15.4 INVESTIGATING THE IMPACT OF TRAFFIC BASED EMISSIONS ON URBAN AIR POLLUTION WITH A NESTED MODEL SYSTEM

Florence-N. Sentuc [a, *], N. Eissfeldt [b], M. Luberichs [a], M. J. Kerschgens [a], R. Schrader [b], A. Ebel [a]
[a] Institute for Geophysics and Meteorology (IGMK), University of Cologne
[b] Center for Applied Computer Science (ZAIK), University of Cologne

1. INTRODUCTION

In relation to the health damage potential of atmospheric trace gases, air quality is one main indicator for quality of life in an industrial conurbation. In the last years, several administrative attempts were made to reduce the emissions of air pollutants, but these steps are opposed in part by an increasing demand for energy. In particular, reduction of ozone precursors (e.g. NO, NO_2 and VOC) is an important objective due to their potential of causing photochemical smog. An outstanding problem in this context is the individual traffic. According to a predicted increasing traffic volume, the environmental effects of motor vehicles intensify, in spite of improved, emission reducing automotive technology.

The spatially and temporally highly variable character of emissions, and the fact that many of the emitted species undergo chemical reaction processes during their transport through the atmosphere, inhibits an exclusively observational quantification of traffic emissions. For that reason the effect of air pollutants can more profitably be estimated by a combination of emission inventories, models of atmospheric dynamics and air chemistry.

Hence, to study the impact of traffic based emissions on urban air quality and the potential benefit of reduction strategies, a high resolution dynamic traffic model is applied, which is coupled with nested models of the atmospheric chemistry and transport.

2. THE CARLOS MODEL SYSTEM

For the simulation of pollution episodes in urban and industrial areas only local-scale information is not sufficient, since local air pollution is the result of temporally and spatially varying emissions as well as of meteorological and chemical processes on various scales. To take these circumstances into account the model system CARLOS (**C**hemical and **A**tmospheric transport in **R**egional and **LO**cal **S**cale; Brücher 2000) was developed at the IGMK which describes the complex relationship between release and transmission of gaseous pollutants in the atmosphere. This model system *(see figure 1)* has multiple-nesting capabilities which allow to account for large scale meteorological features and concentration patterns while simulating local scale structures in nested regions.

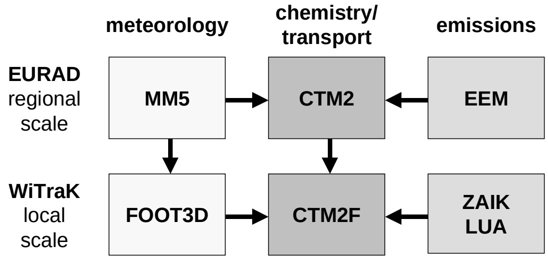

Figure 1: *Schematic chart of the CARLOS model system, including data flow. Additionally, each model can be nested in itself.*

On the regional scale, the EURAD system (**EUR**opean **A**ir Pollution **D**ispersion Model; Hass 1991, Jakobs 1995) is applied to consider transport processes at different scales, making use of model nesting technique. The coarse model domain covers Central Europe with a horizontal resolution of 27km. Two subsequent nesting steps follow, from the first nest (Western Germany, 9km resolution) down to 3km resolution in the second nest domain, covering North-Rhine Westphalia. The output of the meteorological model MM5 is used as input to the chemistry transport model (CTM2). The emission inventories therefore required are provided by the emission module EEM, including information about the emitter groups traffic, house firing, industry and biogene emissions.

The results of these simulations serve as boundary conditions for the WiTraK system's (Brücher 1999) small scale high resolution models (FOOT3D/CTM2F), which are capable to simulate flow and pollution pattern e.g. on the scale of urban districts. On this local scale with a horizontal model resolution of presently 1km, a microscopic dynamic traffic simulator ('queuing model'; Eissfeldt 2002) is employed at the Center for Applied Computer Science (ZAIK) to calculate highly resolved emission inventories for pollutants generated by traffic. Other emission data and air measurements were provided by the State Environmental Agency of North-Rhine Westphalia (LUA NRW).

By simulating individual routes for single vehicles in a road network, the ZAIK model takes into consideration e.g. interactions of the road users and even traffic jams (Gawron 1998). The design of this model also enables studying the impact of local administrative regulations, or municipal development planning on traffic flow and the related emissions. Due to its computational efficiency, it is suitable to

Corresponding author address: Florence-Nathalie Sentuc, Institute for Geophysics and Meteorology, University of Cologne, 50923 Cologne, Germany; e-mail: fsentuc@meteo.uni-koeln.de.

calculate car emissions on the basis of individual vehicle units in a reasonable time, even for huge networks (about 10^6 cars).

3. APPLICATION TO THE COLOGNE AREA

Presently, on the local scale, special emphasis is given to nitric oxides (NO_x) emitted by vehicles in context with summertime ozone (O_3) production. For first studies and model testing a period of August 1997 with high ozone mixing ratios in the state North-Rhine Westphalia was chosen and simulated with the EURAD model system *(for example see figure 2)*.

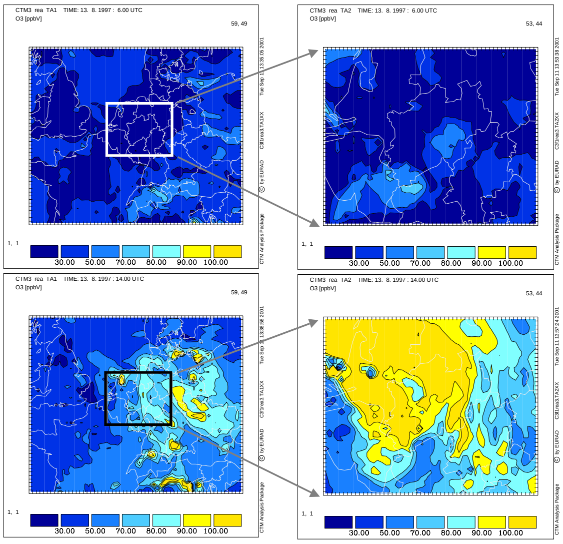

Figure 2: *Near surface concentrations of ozone [ppbV] in the coarse and first nest domain at 6 and 14 UTC 13 August 1997; EURAD CTM2 model output.*

The complete CARLOS model chain was first successfully applied to the city of Wuppertal in Germany (Brücher 2000). In the context of the interdisciplinary Collaborative Research Center (SFB 419), Cologne and its surroundings was chosen as an example for a Central European industrial conurbation. In this third nest domain, the temporally and spatially high resolution traffic emission inventory of the ZAIK model for the city area *(see figure 3)* is used. Together with the other emitter groups there is yet a data set available which describes the present state of air pollution. At the moment the adjustment process to the Cologne area is not completed, but first simulations show encouraging results. Extended analysis will comprise fictitious but realistic traffic scenarios on the local scale (e.g. speed limitations, expansion of the motorway network) to work out the effects of possible reduction strategies.

4. CONCLUSION

The air quality model CARLOS, including a microscopic dynamic traffic model, shows the advantage of applying a complete hierarchy of models for local air pollution assessment. The presented model system provides the capability to describe meteorological and transport phenomena in a wide range of temporal and spatial scales. Further investigations of different scenarios are planned to propose directives and actions to improve air quality.

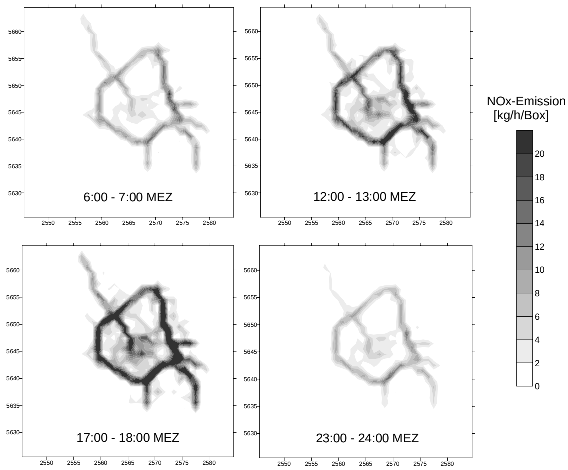

Figure 3: *Computed spatiotemporal amount of NO_x per $1km^2$ grid box, emitted by street traffic on a typical workday around the city of Cologne at different daytimes.*

Acknowledgments

This research was supported by the German Scientific Foundation (DFG) with the Cologne research project SFB 419. We wish to thank all institutions, which provided input data, and all scientists of the research cooperative who contributed to the success of this work.

References

Brücher, W., T. Sperling, F. Steffany, M. Kerschgens, 1999: WiTraK – Windfeld-, Transport- und Klimatologie-Programmsystem, Version 2.5., *Benutzeranleitung, Institut für Geophysik und Meteorologie,* University of Cologne.

Brücher, W., C. Kessler, M. J. Kerschgens, A. Ebel, 2000: Simulation of traffic-induced air pollution on regional to local scales. *Atmospheric Environment* **34**(27), 4675-4681.

Eissfeldt, N. and R. Schrader: Calculation of street traffic emissions with a queuing model. To appear 2002 in: *J. of Comp. Tech.*

Gawron, C., 1998: An iterative algorithm to determine the dynamic user equilibrium in a traffic simulation model. *Int. J. Mod. Phys. C*, **9**(3), 393-407.

Hass, H., 1991: Description of the EURAD chemistry-transport-model version 2 (CTM2). *Mitteilungen aus dem Institut für Geophysik und Meteorologie,* **38**, University of Cologne.

Jakobs, H. J., H. Feldmann, H. Hass, M. Memmesheimer, 1995: The use of nested models for air pollution studies: an application of the EURAD model to a SANA episode. *Journal of Applied Meteorology,* **34**, 1301-1319.

SFB 419: http://www.uni-koeln.de/sfb419/