Regional coupled climate-chemistry modelling

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Global climate change and air quality

Global climate change results in regional effects on

- cloud cover, visible and UV radiation
- temperature, thermal stratification, wind fields
- frequency and intensity of precipitation

➡ **Impact of changed climate on air quality**

On the other side, changes in tropospheric ozone or aerosol particle concentrations have an effect on climate due to

- radiative forcing
- effect on cloud formation

Global climate change and air quality

Global climate chemistry simulations indicate

- for ozone:
  - increase in polluted areas of Asia, USA, and Europe
  - decrease in unpolluted regions
- for aerosol particles:
  - non-uniform picture, strongly depending on projected precipitation patterns

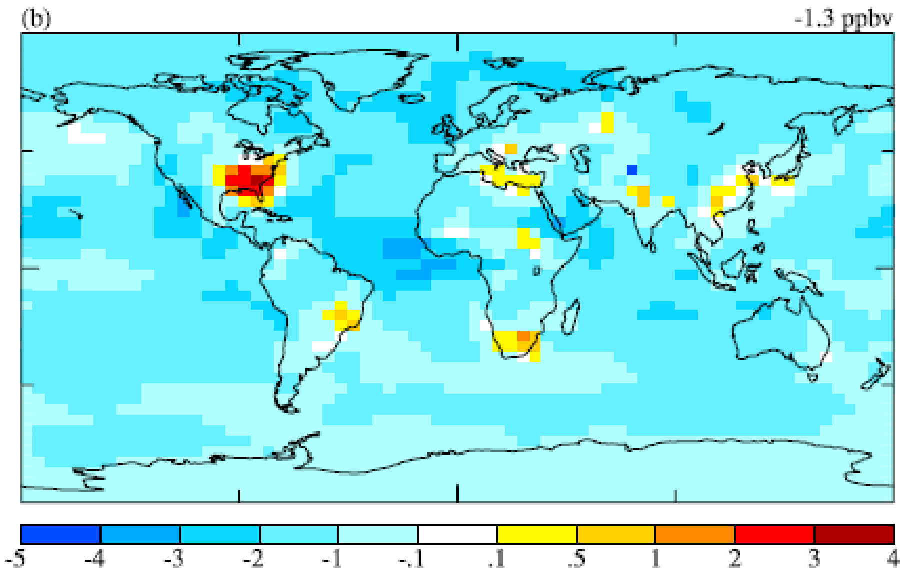
Resolved effects depend on model resolution

Requirement for regional studies

We need a **quantitative assessment** of future air quality conditions

- to estimate the on ecological, economical, and biological systems
- to estimate possible feedback mechanisms
- to develop mitigation and adaptation strategies

➡ For impact assessments data have to be provided on a **regional or local scale**



Change in near-surface ozone from a global CTM (Racherla & Adams, 2006)

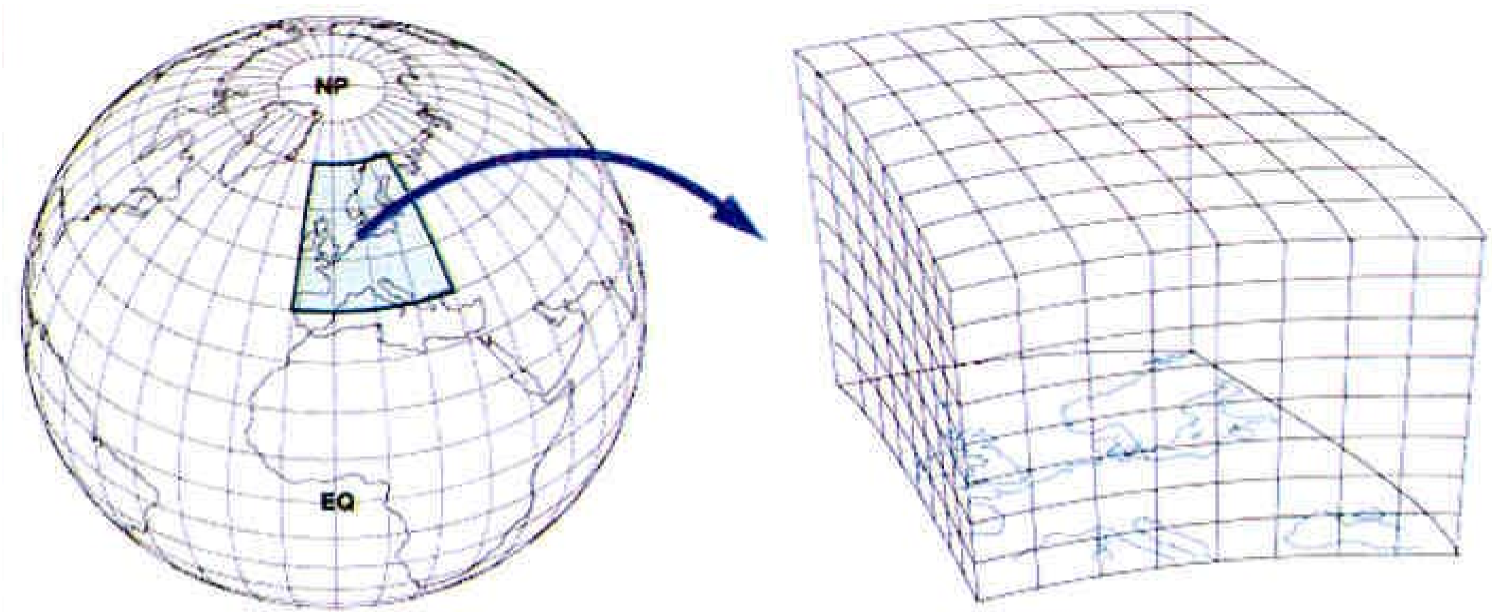
Presently only coarse resolutions are possible for global climate-chemistry simulations

Requirement for regional studies

Special requirements with respect to air quality due to

- nonlinear behaviour of tropospheric chemistry
- requirement of full 3-d meteorological information

→ Climate effect studies require **dynamical downscaling** of global climate scenarios with **regional climate models**



Regional climate-chemistry simulations

Setup and required input

Green house gases, aerosol based on scenarios of population, economy, and technology (IPCC)

Global climate simulations (e.g. ECHAM5, HadCM)

Global anthropogenic emissions, land use

Online coupled or offline global chemistry simulation

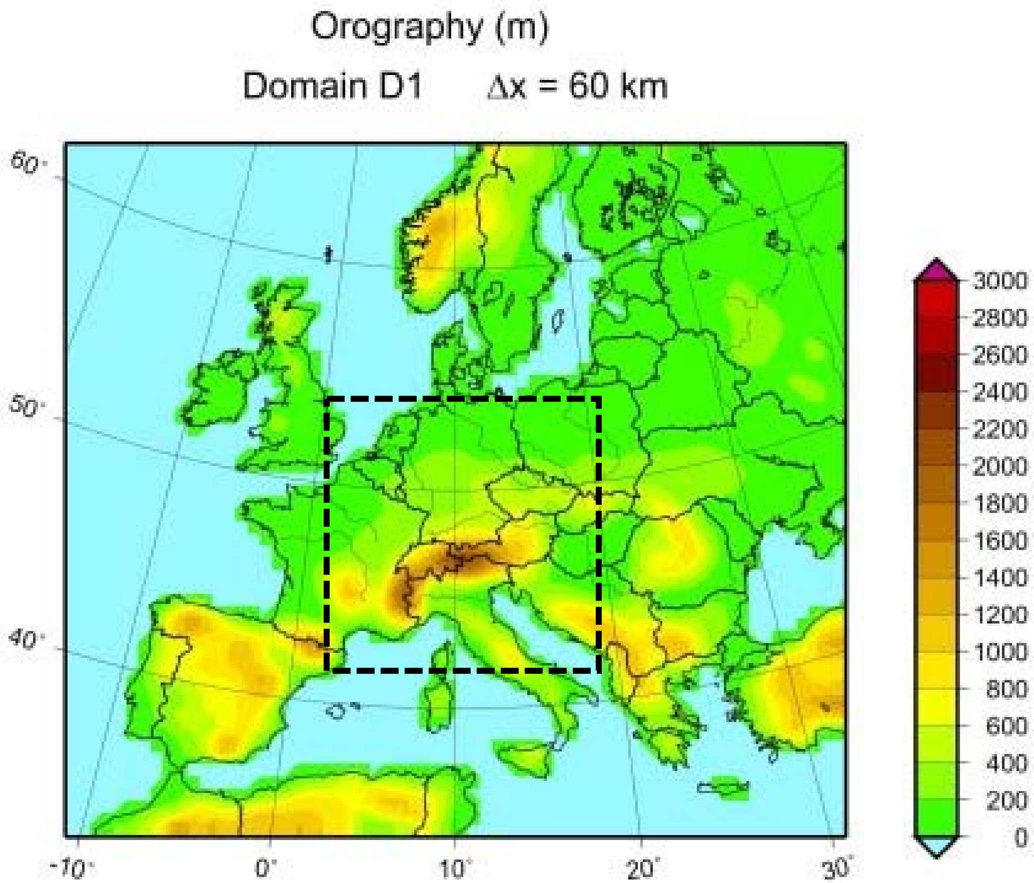
Boundary conditions of meteorological variables

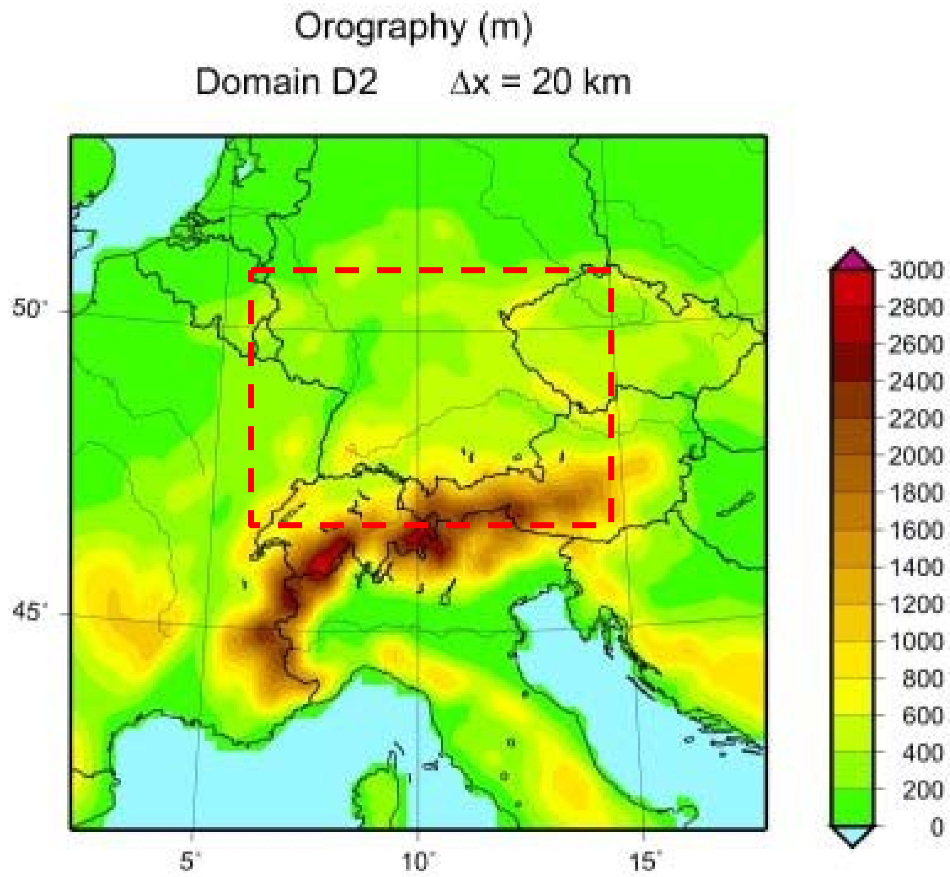
Chemistry boundary conditions

Regional anthropogenic emissions, land use

Regional climate-chemistry model (MCCM, WRF/chem)
Continuous long term simulation

Application example: Southern Germany





Continuous regional simulations with **MCCM** for two time slices:

- 1991 - 2000 ´Present´
- 2031 - 2039 ´Future´

Met. boundary conditions from ECHAM4, 2 nested domains (Δx=60km, Δx=20 km)

Sensitivity study with unchanged anthropogenic emissions

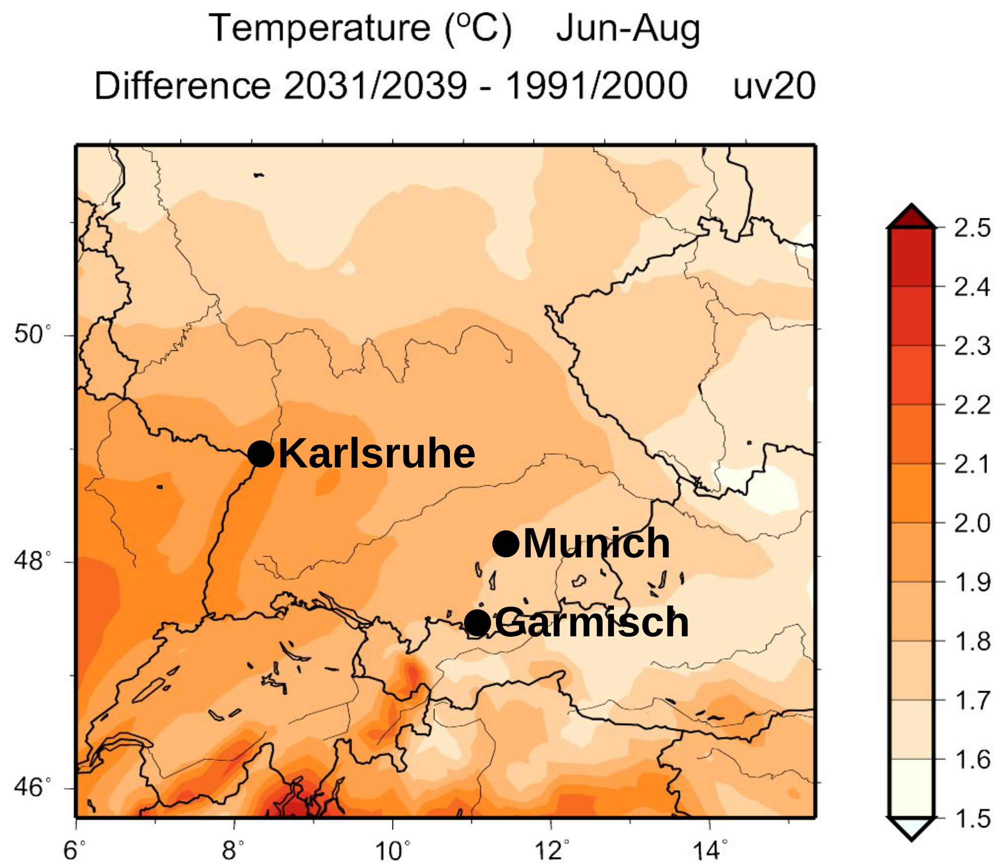
Online coupled climate-chemistry model MCCM

- Based on the PSU / NCAR meteorological model MM5
- Online coupled chemistry
- Terrain following coordinates
- Non-hydrostatic dynamics
- Multiple nesting capability
- Multilayer soil-vegetation-snow model
- RADM, RACM, and RACM-MIM gas phase chemistry mechanism
- Optional MADE/SORGAM aerosol module
- Online photolysis model
- Dry deposition
- Online calculation of BVOC and soil NO emissions

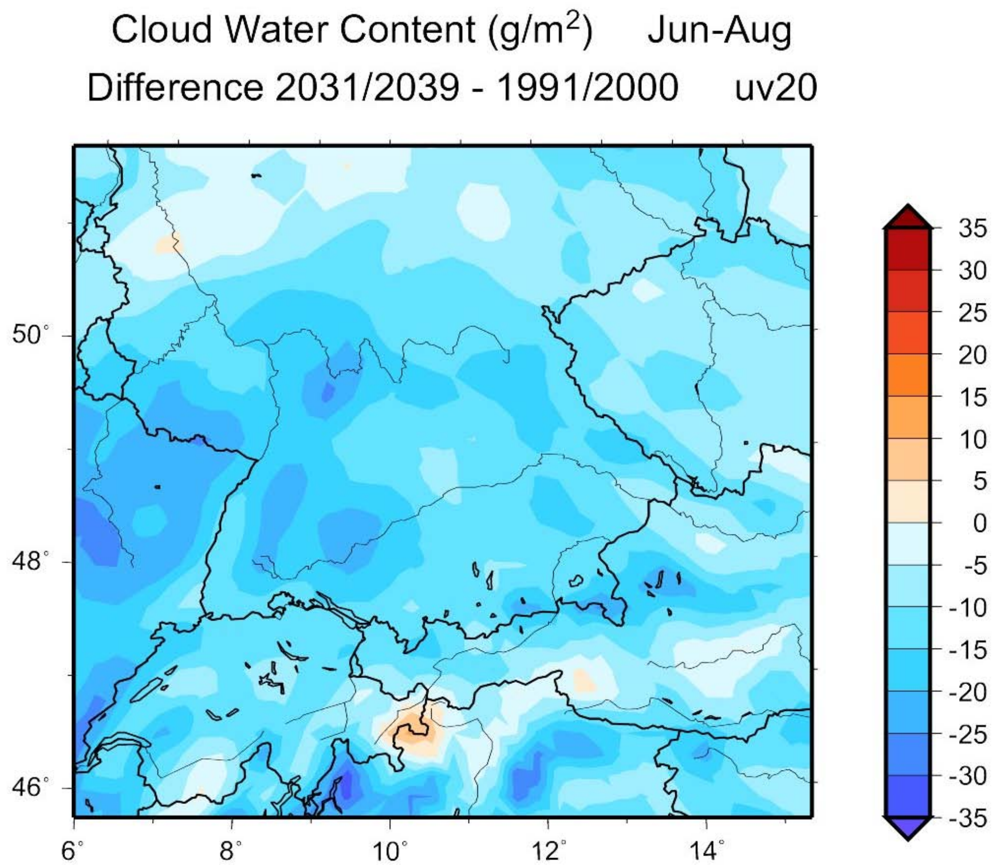
Grell et al. 2000, Atmospheric Environment

Regional climate change in Southern Germany

Change in temperature and cloud water



About 2°C higher temperature

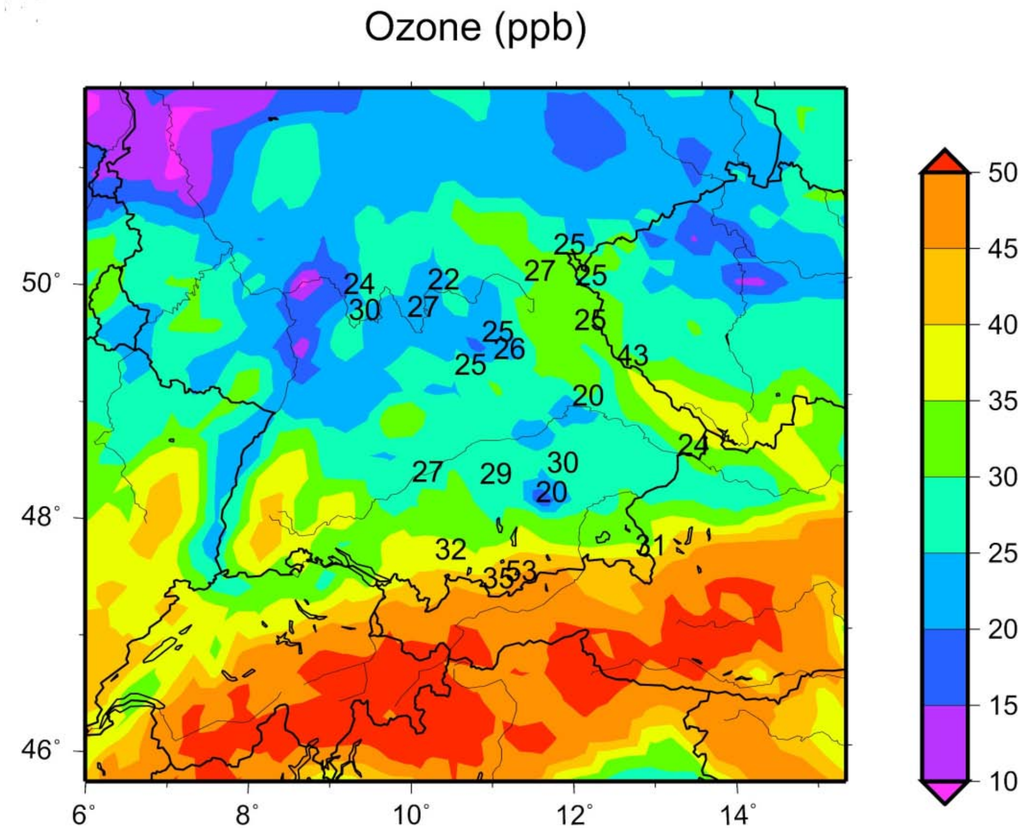


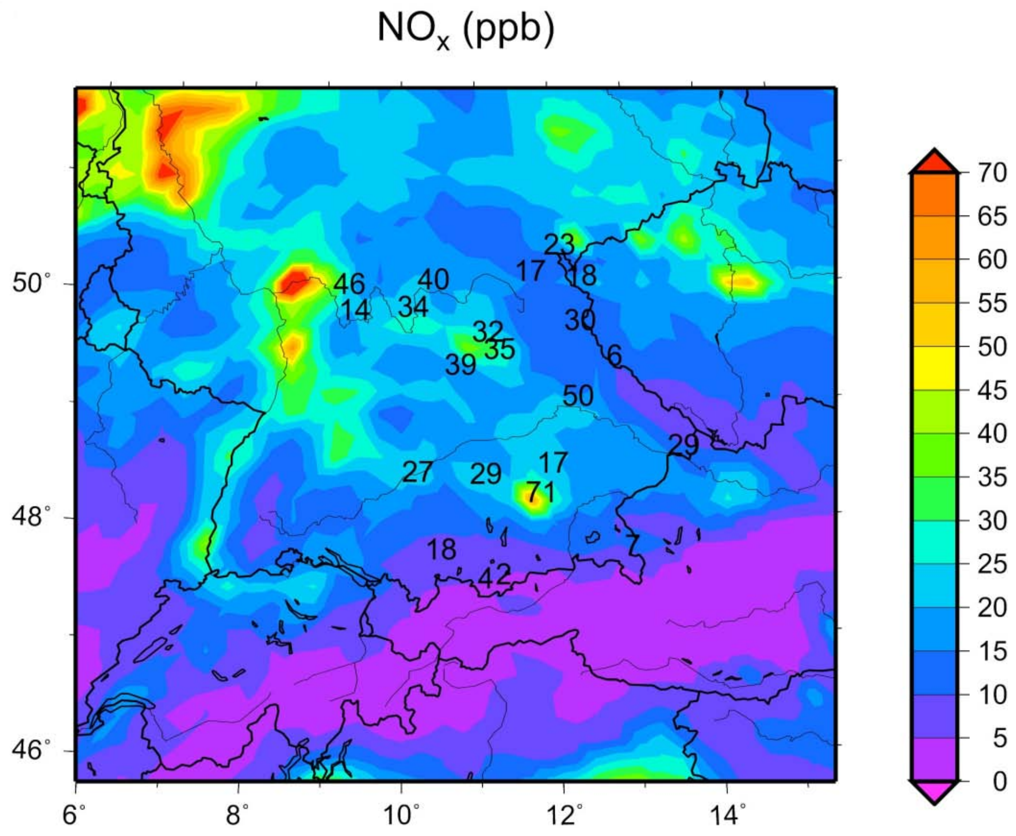
10 – 20 % increase in solar radiation

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

Validation

Mean values for the months June-August 1996-2000

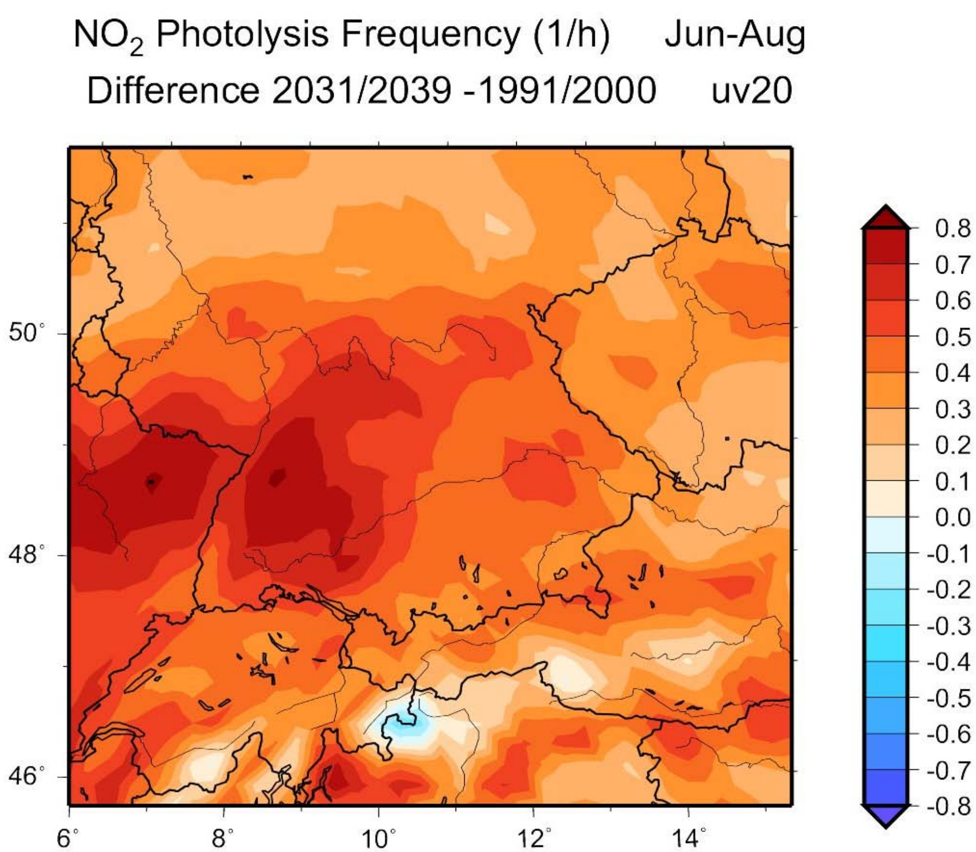




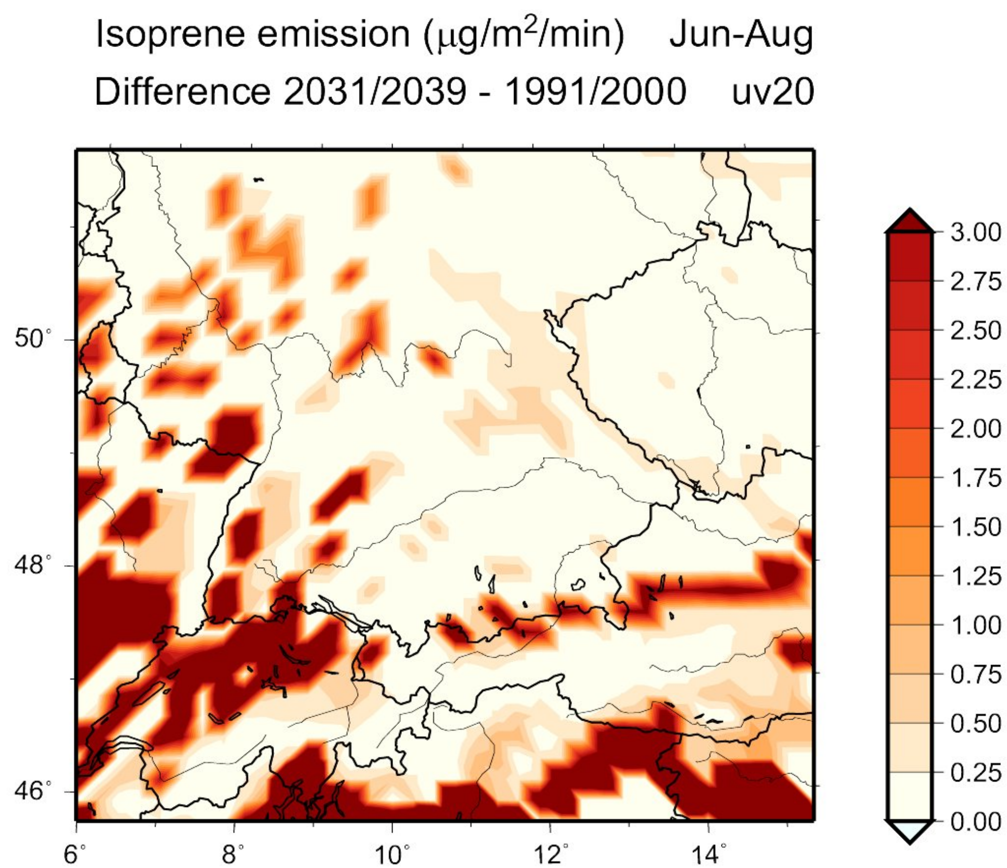
Observations: Bayerisches Landesamt für Umweltschutz

Climate effect on regional air quality

Change in radiation and isoprene emissions



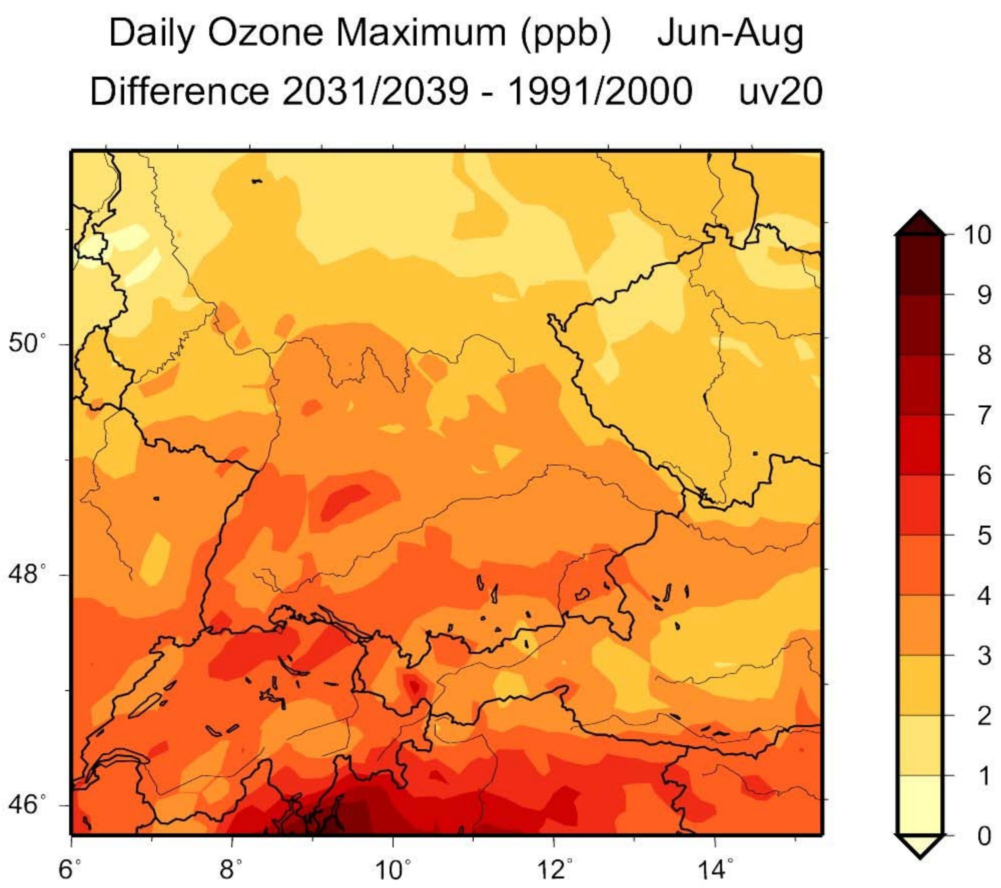
5-10% increase in solar radiation and photolysis



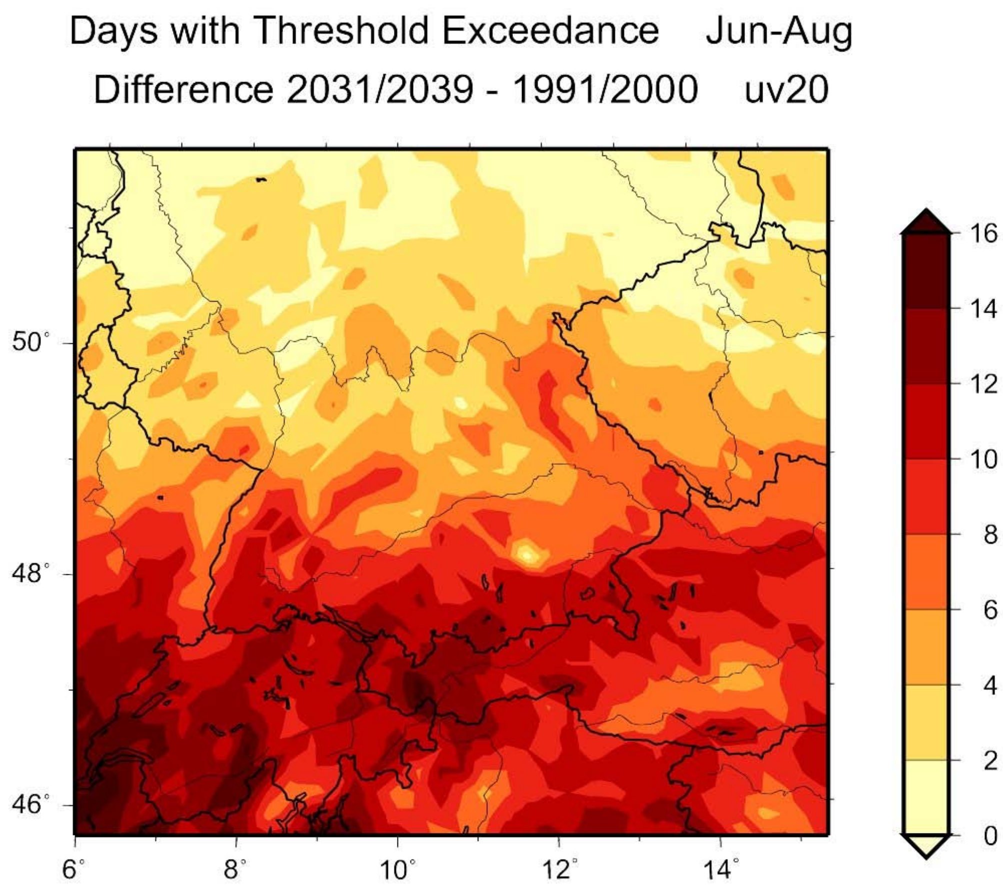
Increase by up to 50 % due to 2° higher temperature and increased solar radiation

Climate effect on regional air quality

Change in near surface ozone



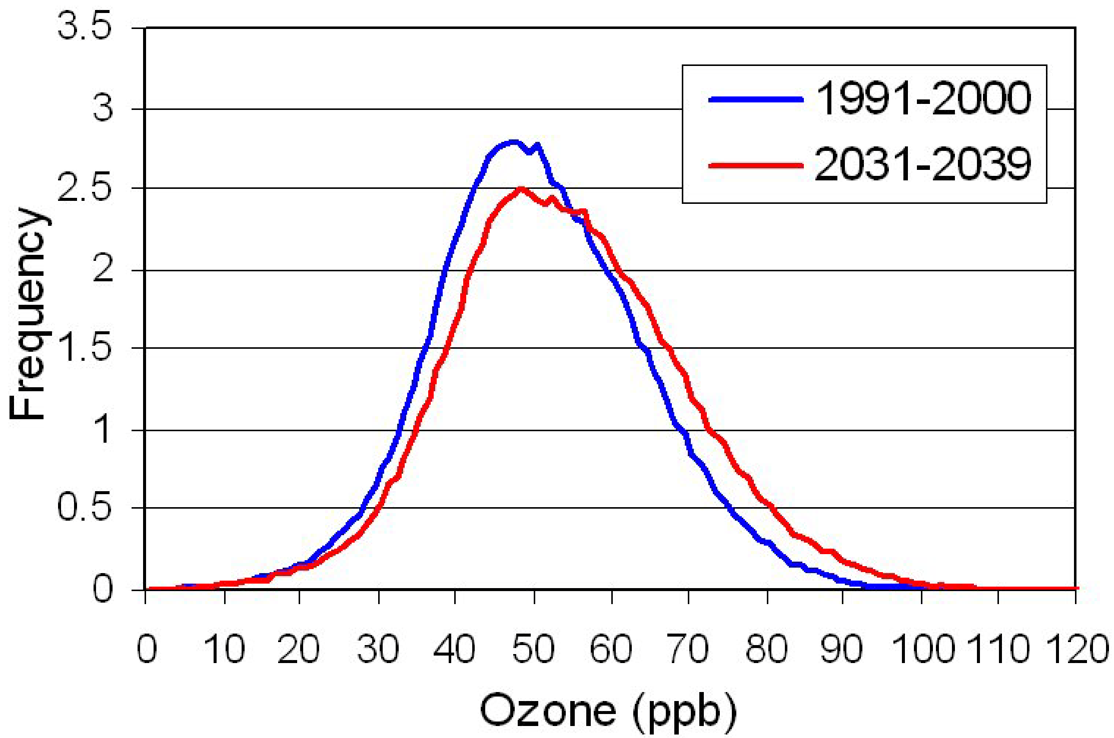
Increase of mean daily ozone maximum by 5 – 10 % (strongly influenced by isoprene increase)

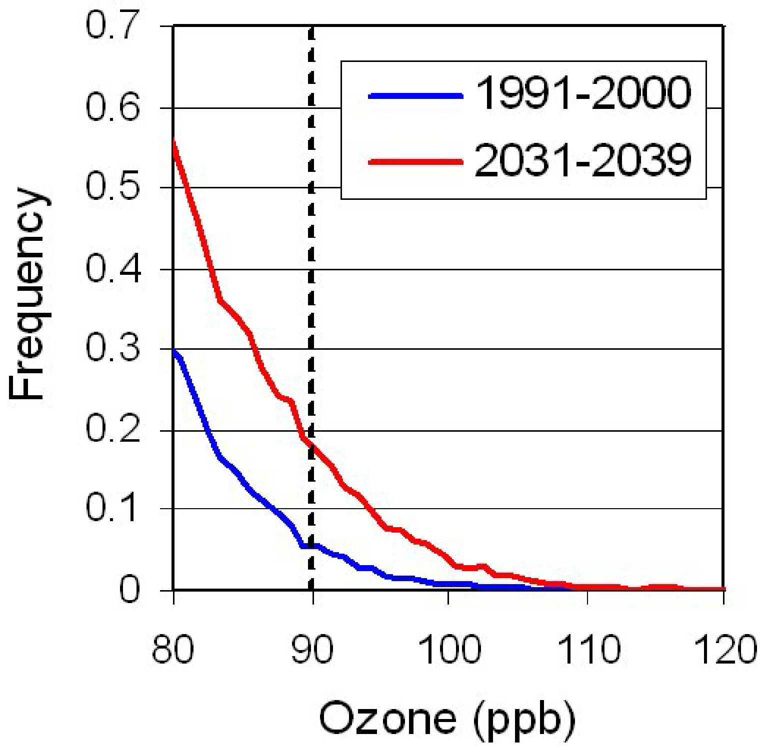


More days with threshold exceedance

Climate effect on regional air quality

Distribution of daily ozone maxima

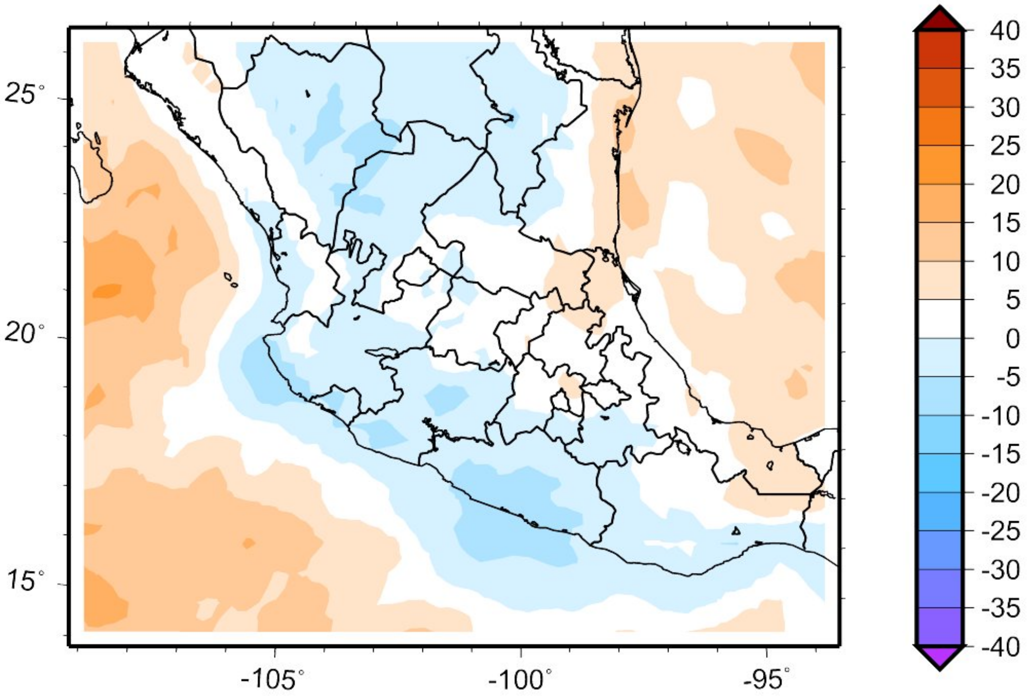


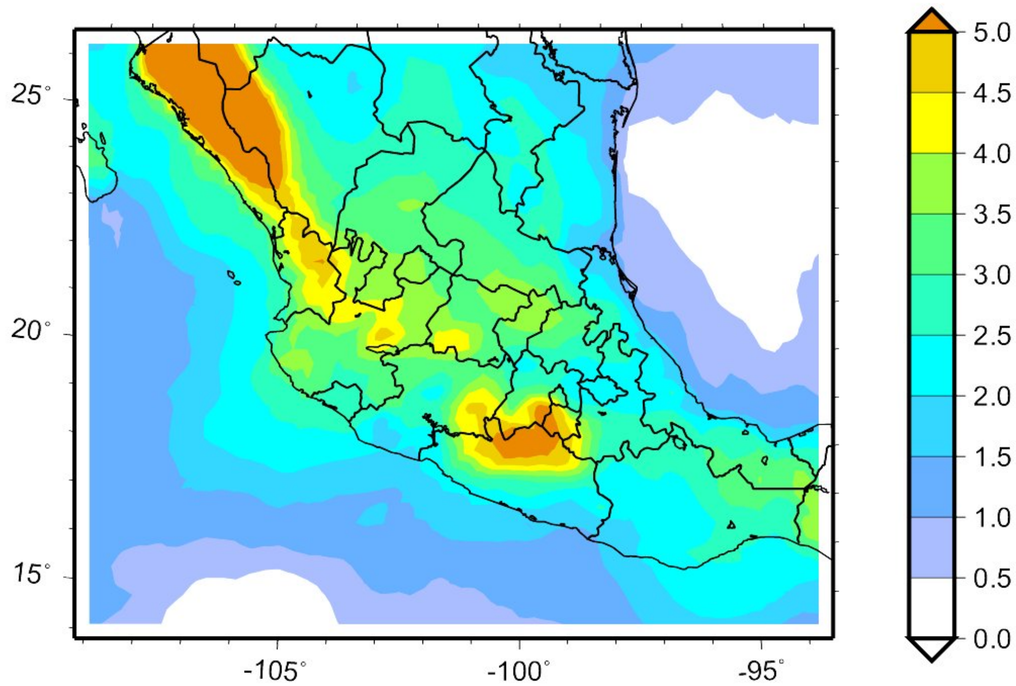


Occurrence of maximum ozone concentrations > 180 $\mu g/m^3$ increases by a factor of 4 over Southern Germany

Present: 99 station-events/year   Future: 384 station-events/year

Another application example: Mexico





Change in cloud cover and solar radiation is less pronounced than for Germany

Most pronounced changes for areas with both (biogenic) VOC and NO_x

Climate-chemistry modeling for China?

Karlsruhe Institute of Technology

What would we need for a regional climate-chemistry simulation for China?

1) Meteorological boundary conditions?
   - ✓ Available from DKRZ, Hadley center and other institutions
2) Chemistry boundary conditions?
   - ✓ Become more and more available
3) Baseline emissions?
   - ✓ 'In principle' existing
   - ? accessible?
   - ✓? quality and resolution
4) Scenarios for regional emissions and land use

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Conclusions

1. Projections with global climate and climate-chemistry models need refinement for impact studies
2. Long term simulations and multi-scenario ensembles are required for uncertainty analysis
3. Good performance for photochemistry
4. Climate effect can compensate the effect of mitigation measures
5. Future studies will also include aerosol particles
6. Good quality baseline emissions required
7. Emission scenarios


Thank you for your attention!
IMK-IFU, Garmisch-Partenkirchen