P1.2 NUMERICAL SIMULATIONS OF OZONE LEVEL SCENARIOS FOR MEXICO CITY

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1. INTRODUCTION

Mexico City belongs to a number of cities in the subtropical and tropical regions which suffer from severe air pollution episodes. High concentrations of ozone and related photooxidants as well as of particulate matter are causing health effects, ecological damages and economic losses. Although rigorous abatement measures were implemented by the city authorities during the past 10 years the air pollution situation in the Mexico City Metropolitan Area (MCMA) is still a severe problem as the concentrations of ozone and its precursors as well as aerosol particles still exceed significantly the threshold values.

The effect of present day emissions and as well as projected future emissions on primary pollutant concentrations and ozone concentrations in the Mexico City Metropolitan Area was investigated using the coupled meteorology chemistry model MCCM (Grell et al., 2000).

2. METHODS

2.1 Model Description and Setup

For simulating the effect of different precursor emissions scenarios on ozone levels in Mexico City the coupled meteorology chemistry model MCCM (Grell et al., 2000) was applied for three nested model domains. MCCM simulates simultaneously the meteorological and air chemistry fields over the model domain and provides time dependent three-dimensional distributions of all the major inorganic and organic species relevant to oxidant formation. The meteorological part of the model is based on the Fifth-Generation NCAR/Penn State Mesoscale Model, MM5 (Grell et al., 1995). The online coupling of meteorology and chemistry provides fully consistent results without interpolation of data.

MCCM includes two separate detailed gas-phase chemistry mechanisms (RADM2 and RACM) with 39 and 47 chemical species respectively and particulate matter (PM10) as a passive tracer. Furthermore, formation of particulate matter in the gas phase such as sulfate, nitrate and organic acids is accounted for by the gas phase chemistry mechanisms. This secondary aerosol material due to chemical reactions also contributes to PM10 and is added to the primary PM10. Both chemical mechanisms are well-tested and can be applied over a wide range of reactant concentrations For the present application the RADM2 chemical mechanism (Stockwell et al, 1990) was applied.

In association with the gas phase chemistry, 22 photolysis frequencies are computed online within MCCM depending on cloud cover, ozone, temperature and pressure in the model atmosphere.

Biogenic VOC and NO emissions are calculated based on land use data, surface temperature and radiation. Anthropogenic emissions are read from a preprocessed emission input with hourly temporal resolution.

For the present study only meteorological simulations were performed for Domain 1 and Domain 2 due to the lack of emissions for these areas. For Domain 3 meteorology and chemistry were simulated. The first domain with a horizontal resolution of 18 km covers practically whole Mexico, the second domain with 6 km resolution the central part of Mexico. The innermost domain has a horizontal resolution of 2 km and includes the Mexico City Metropolitan Area and some of the surrounding mountains (Figure 1).

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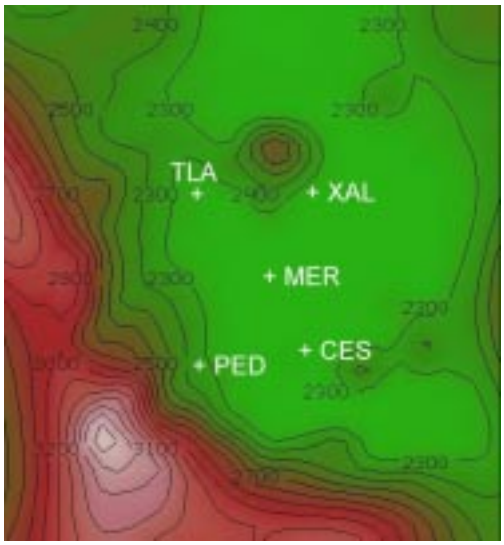

Fig. 1: Topography of the innermost model domain (Domain 3) and position of five stations of the RAMA (Red Automática de Monitoreo Atmosférica) observational network. The measurement stations are located in the center (station Merced [MER]) and in the suburbs of the city. The extent of Domain 3 is 80 km in North-South direction and 72 km in East-West direction.

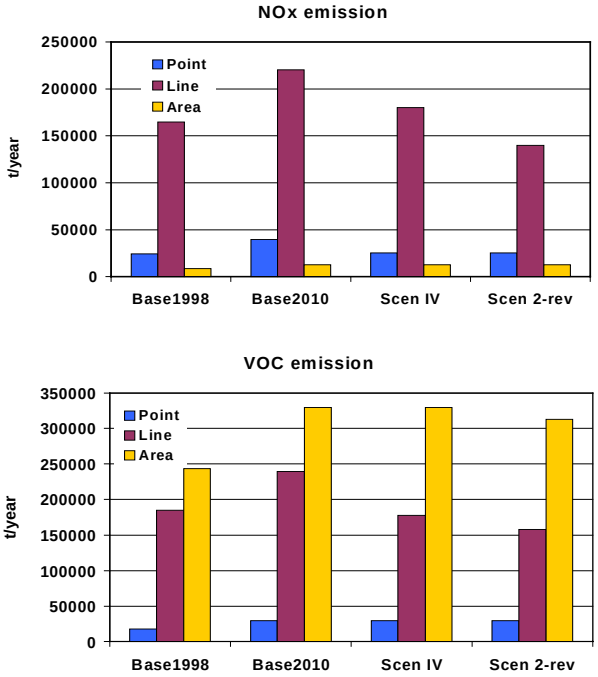

Fig. 2: Annual NOx Emissions (above) and VOC Emissions (below) in t/a for the baseline 1998 case, the projected baseline 2010 case and two mitigation scenarios.

2.2 Emission Scenarios

Yearly emission data for point sources, line sources, and area sources were supplied by CAM (Comisión Ambiental Metropolitana) in Mexico City for the year of 1998, for a projected baseline case in the year 2010, and for different mitigation scenarios. The various abatement scenarios are defined by closing power plants, reducing traffic emissions by replacing parts of the car fleet etc. In order to use these emissions as hourly input for MCCM the emissions were distributed over the grid cells of the model using e.g. geographical information on streets and administrative units with consideration of temporal traffic variations.

Figure 2 displays the NO and the VOC emissions for 1998 and the projected emissions for 2010. Futhermore it includes the emissions for a mitigation scenario that includes the replacement of old private cars, low sulfur diesel standards, the replacement of microbuses, and the relocation of two power plants (Scenario IV) and a very restrictive mitigation scenario that includes additionally restrictions in private car traffic and a reduction of the area VOC emissions (Scenario 2-rev). As Figure 2 shows, the mitigation measures of Scenario IV which is more realistic than Scenario 2-rev cannot even compensate the projected increase of the emissions between 1998 and 2010.

3. RESULTS

3.1 *Reference case and Comparison with Measured Data*

For comparison of the model results with the observational data of the RAMA observational network an 8 day episode in May 1998 with high ozone concentrations was selected. The simulations run from May 3 1998, 7 a.m. until May 11 1998, 7 a.m. local time. The initial conditions for the chemical species were based on measurements.

A comparison of modeled ozone concentrations for the episode with measured values at different locations within Mexico City is given in Figure 3. At the station Pedregal (PED), ozone concentrations are frequently higher than at sites closer to the city center. A reason for this is that the thermal winds during daytime are directed towards the mountains and therefore ozone precursors emitted in the center of the city are mostly transported towards the south west of the city. The simulation results show that MCCM is well able to reproduce temperatures and wind directions for the complex topography of the Mexico City area.

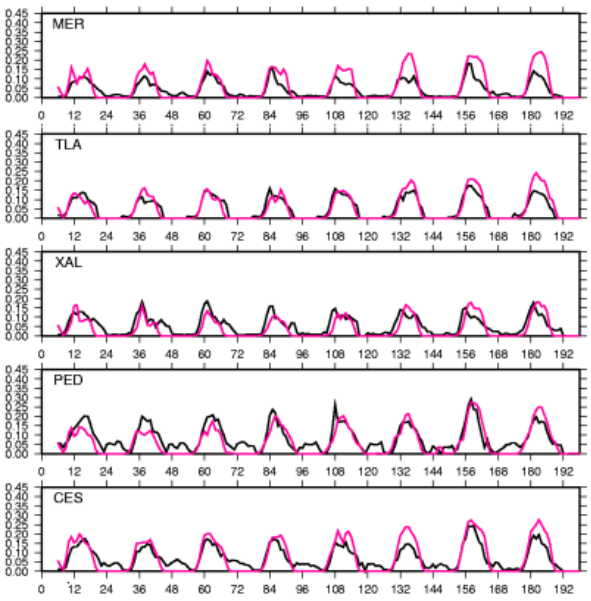

Fig. 3: Measured (black lines) and simulated diurnal course of near surface ozone concentrations (red lines) in ppm for May 3 1998, 7 a.m. local time to May 11 1998, 7 a.m. local time for the locations given in Fig. 1.

3.2 *Scenario Simulations*

In order to investigate the effect of the projected increase of ozone precursor emissions and possible mitigation measures simulations were carried out for different emission scenarios for the meteorological conditions of the baseline case in May 1998. Figure 4 shows the 8 day average of the near surface ozone concentrations at 4 p.m. local time for the projected 2010 baseline emissions. A comparison with the ozone distributions found for the 1998 baseline emissions shows almost identical patterns, with maximum ozone concentrations being only slightly higher for the 2010 than for the 1998 emissions.

Figure 4 reveals that, in agreement with observations, the maximum ozone concentrations occur in the south west of the city, which is downwind of the city center, as an uphill flow is prevailing during the afternoon. The minimum ozone concentrations are found in the center of the city, where the NO emitted by traffic titrates the ozone, and in the northern part of the city at places where the NO emissions from industry and power plants locally reduce the ozone concentrations

Compared to the ozone concentrations predicted for the 2010 baseline emissions, the emission reductions of Scenario IV result in a decrease of the daytime ozone concentrations between 5 and 25 ppb at most locations. However, in the center of the city and for the locations where power plants are switched off, the noontime ozone concentrations are higher for the mitigation scenario than for the baseline case since less ozone is titrated in case of the reduced NO emissions at these locations.

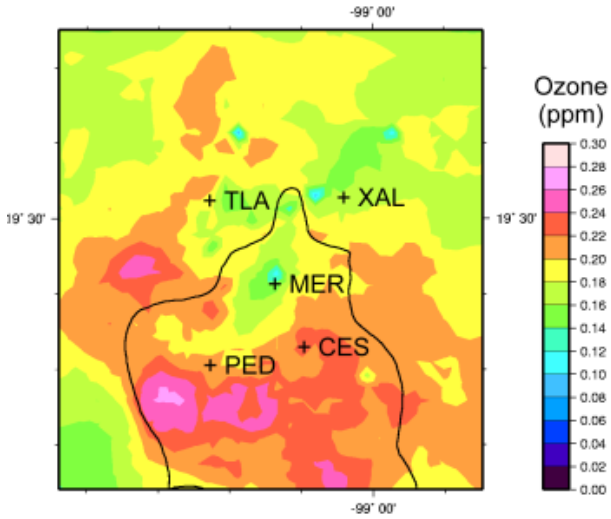

Fig 4: Average surface ozone concentration (in ppm) over 8 days at 4 p.m. Mexican summer time for the baseline 2010 emission scenario.

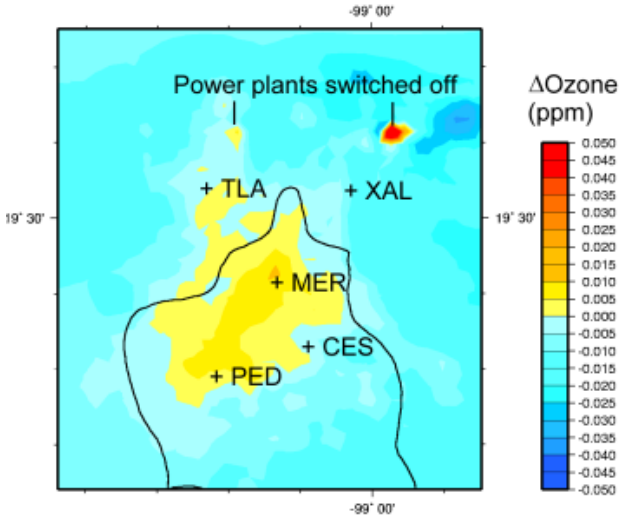

Fig. 5: Difference in the 8 day average of the surface ozone concentration (in ppm) at 1 p.m. Mexican summer time between the 2010 baseline case and Scenario IV.

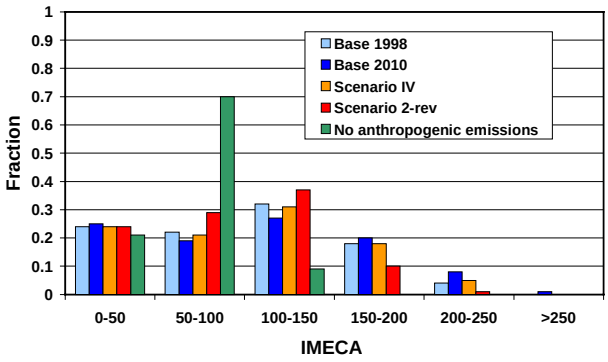

Fig 6: Simulated frequency of different ozone concentration ranges within the Mexico City area during the 8 day episode in May 1998. The IMECA intervals correspond to the following values in ppb: 0-55, 55-110, 110-171, 171-232, 232-293, >293.

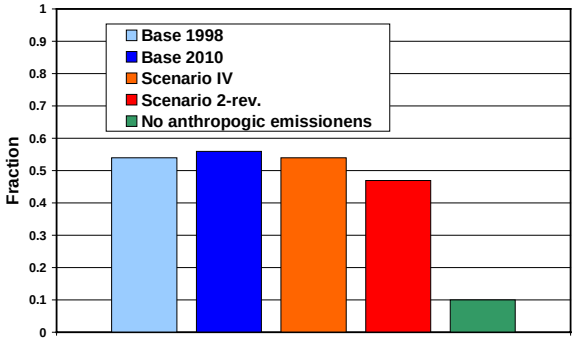

Fig 7: Fraction of hours with ozone above 100 IMECA (= 110 ppb) within Domain 3 during the 8 day episode. The fraction of daylight hours during the episode is 0.54.

The effect of the different emission scenarios on the air quality index for Mexico City (Indice Metropolitano del la Calidad del Aire: IMECA) is displayed in Figures 6 and 7. For comparison a fictive scenario without any anthropogenic emissions is also included in these figures. The initial conditions for the chemical species were the same for this case as for the other scenarios. Therefore, still some photochemistry occurs mainly during the first half of the episode, which results in ozone concentrations between 50 and 100 ppb during most of the daytime hours (Figure 6). The photochemistry due to the initial values is also the reason for the ozone concentrations above 110 ppb in the no emission case in Figure 7.

Figure 6 shows that the projected increase of the anthropogenic emissions between 1998 and 2010 results in an larger number of hours with IMECA>200. This situation can only be mitigated by very strict emission reduction strategies like those applied in Scenario 2 rev. However, even with this emission reduction strategy it is still not possible to achieve good air quality, i.e. IMECA<100. Figure 7 shows that ozone exceeds 100 IMECA in over 50% of the time of the whole episode for the 1998 and 2010 baseline cases and for Scenario IV. For Scenario 2 rev. the occurence is below 0.5, i.e. only for this scenario the ozone concentration exceeds 110 ppb during less than 50% of the whole episode.

4. CONCLUDING REMARKS

The coupled meteorology chemistry model MCCM (Grell et al., 2000) was applied to investigate the effect of different precursor emission scenarios on ozone concentrations in Mexico City. The model results indicate that taken the projected emissions for the year 2010, extremely strong emission reduction measures for Mexico City would be necessary in order to significantly improve the air quality in Mexico City.

Emission reductions were found to reduce frequency of peak ozone concentrations above 200 ppb. However, for the regarded episode the number of hours with ozone concentrations between 100 and 200 ppb was found to be almost uneffected by realistic emission reduction measures.

However, simulations over longer time periods will be necessary to put the above statements on a more general basis. Furthermore emission data bases for larger areas are necessary to account for both long term and long range transport effects of emission reductions.

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5. REFERENCES

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