Impact of climate change on air quality in and around Mexico City

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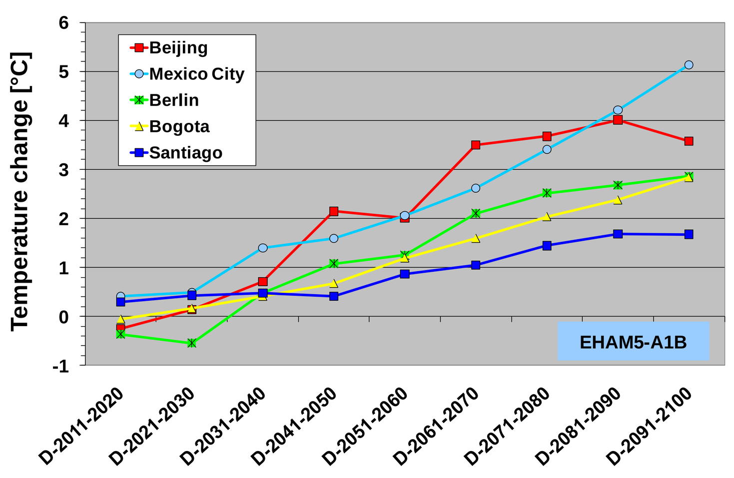
Introduction



Besides the anthropogenic and biogenic emission of primary pollutants the concentration and deposition of airborne pollutants depends strongly on the meteorological conditions. Therefore, the effects of global climate change can also have an impact on regional air quality. For example, changed meteorological conditions can affect the horizontal transport as well as the vertical exchange of pollutants, changes in solar radiation can affect the production of photochemical compounds, or changes in temperature and solar radiation can affect the emission of biogenic precursors of near-surface ozone.

The change of global climate can be assessed by long term simulations with global climate models, which only have a coarse spatial resolution (usually > 100 km). Regional studies are required in order to resolve the effects of the spatial distribution of pollutant sources. Furthermore, data also have to be provided on a regional or local scale for further impact assessments .

Method

A method for the quantitative assessment of the effect of climate change on regional air quality is the dynamical downscaling of global climate model results with a regional climate-chemistry model. Studies for Europe with the coupled regional climate-chemistry model MCCM (Forkel and Knoche, 2006, J. Geophys. Research, 111, D12302, doi:10.1029/2005JD006748) have shown that regional climate change results in a significant increase the concentrations of photochemical compounds in Europe. In particular, extremely high values in near-surface ozone were found to increase under future climate conditions.

To investigate the potential effects of climate change on photochemistry in Mexico, regional simulations with the coupled 3-dimensional meteorology-chemistry model MCCM were performed for present day and possible future conditions.

Setup of the regional climate chemistry simulations for Mexico

The regional climate-chemistry simulations for Mexico were performed with MCCM using the RADM2 gas phase chemistry mechanism. Two time slices of 5 years were selected for the downscaling: beginning of the 90ths of the previous century and of the 40ths of this century.

The meteorological boundary conditions for the regional simulations were derived from output of a simulation with the global model ECHAM5 for the greenhouse gas scenario A1B. The global simulation with resolution T63 (ca. 1.875 or 180 km) was downscaled to a horizontal resolution of 36 km.

As the global climate simulations do not supply boundary conditions for tropospheric chemistry typical concentrations were used as boundary values for the chemical constituents. For the future time slice the same anthropogenic emissions as for the present day simulations were used in order to display the pure climate effect.

Due to the year-to-year variability, simulations over several years are necessary. The results for Mexico must still be considered as preliminary due to the small number of years covered by the regional simulations.

MCCM (Mesoscale Climate Chemistry Model)

Meteorological part
- Based on MM5
- Non-hydrostatic
- Nesting capability
- Soil and snow model

Online chemistry part
- RADM2, RACM, RACM-MIM
- Photolysis model
- Aerosol module
- Biogenic emission module

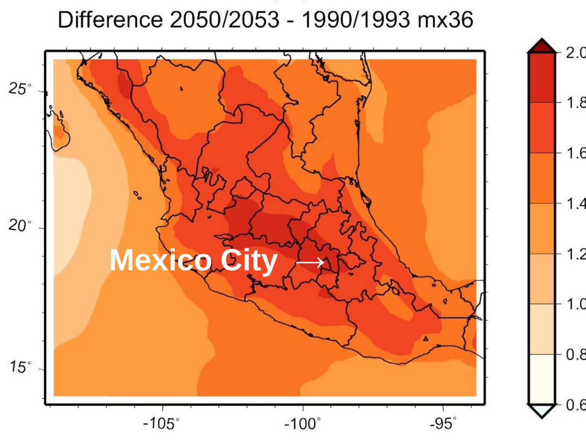
Input : Any met. input suitable for MM5, initial concentrations of chemical compounds and hourly anthropogenic emissions

Output : 3-d meteorological fields, snow height, photolysis frequencies, concentrations of chemical compounds in the gas and particle phase, …

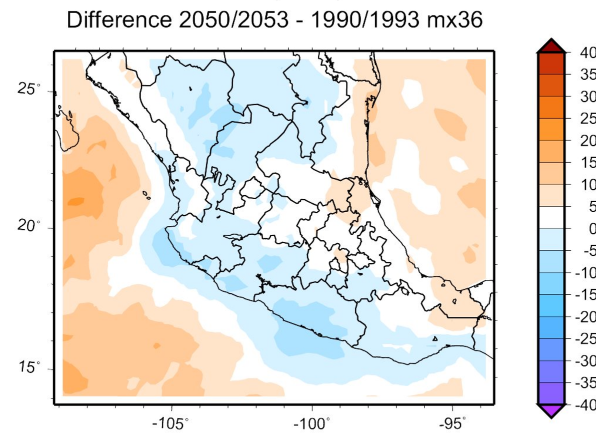
Applications Episodes and sensitivity studies
Real time air quality simulations
Regional climate chemistry simulations

Grell et al. 2000, Atmospheric Environment

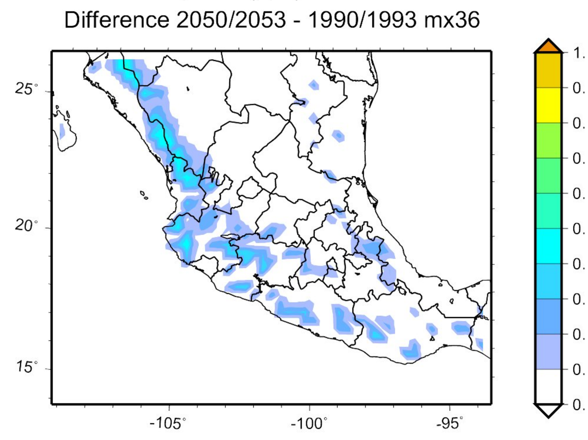
Results



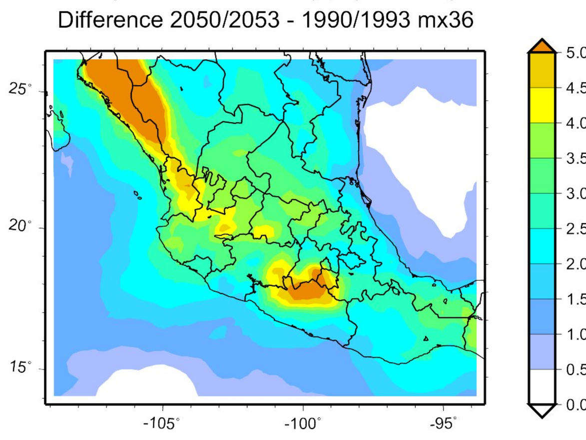
Similar values but more pronounced regional structures then in global simulation results



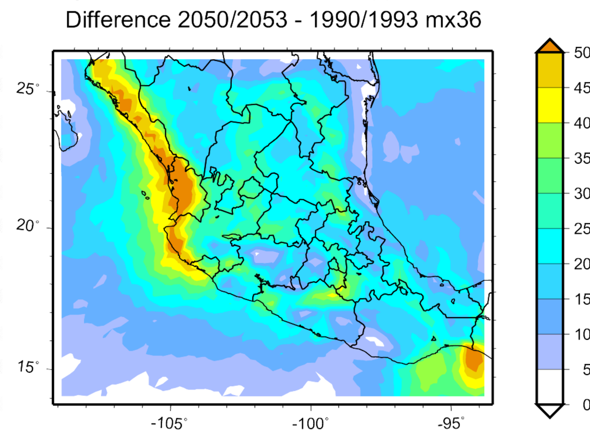
Change in cloud cover and solar radiation less pronounced than in Central Europe



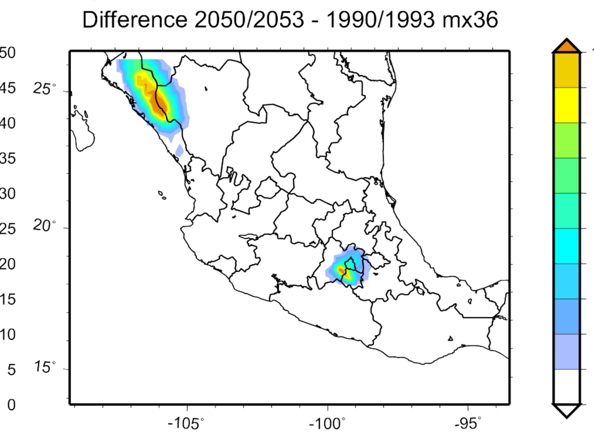
Isoprene emissions increase by 30 – 40 %. The pattern reflects the location of forest areas.



Most pronounced changes in mean ozone maxima for regions with both high (biogenic) VOC and NO_x



For the Mexico City plume the number days with mean ozone > 60 ppb is already at maximum



Indication of increase of extreme values of maximum ozone in some regions

About 2 degrees higher temperatures were simulated for future climate conditions. Due to the higher temperatures, the emissions of isoprene, which is an important precursor for near-surface ozone, were found to increase by 30 – 40 %. Changes in solar radiation were found to be only small over Mexico, and have therefore only minor effects on isoprene emissions and photochemistry.

The higher isoprene concentrations result in an increase in maximum ozone concentrations by up to 5 ppb (10 $\mu g/m^3$, i.e. 4 – 8 %). Most pronounced changes occur in areas where both (biogenic) VOC and NO_x show high values. The number of days with exceedance of 60 ppb for the 8-hourly ozone mean increases significantly. An exception is the plume of Mexico City, where practically no further exceedances of the threshold were possible. However, the preliminary results indicate an increase of the number of days with mean ozone above 90 ppb and also higher extreme values of maximum ozone in the Mexico City plume.

Conclusions

The results of the coupled climate chemistry simulations with MCCM indicate an increase of summer temperatures and higher photooxidant concentrations in Mexico for future climate conditions. As unchanged anthropogenic precursor emissions were assumed for this study, the increase of maximum ozone concentrations due to the more favourable conditions for photo smog situations could by compensated by regional emission reduction measures. On the other hand, there exists the risk, that regional emission mitigation measures can be negated by the effect of changed climate conditions.

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