Long-Term Simulation of Particulate Matter over Europe with the EURAD Modeling System

E. Friese, H.J. Jakobs, M. Memmesheimer, H. Feldmann, A. Ebel, M.J. Kerschgens

University of Cologne, EURAD-project, Aachener Straße 201-209, 50931 Cologne, Germany

RIU EURAD

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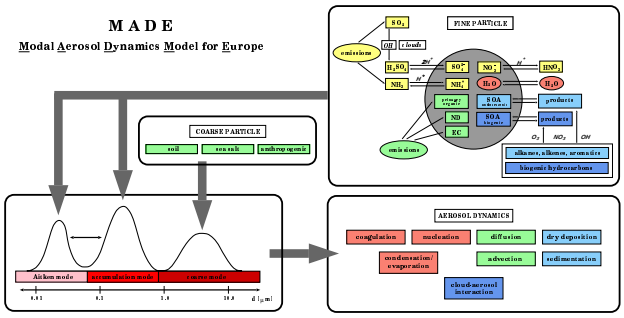
Introduction

Long-term runs of comprehensive air quality models can provide data which are useful for several purposes. The derived data can be used for the investigation of physical and chemical processes controlling the concentrations of atmospheric pollutants. Long-term simulations are more suited for model evaluation than episodic simulations which extend over a few days or weeks only. Another important application is the development of air pollution abatement strategies. The data provided by a long-term run render possible an air quality assessment of the whole area of investigation, in particular for regions where measurements are incomplete.

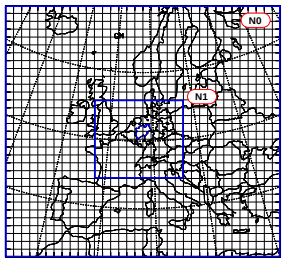
Summary

Using the EURAD modeling system a long-term air quality simulation with respect to the whole year 1997 has been performed for the European scale with horizontal resolutions of 125 km and 25 km respectively. The Modal Aerosol Dynamics Model for Europe (MADE, Ackermann *et al.*, 1999, Schell *et al.*, 2001, Friese *et al.*, 2000) is used to provide hourly PM_{10} concentrations for each grid box. Mixing ratios of gas-phase species are calculated using the RACM mechanism. A first evaluation of model results has performed for the region of Northrine-Westfalia. In average 60% to 85% of modelled PM_{10} concentrations are inside tolerances which are recommended by the European Commission for model quality assessment. The highest yearly averages of PM_{10} concentrations are located over the congested areas of Northrine-Westfalia and in the vicinity of Paris. The results have been analysed with respect to the EU directives 96/62 and 99/30. In large areas of middle Europe the limiting value of 35 days per year with averaged PM_{10} concentrations higher than 50 µg/m³ is clearly exceeded.



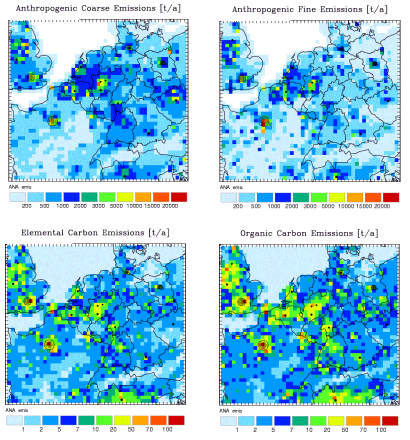
Within MADE the particle size distribution is treated by three lognormal modes. Each mode represents a population of internally mixed aerosol particles. The mixture within the two fine particle modes is composed of primary and secondary aerosol species, while only primary particles are contained in the coarse mode. Currently the chemical composition of the secondary inorganic species is treated in the SO_4^{2-} - NH_4^+ - NO_3^- - H_2O - system. Coagulation, condensation, deposition, sedimentation and transport are considered as processes modifying the aerosol population. Sources for aerosol particles are modelled through nucleation and emission. The cloud module of the CTM is extended to a simple description of the cloud processing of aerosol particles. It is assumed that CCN are formed by accumulation mode particles which are 100% absorbed into the cloud water. The Aitken mode forms interstitial aerosol which is scanvenged by cloud droplets. All new sulfate produced changes the accumulatrion mode mass.

Grid Design

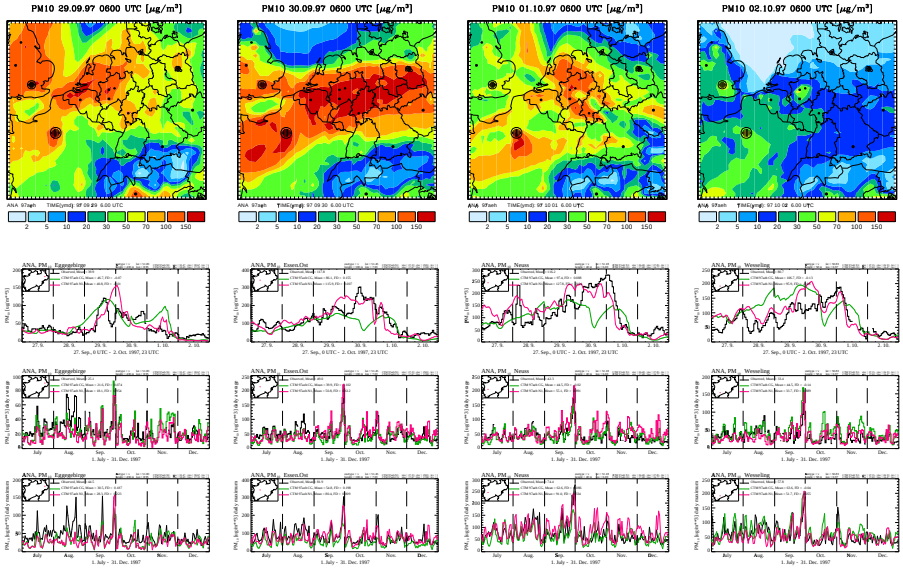


All model runs were performed for two domains with different horizontal grid resolution. Covering whole Europe the mother domain (N0-domain) is divided into 34x32 grid cells of 125 km spacing. This coarse resolution is refined in the N1-domain which covers parts of central Europe. The N1-domain contains 51x46 grid cells with a spacing of 25 km. In the vertical, 23 sigma-coordinate layers are used. The bottom layer has a thickness of approximately 40 m. The model top is set to 100 mb.

Emissions

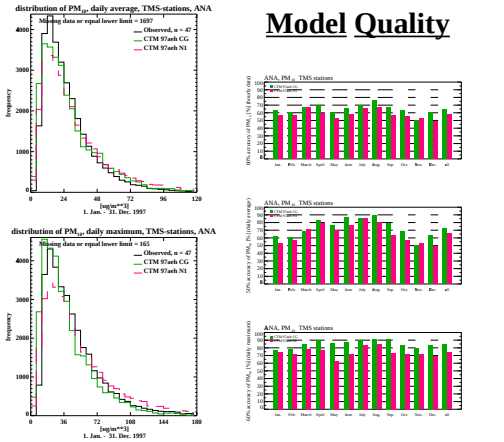


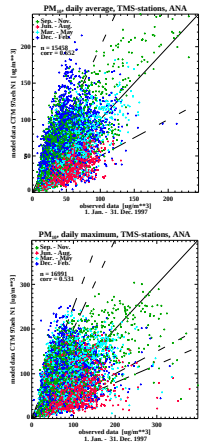
This figure show yearly emission rates for the N1-domain of four primary aerosol species treated by MADE. An emission inventory for 1995 of anthropogenic $PM_{2.5}$, PM_{10} and TSP for several source categories with a horizontal resolution of 0.5 x 0.25 degrees is provided by the TNO Institute of Environmental Sciences. Emission rates of coarse (upper left) and fine (upper right) unspecified particulate matter of anthropogenic origin are took out of this inventory. Emission rates of elemental carbon are proportionally coupled with a factor of 0.005 to gas-phase emissions of carbon monoxide. The EMEP emission inventory for 1998 with a horizontal resolution of 50 square kilometers is used for the gas-phase. Resulting elemental carbon emission rates for a wintertime weekday scaled to yearly values are depicted in the lower left figure. It is assumed that primary organic carbon emission rates can be derived using an OC/EC ratio of 1.5. The lower right figure show the resulting emission rates.



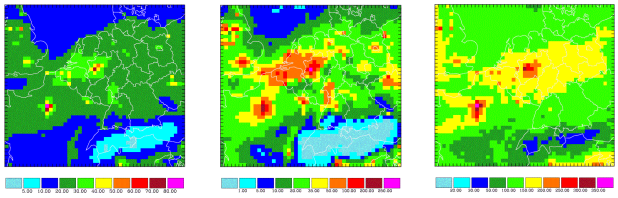
The special merits of the episode from September 29th to October 2nd, 1997 are very high PM_{10} concentrations over large areas of middle Europe caused by a stable high pressure weather situation. PM_{10} concentrations at 6:00 UTC in the bottom layer of the N1-domain are depicted in the upper row of figures for each of the four days. Time series comparisons of measured PM_{10} concentrations (black) with model results for the N0-domain (green) and for the N1-domain (red) from 0:00 UTC September 27th to 23 UTC October 2nd are located in the second row of figures. Four different measurement sites from the Environmental Agency (LUA) of Northrine-Westfalia are used. The three sites Essen-Ost, Neuss and Wesseling are urban whereas Eggegebirge is rural. Both the slowly increasing PM_{10} concentrations and the sharp decrease at October 1st at the urban stations is qualitatively matched by the N1 model run. The third and fourth row of figures show daily averages and daily maxima of PM_{10} concentrations for the second half of 1997 for the same measurement sites as above.

Model Quality





Scatter diagrams (right) and frequency distributions (left) of PM_{10} concentrations to compare measurements against model results. The upper and lower figures show daily averages and daily maxima respectively. In the scatter diagrams the dashed lines indicate a tolerance of 50% for daily averages and 60% for daily maxima respectively. The tolerances used are recommended by the European Commission (directive 99/30). All 47 measurement sites from the Environmental Agency (LUA) of Northrine-Westfalia for which PM_{10} measurements are available are used for the evaluation. The middle figures show the percentage per month of modelled hourly (top), daily averaged (middle) and daily maximal (bottom) PM_{10} concentrations which are inside a 50% and 60% tolerance for averaged and hourly values respectively. Again all 47 measurement sites available are used. In average 60% to 85% of the modelled PM_{10} concentrations are inside the tolerances. Results for the N0-domain are better than those for the N1-domain. This is caused due to a few point sources in Northrine-Westfalia which source strength is probably too high.



Yearly average (left) and yearly maximum (right) of modelled PM_{10} concentrations. The highest values are located over the congested areas of Northrine-Westfalia and in the vicinity of Paris. The modelled PM_{10} concentrations have been analysed with respect to the EU directives 96/62 and 99/30. Based on this analysis the middle part of the figure show the number of days of the year 1997 on these the PM_{10} concentration in the bottom layer of the N1-domain is higher than 50 µg/m³. In large areas of middle Europe the limiting value of 35 days per year is clearly exceeded.

References

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Acknowledgements

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