

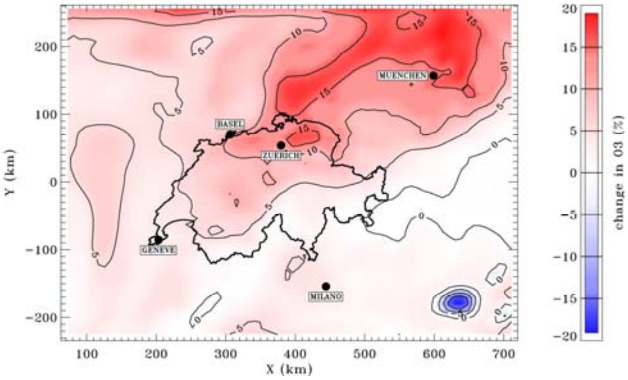

Fig. 1 ; Scenario 1 (1985 CLE) – base case (2000 CLE). The predicted difference in O_3 mixing ratios (%) relative to the base case on 5 August 2003, at 14:00-15:00 UTC.

Scenario 2: 2000, NC

In this case, simulations were performed using emissions prepared for the year 2000 assuming an uncontrolled economic development. Higher emissions in this scenario with respect to the base case (2000 CLE) would lead to higher peak ozone levels in the Swiss Plateau. The difference would have been about 15-20 % in the north and about 10% in the south.

Scenario 3: 2010, GOTH

Emissions used for this scenario case, are for the year 2010 following the Gothenburg Protocol. In this case, the predicted ozone mixing ratios would be less than in the base case in the whole model domain. The predicted difference in peak ozone concentrations relative to the base case is about 5 - 6 % in northern Switzerland and 6 – 10 % in the south (Figure 2). Results of Scenarios 3 and 4 are very similar because of the similar emission levels.

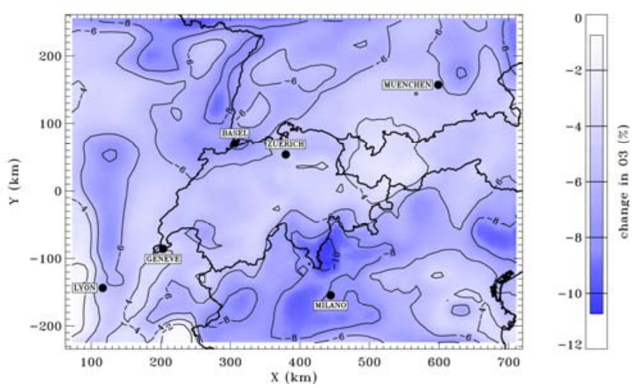

Fig. 2 ; Scenario 3 (2010 GOTH) - base case (2000 CLE). The predicted difference in O_3 mixing ratios (%) relative to the base case on 5 August 2003, at 14:00-15:00 UTC.

Scenario 5 : 2010, GOTH 100 / 50

Gothenburg target emissions were used for Europe. For Switzerland, on the other hand, Gothenburg target emissions were reduced to half. This kind of further reduction of emissions in Switzerland would lead to a stronger decrease in peak ozone levels in northern Switzerland (from 6% in the western part of Switzerland up to 15 % in the northeast). In the south, the difference is basically the same as in scenario 3 with a 6-10 % decrease.

Scenario 6 : 2010, GOTH 50 / 50

Reducing Gothenburg target emissions to half everywhere in the model domain would decrease peak ozone levels substantially: 10-18 % in the north and up to 20 % in southern Switzerland (Figure 3).

Scenario 7 : 2000, CLE 100 / 0

In this scenario, anthropogenic emissions in Switzerland were switched off and emissions abroad were kept the same as in the base case (2000 CLE). Only biogenic emissions were considered in Switzerland in this hypothetical case. This would bring ozone levels down by 5-30% in the north, with the greatest reductions around Zurich, but no significant change would be seen in the south where ozone levels would still be affected by the emissions abroad.

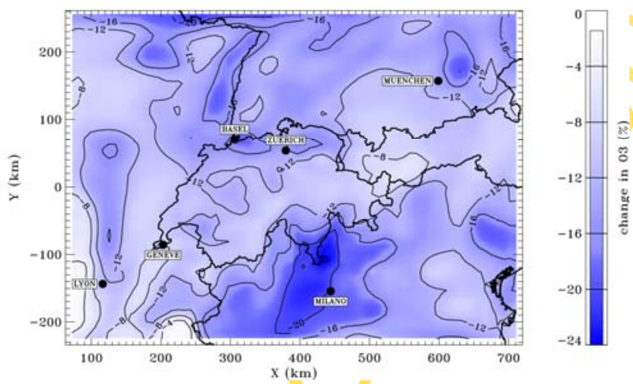

Fig. 3 ; Scenario 6 (2010 GOTH 50 / 50) - base case (2000 CLE). The predicted difference in O_3 mixing ratios (%) relative to the base case on 5 August 2003, at 14:00-15:00 UTC.

The number of hours on 5 August, 2003 when ozone concentrations are higher than 60 ppb were calculated for all model grid cells of the fine domain. In Figure 4, the red regions are those where the threshold is most exceeded and dark blue regions are least exceeded. In base case, highest exceedances are in the south. Reducing Gothenburg target emissions to half only in Switzerland (scenario 5, not shown) would not change the figure very much with respect to scenario 3. On the other hand, reducing Gothenburg emissions also abroad by half (scenario 6) would make a significant difference. However, these results suggest that there will still be regions in this case where ozone threshold would be exceeded. The hypothetical case where anthropogenic emissions in Switzerland were set to zero (scenario 7, not shown) seems not be very effective as long as emissions abroad remain the same. Especially southern regions are still affected by the emissions in Italy.

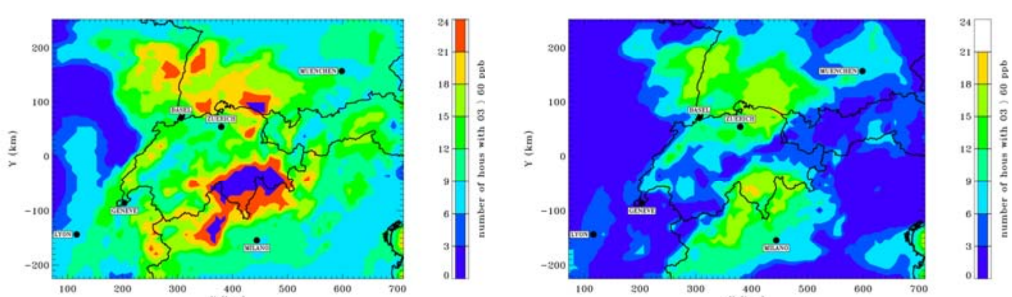

Fig. 4 ; Predicted number of hours in grid cells where ozone mixing ratios exceeded 60 ppb during 5 August 2003. Base case (left), Scenario 6 (right).

In summary, model predictions suggest that peak ozone concentrations in 1985 were about 5-15 % higher in Switzerland than in 2000 for the same meteorological conditions. If there were no mitigation measures, peak ozone levels would have been 15-20 % and 10-15 % higher in northern and southern Switzerland, respectively. These results suggest that reductions of the precursor emissions since 1985 were effective to decrease the local ozone production although this effect cannot be seen by the measurements except in the region of Zurich. This is probably due to the increase in the background ozone (Ordonez *et al.*, 2005). Scenarios with the future emissions showed that the Gothenburg Protocol on emissions, if strictly applied, would lead in 2010 to about 5-6 % decrease in the peak values in most areas and 10% in southern Switzerland. Decreasing Gothenburg target emissions to half is more efficient if this is carried out in whole Europe. In that case, peak ozone levels would be 10-20 % lower in Switzerland. Tests with zero anthropogenic emissions in Switzerland suggest that even extreme measures cannot bring ozone levels below legal thresholds if taken only in Switzerland. The question if half of the Gothenburg target emissions are enough to meet the standard, needs to be answered by investigating air quality for longer time periods than this episode. Investigations of longer time periods would put the conclusions on more solid ground. A crucial factor for Europe and Switzerland will be the development of the background ozone concentrations.

REFERENCES

Andreani-Aksoyoglu S., J. Keller, (1995) Estimates of monoterpene and isoprene emissions from the forests in Switzerland. Journal of Atmospheric Chemistry 20, 71-87.

BUWAL, (2004) Masnahmen (in german), http://www.umwelt-schweiz.ch/buwal/de/fachgebiete/fg_luft/themen/massnahmen/index.html.

ENVIRON, (2004) User's Guide, Comprehensive Air Quality Model with Extensions (CAMx). Version 4.10s. ENVIRON International Corporation, Novato.

Gery M. W., G.Z. Whitten, J.P.Killus, and M.C. Dodge, (1989) A photochemical kinetics mechanism for urban and regional scale computer modeling. J. Geophys. Res. 94, 925-956.

Horowitz L. W., Walters S., Mauzerall D. L., Emmons L. K., Rasch P. J., Granier C., Tie X., Lamarque J.-F., Schultz M. G., Tyndall G. S., Orlando J. J., Brasseur G. P., (2003) A global simulation of tropospheric ozone and related tracers: Description and evaluation of MOZART, version 2. JOURNAL OF GEOPHYSICAL RESEARCH 108, 4784, doi:10.1029/2002JD002853.

Keller J., S. Andreani-Aksoyoglu, M. Tinguely, A.S.H. Prevot, (2005) Emission scenarios 1985-2010: Their influence on ozone in Switzerland. PSI Report 05-07, Paul Scherrer Institute,

Ordonez C., Mathis H., Furger M., Henne S., Hueglin C., Staehelin J., Prevot A. S. H., (2005) Changes of daily surface ozone maxima in Switzerland in all seasons from 1992 to 2002 and discussions of summer 2003. Atmospheric chemistry and physics 5, 1187-1203.

PSU/NCAR, (2004) MM5 Version 3 Tutorial Presentations.

Acknowledgements

We are grateful to the following institutes for providing weather, emission and air quality data: MeteoSwiss, FUB, UBA, TNO, INFRAS, METEOTEST, EMEP, IIASA. This study was financially supported by BUWAL.