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Simulation of the impact of climate change on regional air quality

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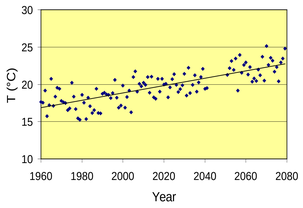
Introduction



It can be expected that increased temperature and changed cloudiness due to climatic change will have an effect on UV radiation, isoprene emission, and on near surface photooxidant concentrations.

To investigate the potential effects of climate change on photochemistry in Southern Germany and Mexico, regional simulations with the coupled 3-dimensional meteorology-chemistry model MCCM were performed for present day and possible future conditions. Regional simulations are required to resolve the effects of the spatial distribution of pollutant sources.

Setup of the regional climate chemistry simulations

The regional simulations with MCCM were driven by boundary conditions provided by a long term simulation of a global climate model. The dynamical downscaling of the global simulation was performed with MCCM (Grell et al., 2000), which is based on the NCAR/Penn State University mesoscale model MM5. MCCM includes a detailed land-surface-model, online coupled atmospheric gas phase chemistry and a photolysis model. The simulations were performed using the RADM2 gas phase chemistry.

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.

Properties of MCCM (MM5/chem)

- Based on the NCAR / Penn State University mesoscale meteorological model MM5
- Online coupled chemistry
- Non hydrostatic dynamics
- Multiple nesting capability
- Multilayer soil model with vegetation and snow
- Different physics options as in MM5
- Possibility of four dimensional data assimilation (FDDA) for meteorology
- Different gas phase chemistry mechanisms (RADM2, RACM, and RACM with updated isoprene chemistry)
- Aerosol module
- Online photolysis model with 23 photolysis frequencies
- Anthropogenic emissions
- Online calculation of biogenic VOC- and NO emissions based on land use, surface temperature, and radiation
- Dry deposition

Setup for Europe and Southern Germany

The regional climate chemistry simulations for Europe and Southern Germany are based on boundary conditions provided by a long term simulation of the global climate model ECHAM4 and the greenhouse gas scenario IS92a, which is comparable to the scenario A1B. In two consecutive one-way nesting steps, the global simulation with resolution T42 (ca. 2.5) was downscaled to a resolution of 60 km for Europe and 20km for Central Europe and the Alpine region. Two time slices of about 10 years were selected for the downscaling: the 90ths of the previous century and the 30ths of this century.

Setup for Mexico

The meteorological boundary conditions for the regional simulations for Mexico were derived from ECHAM5 output for the greenhouse gas scenario A1B. The horizontal resolution of the regional simulation is 36 km. The results for Mexico must still be considered as preliminary due to the small number of years covered by the simulations.

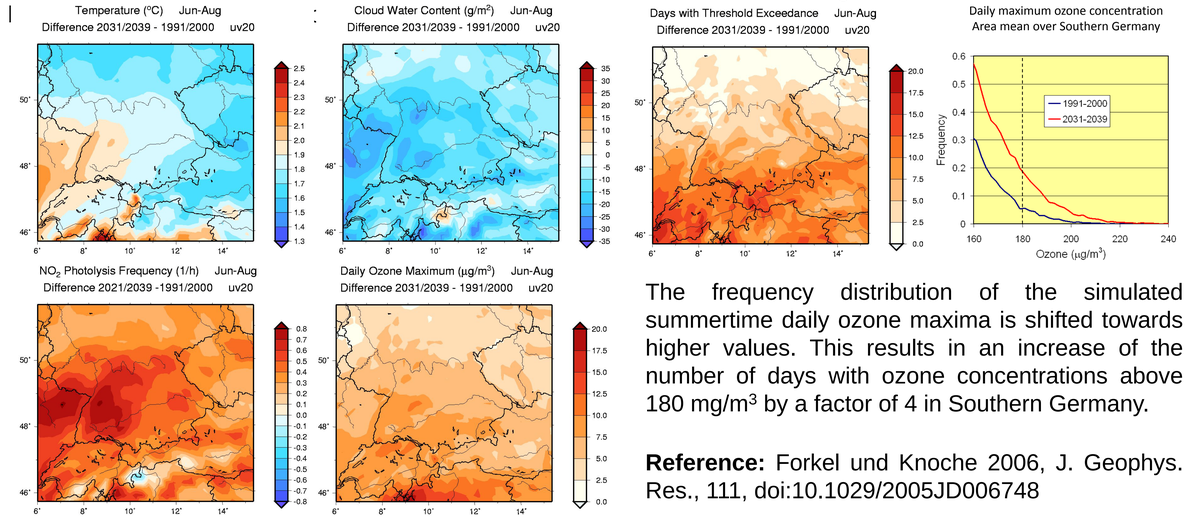
Results

Europe and Southern Germany

For future climate conditions the results show an increase of the mean summertime temperature by about 2 degrees. Mean cloud water and cloud ice content as well as the number of cloudy days show a pronounced decrease during summer, which results in higher photolysis frequencies and biogenic VOC emissions.

Under the model assumption of unchanged anthropogenic emissions this leads to an increase of the mean values of all photooxidants except PAN in the summer months.

In the case of near surface ozone the mean daily maximum concentration increases by 4–12 mg/m^3 or nearly 10 % in Southern Germany and the target value of 120 mg/m^3 for the 8 hour average of the ozone concentration will

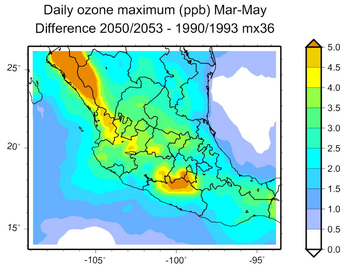


The frequency distribution of the simulated summertime daily ozone maxima is shifted towards higher values. This results in an increase of the number of days with ozone concentrations above 180 mg/m^3 by a factor of 4 in Southern Germany.

Reference: Forkel und Knoche 2006, J. Geophys. Res., 111, doi:10.1029/2005JD006748

Mexico

Due to almost 2 degrees higher temperatures isoprene emissions were found to increase by 30 – 40 % although change in solar radiation is only small. This results in an increase in maximum ozone concentrations by up to 10 mg/m^3 (4 – 8 %). Most pronounced changes occur in areas where both (biogenic) VOC and NO_x show high values. The preliminary results indicate in particular an increase of the extreme values of maximum ozone



Conclusions

The results of the coupled climate chemistry simulations with MCCM indicate an increase of summer temperatures and of photo smog situations under future climate conditions for Europe as well as for Mexico. As unchanged anthropogenic 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.

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