A One-Year Simulation of Photochemistry over Europe with a Complex Chemistry Transport Model

Contribution to subproject GLOREAM and TOR2

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Summary

During the year 2001 many efforts have been made to allow a broader applicability of the EURAD model for scientific and assessment purposes. The new applications include short-term forecasts to be used for the scientific community, environmental agencies and the public (http://www.eurad.uni-koeln.de). EURAD has become a more efficient model, which can now be used for long-term applications (one year or longer on different horizontal scales).

The reference year 1997 has been chosen to study air pollution over Europe and especially over Northrhine-Westfalia (NRW). The model is used in a nesting mode with three grids (Europe 125 km, Central Europe 25 km, 5 km NRW, 23 vertical layers, ~15 layers in the PBL). The chemistry-transport calculations are performed using the RACM mechanism (with a Rosenbrock solver) and an aerosol dynamics module including secondary organic aerosols. Average pollution distributions are calculated as well as nonatainment periods of the relevant pollution thresholds given by the EU-directives 96/62 and 99/30. Especially for the aerosols the pollution levels are above the desired levels (see Friese et al., this issue).

Ozone seems to be slightly underestimated by the RACM mechanism (compared to observations and RADM2), especially the peak concentrations do seldom exceed 200 $\mu g/m^3$. The highest yearly averages of ozone were found south of the Alpine main ridge. Whereas the NO_x concentrations are the highest around the major urban and industrial regions over Europe. The evaluation (according the EU directives) of the results shows a seasonality of the agreement between simulation and observation for some species. For polluted sites the agreement is good in summer. The largest discrepancies were found in early spring and late autumn. For background sites there was no seasonal trend in the model quality. For nitrogen oxides the model performance was lower in summer than in winter. A possible explanation for this may be the larger measurement uncertainties at low concentrations.

Introduction

EURAD is a complex three-dimensional model system for chemistry transport and meteorological simulations (Hass et al., 1997; Memmesheimer et al., 1997). It has been used for numerous episodic studies on air pollution events, emission scenarios and sensitivity experiments. The power of modern computer hardware and efforts to increase the numerical effectivity of the model system enable an improvement of the feasible range of applications. There is a demand for air pollution forecast system by the environmental agencies, the scientific community and the public. In addition, longer investigation periods with full treatment of chemistry and dynamics is desired, as well as more complex applications with respect to chemical mechanisms (including aerosols) or model domain (size and distribution). During the year 2001 many steps have been made to achieve these goals.

Objectives

The main objectives are the improvement and evaluation of the EURAD modelling system. This includes the development of a real time air pollution forecast system. This system can be used to predict episodes of enhanced pollutant concentrations. In addition this is a tool to assist the planning of field campaigns.

Scientific objectives are the investigation of the current air pollution situation over European and the calculation of trace gas fluxes and budgets. A detailed analysis of dynamical and chemical processes of air pollution events Emission scenarios for the planning of air pollution control strategies is calculated.

Activities

There have been several technical developments within the model code of the EURAD-CTM. A new chemical solver (Rosenbrock) has been implemented in the model. The use of the chemical pre-processor kpp allows for several chemical mechanisms to be used in the model – including RACM (Stockwell et al., 1997). A modified version of the aerosol dynamics module, which includes secondary organic aerosol, has been developed (Friese et al., 2000; Schell et al., 2001).

Routine simulations of the complete EURAD modelling systems have been established for a daily pollution forecast (see Jakobs et al., this issue).

The EURAD model has been used to simulate the whole year of 1997 on different horizontal scales (Europe, Central Europe, Northrhine-Westfalia (NRW)). The main focus of the project (sponsored by the Environmental agency of NRW) is the assessment of the EU air pollution directives. The results will also be used for other purposes in the focus of TOR2.

A study of vertical transport and budgets of ozone in frontal systems has been finished (PHD thesis by Heike Kunz).

The regional focus of the model applications is not longer only Europe. There are applications including parts of North America, the Atlantic and Europe to study transport and chemical transformations in this region. Additionally the model has been applied to the southern hemispheric tropics to study transport barriers and stratospheric-tropospheric exchange.

Results

The reference year 1997 has been chosen to study the current air pollution over Europe and especially over NRW. The model is used in a nesting mode with three grids (Europe 125 km, Central Europe 25 km, 5 km NRW, 23 vertical layers, ~15 layers in the PBL). The chemistry-transport calculations are performed using the RACM mechanism (with a Rosenbrock solver) and an aerosol dynamics module including secondary organic aerosols.

Average pollution distributions are calculated as well as nonatainment periods of the relevant pollution thresholds given by the EU-directives 96/62 and 99/30. Especially for the aerosols in large areas the pollution levels are above the desired thresholds. There are a number of episodes with increased concentration levels. The highest concentration levels of the primary occur in the winter. PM_{10} also shows increased values during these periods but the peak values in 1997 are found in the late summer (see Friese et al., this issue).

The simulation results are evaluated against EMEP and TOR monitoring data as well as data from the TEMES sites of NRW. Ozone seems to be slightly underestimated by the RACM mechanism (compared to observations and RADM2), especially the peak concentrations do seldom exceed 200 $\mu g/m^3$. The highest yearly averages of ozone were found south of the Alpine main ridge. Whereas the NO_x concentrations are the highest around the major urban and industrial regions over Europe. The evaluation (according the EU directives) of the results shows a seasonality of the agreement between simulation and observation for some species. For polluted sites the agreement is good in summer. The largest discrepancies were found in early spring and late autumn. For background sites there was no seasonal trend in the model quality. For nitrogen oxides the model performance was lower in summer than in winter. A possible explanation may be the larger measurement uncertainties at low concentrations. Time series of ozone maximum is given in figure 1, average ozone values over Europe in figure 2.

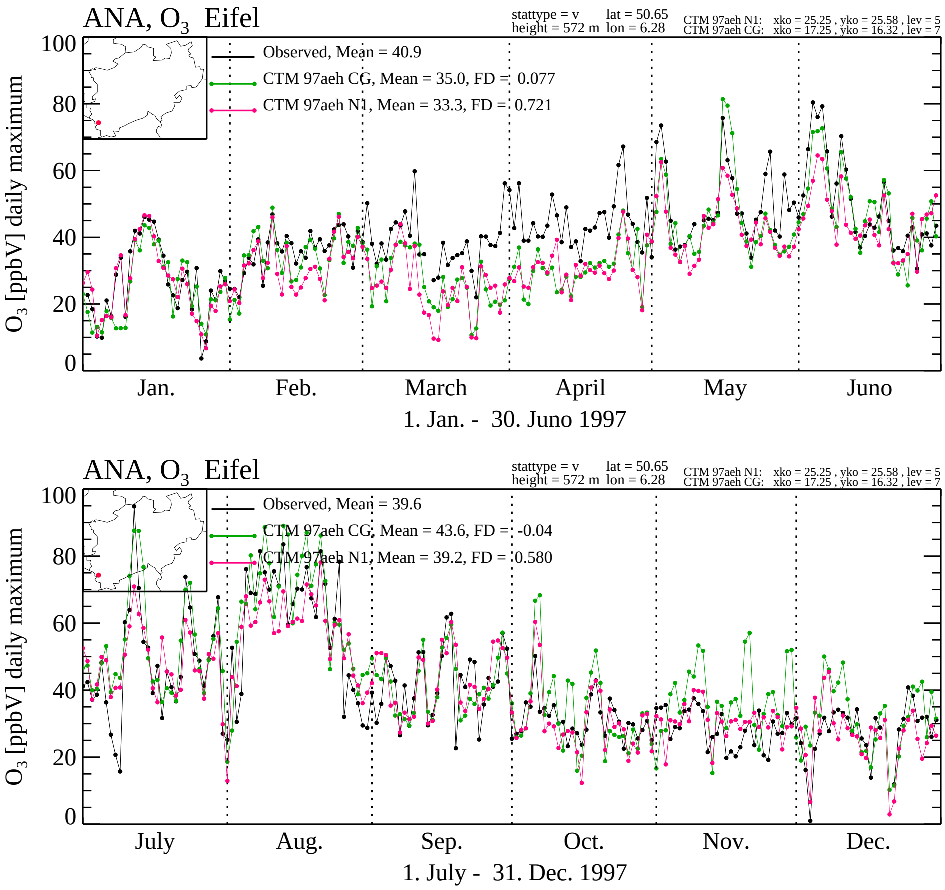

Figure 1: Time series of daily ozone maxima in ppbV for 1997 for the remote measurement site Eifel (TEMES measurement network, environmental agency NRW). Black: observed, green: mother domain, red: N1-domain.

Conclusions

The EURAD model has proved to be able to calculate the photochemistry over Europe for longer periods. The model performance has been tested. The dataset is suitable for scientific objectives. Especially budget calculations show the main source regions of photochemical ozone. In the average ozone concentrations there is a clear north south trend. Whereas peak concentrations may even occur over Central Europe

The deviations in the calculated ozone concentrations between calculations using the RACM mechanism compared to RADM2 simulations seem at least partly caused by the more detailed chemistry of the biogenic emitted components.

Acknowledgements

EURAD is financially supported by the BMBF within the framework of the AFO2000 programme. The Environmental Agency of North Rhine-Westphalia supports the long-term applications in particular with respect to the EU directives 96/62 and 99/30. The support by the German Weather Service (DWD), NCEP (U.S.), the IER, University of Stuttgart, EMEP and the TNO is gratefully acknowledged for providing meteorological and emission data. The numerical calculations have been supported by the ICG-II, ZAM and NIC of the Research Centre Jülich and the RRZK, Uni. of Cologne. A. Strunk, L. Niedrazik and J. Schwinger, in particular for the EURAD forecast, have supported the web presentation of EURAD.

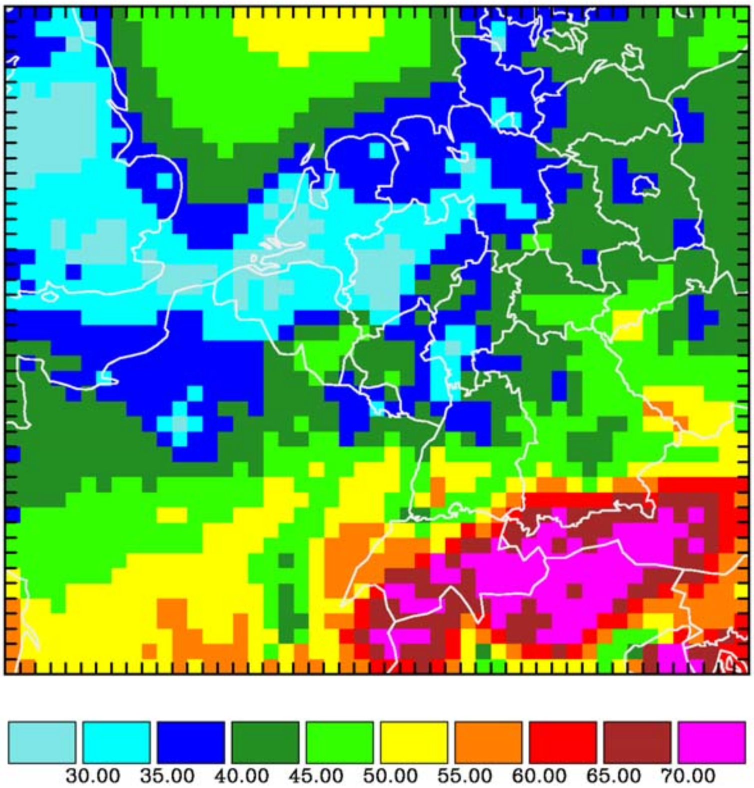

Figure 2: Average ozone concentration in µg/m^3 over Central Europe (Nest1) in 1997 simulated with the EURAD model.

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Aims for next year (i.e. 2002) and list of publications in 2001

Several activities which started in previous years will be continued:

The air pollution forecast will be published at http://www.eurad.uni-koeln.de every day. A database with simulated pollution maps is also available there.

Emission scenarios will be calculated in the framework of the TOR2 model comparison initiative. The work on the standard pollution pattern will also be continued.

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