1.20 LONG-TERM MODEL CALCULATIONS OF PARTICULATE MATTER AND PHOTOOXIDANTS FROM REGIONAL TO LOCAL SCALE WITH FOCUS ON NORTH-RHINE-WESTPHALIA

Michael Memmesheimer, Elmar Friese, Christoph Kessler[*], Hermann J. Jakobs,, Hendrik Feldmann, Georg Piekorz, Adolf Ebel

Rhenish Institute for Environmental Research, EURAD-Project, University of Cologne, Germany

also at Ford Research Center, Aachen

INTRODUCTION

Comprehensive air quality models (AQMs) have been developed during the last decades to simulate the transport, chemical transformation and deposition of air pollutants on the regional scale. The first applications of AQMs had been performed on episodes, e.g. for the investigation of photo-oxidant formation, including sequential nesting to get a better horizontal resolution and more information for regions of special interest with appropriate boundary values (Vogel et al., 1995; Kessler et al., 2001; Frohn et al., 2002). In recent years the formation of secondary particles and particle dynamics has been included into the models (Binkowski, 1999; Schell et al., 2002, Riemer et al., 2003). The rapid development of modern information technology now allows the application of comprehensive AQMs on an annual time scale well as short-term prediction (chemical weather forecast, Jakobs et al., 2002). The EURAD model has been used since 2001 for daily short-term predictions of air quality including gaseous compounds as CO, NO_2, SO_2 and Ozone as well as atmospheric particles e.g., as PM10. The results are displayed as graphics daily in the internet (www.eurad.uni-koeln.de).

Long-term runs for the years 1997 and 2002 have been carried out to analyse the air pollution situation in Europe with strong emphasis on North-Rhine-Westphalia (NRW). Long-term runs can provide data which are useful for several purposes. Physical and chemical processes controlling the concentrations of air pollutants can be studied. This led to a better understanding of processes in the atmosphere and supports the analysis of measured data. The modelling systems can also be applied as a tool to develop optimised air pollution abatement strategies. The results of the models allow the assessment of air quality in regions where observations are incomplete or missing. Strongly polluted areas as NRW have been considered in detail using nesting techniques. Examples for typical weather conditions leading to high PM10 concentrations during fall and winter, including the results of the forecast system for winter 2002/2003, are discussed.

MODEL DESCRIPTION

The chemistry-transport model of EURAD (EURAD-CTM) is used to perform the calculation of transport, chemical transformation and deposition of air pollutants. Meteorological fields are provided by the mesoscale meteorological model MM5, transport is modelled within the CTM by solving the 3-D advection and diffusion equation. Gas-Phase chemistry is handled with the RACM chemical mechanism, dry deposition is treated with a resistance model, cloud process are parameterized following Binkowski, 1999, and Friese et al., 2000. The Modal Aerosol Dynamics Model MADE has been applied with extensions to account for the formation of secondary organic aerosols (Schell et al., 2002). MADE provides size resolved concentrations of secondary (SO_4^{2-}, NO_3^-, NH_4^+, biogenic and anthropogenic organic) and primary (EC, OC, unidentified particulate matter) aerosol species.

RESULTS

The calculations have been performed for the years 1997 and 2002 using a one-way nesting scheme (see figure 1). The European Scale is covered with a horizontal grid resolution of 125 km (N0), an intermediate N1 with 25 km, and a resolution of 5 km has been applied to simulate the region of North-Rhine-Westphalia (N2). Episodes of particular interest are treated by a further nest (N3). In the vertical the atmosphere is divided into 23 layers between the surface and 100 hPa. 15 layers are below 3000m, the lowest layer is about 40 m thick. Model runs for the N0, N1, and N2 have been completed. All concentrations in the gas-phase and the aerosol phase have been stored on an hourly basis. Wet or dry deposition of gas-phase and aerosol species is also stored. As an example for model results the PM10 concentration for 1997, Sept. 30, 6 UTC for all nests is displayed in figure 2. Figure 3 shows the results for the N2 region (NRW) for the annual average of PM10 and the number of days exceeding the limit value of 50 µg/m^3. Results have been compared with measurements on the European as well as on the local scale (see also Figure 3 as an example). Results for a simple emission scenario without anthropogenic emissions in NRW illustrated the impact of sources from outside NRW. This is illustrated for PM10 in Figure 4 for a specific episode in autumn 1997.

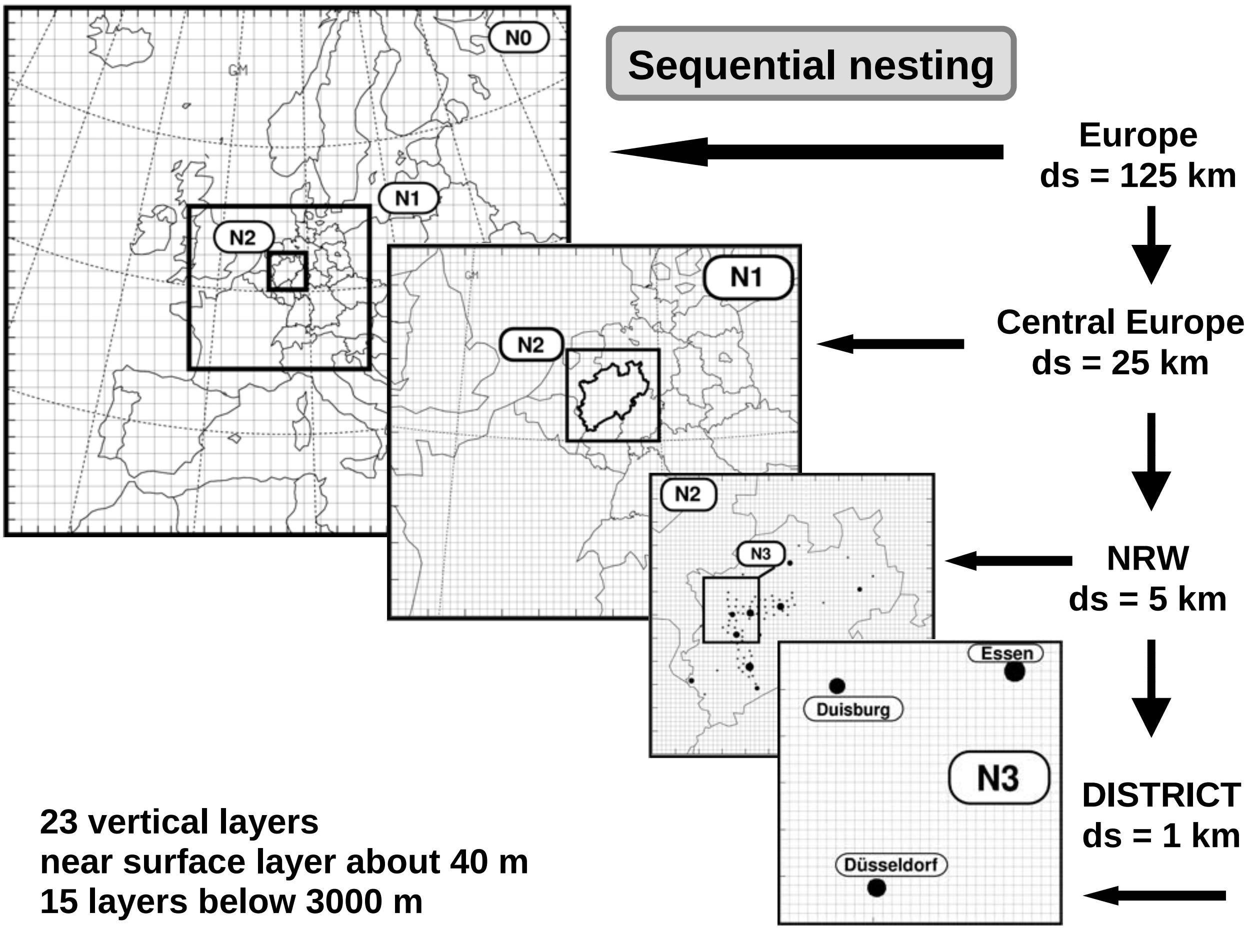

Figure 1. Sequential nesting from European to district scale, N3 can be selected optionally within N2 with a grid size of 1 km. The vertical resolution is usually done with 23 layers up to 100 hPa (after Memmesheimer et al., 2003). Annual runs have been done for No, N1 and N2.

The modelling system also provides daily short-term predictions which are made available to the public by internet (www.eurad.uni-koeln.de). Data and graphics from the forecast are stored in a data archive. Graphics are available on the EURAD web site for the years 2002 and 2003 for PM10, NO_2, SO_2, CO and Ozone for each day.

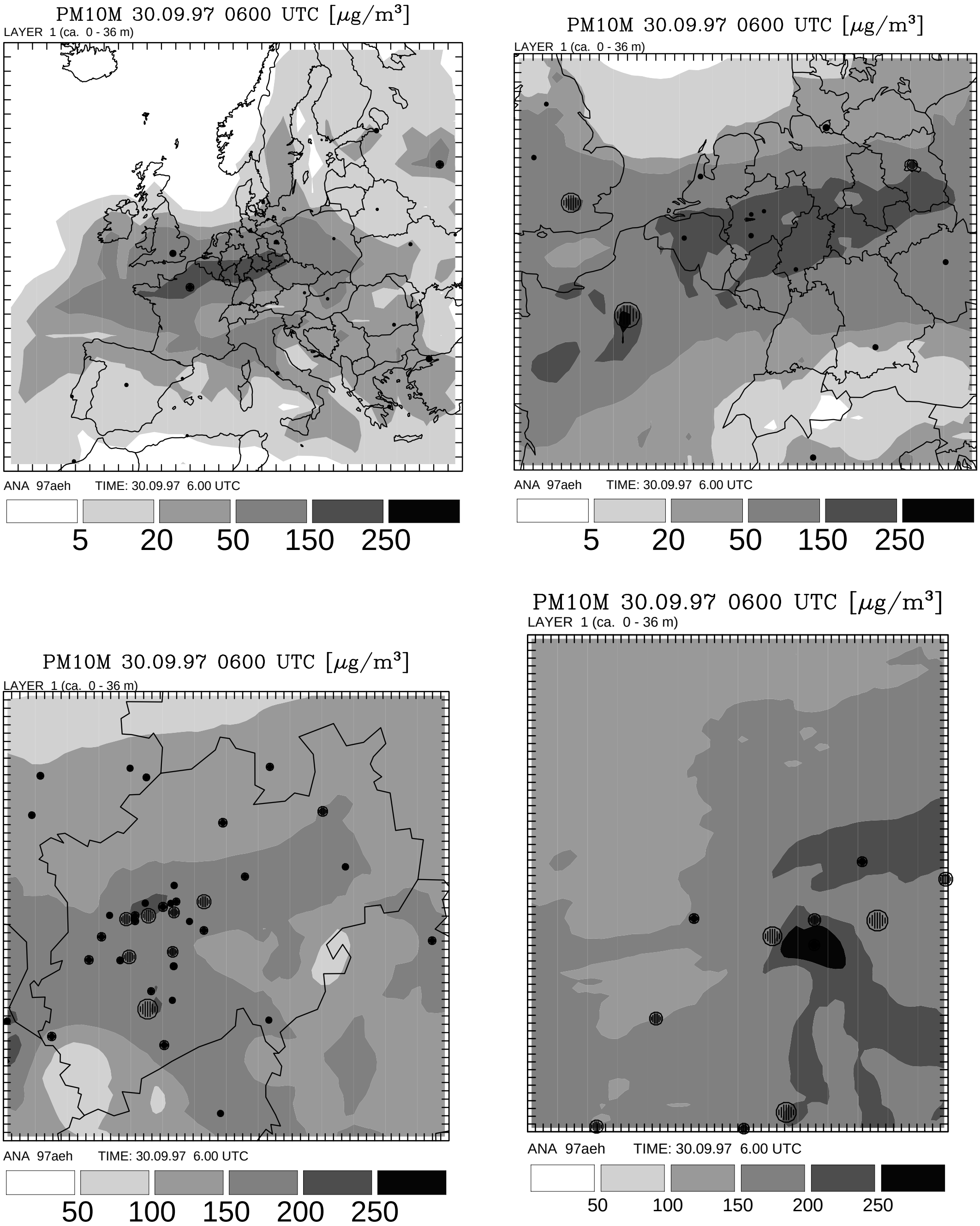

Figure 2. Example for the nesting application of the EURAD modelling system. The PM_{10} mass concentration over Europe and nested areas focussed on Northrhine-Westphalia are shown for Sept. 30, 1997, 06 UTC. In that case particles have been accumulated within a stable high pressure system over Central and Western Europe (upper left, horizontal grid size 125 km). Nesting has been done with horizontal grid sizes of 25 km (N1, upper right), 5 km (N2, lower left), and 1 km (N3, lower right). The black dots show the location of larger cities.

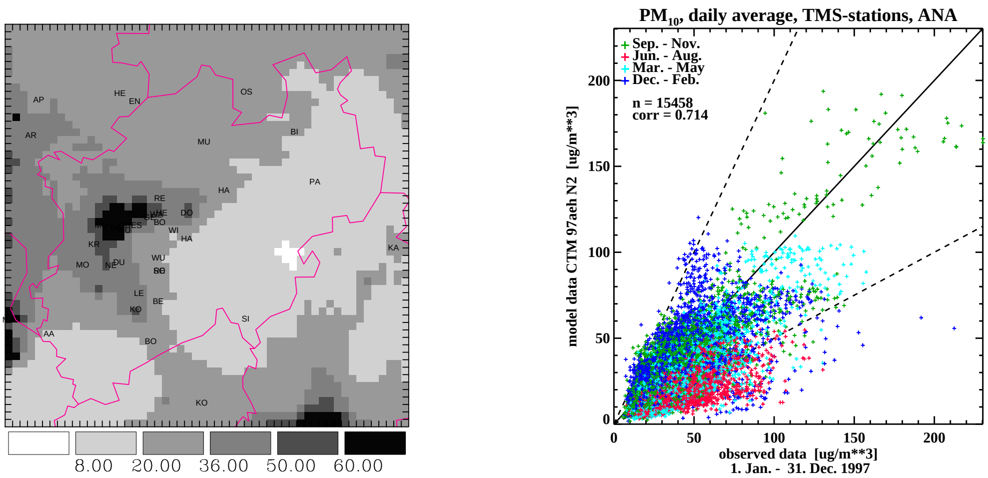

Figure 3. Example for the analysis of the annual run of the EURAD system for the year 1997 for NRW (Nest 2, horizontal grid size 5 km) with respect to the EU directive on air quality control (96/62) and its daughter directives (e.g. 99/30). Displayed are the numbers of days exceeding a daily average in the PM_{10} mass concentration of 50 $\mu g/m^3$ (left). Comparison with observations is shown on the right panel for the LUQS measurement network (LUA-NRW).

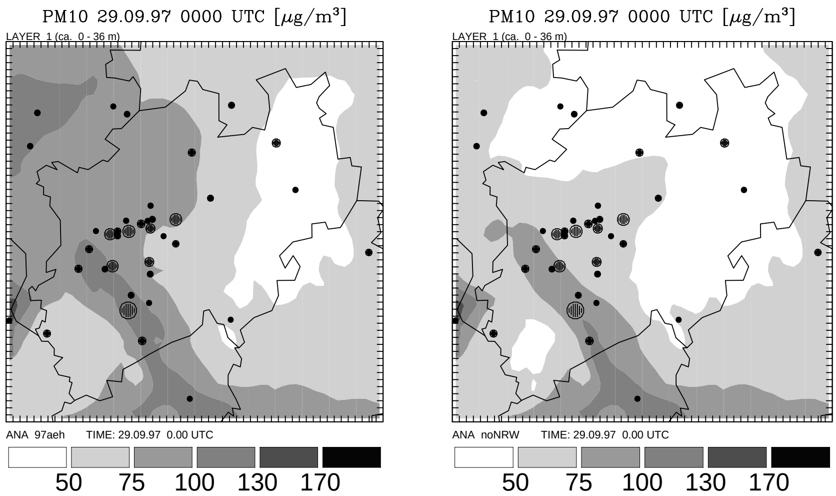

Figure 4. Emission scenario study for NRW for a selected episode in September/October 1997 with high particle concentrations over Europe. All anthropogenic emissions in NRW have been set to zero, starting with September 27, 00 UTC. Shown are the model results for PM_{10} for September 29, 1997. Left: PM_{10} for the base case, Sept. 29, 00 UTC; right: PM_{10} for the scenario. Major wind direction in the night (00 UTC) is from southeast evidently transporting PM_{10} along the Rhine valley into NRW, PM_{10} in the Netherlands is clearly reduced in the scenario case.

CONCLUSIONS

The results for the long-term runs performed with the EURAD modelling system as well as the daily forecasts provided since 2001 show in general a good agreement with measurements. However, the agreement in summer, in particular in Mediterranean countries, might be improved by including additional sources as wind blown dust. It is clearly shown that the model is a helpful tool for short term forecast of air quality as well as air pollution emission scenario studies and long-term runs with respect to EU directive 96/62 and its daughter directives (e.g. 99/30). Future developments aim on the extension to the hemispheric scale and the use of observational data (ground-based, lidar, satellite) by sophisticated data assimilation methods (Elbern and Schmidt, 2001).

ACKNOWLEDGEMENTS
This work was supported by the Environmental Agency (LUA) of Northrhine-Westphalia (NRW) within the ANABEL project and the BMBF within the AFO2000 programme, in particular the IDEC project (07ATF02), where the fruitful cooperation with ICG-II of the Research Center Jülich and the Institute of Geophysics and Meteorology of the University of Cologne is gratefully acknowledged. We thank EMEP, TNO, UBA and LUA for providing emission data and ECMWF and DWD for giving access to global meteorological data. LUA also provided monitoring data for NRW. Land use data were gratefully received from IfU/Research Center Karlsruhe. The numerical calculations have been supported by the ZAIK/RRZK, University of Cologne, and the Research Center Juelich (NIK/ZAM).

REFERENCES
Binkowski, F.S., 1999 Aerosols in MODELS-3 CMAQ, in Science Algorithms of the EPA Models-3 Community Multiscale Air Quality (CMAQ) Modelling System, EPA 600/R-99-030, EPA.

Friese, E., M. Memmesheimer, I.J. Ackermann, H. Hass, A. Ebel and M.J. Kerschgens, 2000. A study of aerosol/cloud interactions with a comprehensive air quality model. J. Aerosol Sci., **31**, Suppl 1, 54-55.

Friese, E., H.J. Jakobs, M. Memmesheimer, H. Feldmann, C. Kessler, G. Piekorz, A. Ebel, 2002: Ausbreitungsrechnungen für Nordrhein-Westfalen zur Anwendung im Rahmen der Beurteilung der Luftqualität nach EU-Richtlinien. Abschlußbericht zum FuE-Vorhaben ANABEL, im Auftrag des Landesumweltamtes Nordrhein-Westfalen.

Frohn, L.M., J.H. Christensen and J. Brandt, 2002. Development of a high-resolution nested air pollution model. J. Comp. Phys., 179, 68 – 94.

Jakobs, H.J., S. Tilmes, A. Heidegger, K. Nester, G. Smiatek, 2002. Short-term ozone forecasting with a network model system during summer 1999. J. Atmos. Chem **, 42**, 23 – 40.

Kessler, C., W. Brücher, M. Memmesheimer, M.J. Kerschgens, A. Ebel, 2001: Simulation of Air Pollution with Nested Models in North-Rhine-Westphalia. *Atmos. Environment*, 35, S3 – S12.

Memmesheimer,M., E. Friese, A. Ebel, H. J. Jakobs, H. Feldmann, C. Kessler, G. Piekorz: 2003: Long-term simulations of particulate matter in Europe on different scales using sequential nesting of a regional model, submitted to International Journal of Environmental Pollution, December 2003.

Riemer, N., H. Vogel, B. Vogel, B. Schell, I.J. Ackermann, C. Kessler, H. Hass, 2003: The impact of the heterogeneous hydrolysis of N_2O_5 on Chemistry and Nitrate aerosol formation in the lower troposphere under photosmog conditions, *J. Geophys. Res*., 108, D4, 4144, doi:10.1029/2002JD002436.

Schell, B., I.J. Ackermann, H. Hass, F.S. Binkowski, A. Ebel, 2002. Modeling the formation of secondary organic aerosol within a comprehensive air quality modeling system. J. Geophys. Res., 106, 28275 – 28293.

Vogel, B., F. Fiedler, H. Vogel, 1995: Influence of topography and biogenic volatile organic compounds emissions in the state of Baden-Württemberg on ozone concentrations during episodes of high air temperatures, J. Geophys. Res., 100, 22907 – 22928.

Elbern, H., and H. Schmidt, 2001:Ozone episode analysis by four-dimensional variational chemistry data assimilation, J. Geophys. Res., 106, No. D4, 3569—3590.