

# MODIFICATION OF THE VISIBILITY BY SOOT AEROSOL ON THE REGIONAL SCALE - NUMERICAL SIMULATIONS

N. RIEMER, H. VOGEL, B. VOGEL and F. FIEDLER

Institut für Meteorologie und Klimaforschung, Forschungszentrum Karlsruhe/  
Universität Karlsruhe, Postfach 3640, D-76021 Karlsruhe

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## INTRODUCTION

Soot particles are ubiquitous in the troposphere and participate in tropospheric chemistry, scatter and absorb light and affect human pulmonary health. While freshly emitted soot particles are hydrophobic their hygroscopic qualities can change due to coagulation with soluble aerosols and condensation processes. Hereby the growth of the particles in response to ambient relative humidity, the ability of being activated as cloud condensation nuclei and the optical properties are determined. This study focuses on the transformation of externally mixed soot into an internal mixture as it happens on the regional scale. We use an extended version of the aerosol module MADE (Ackermann *et al.*, 1998) which is fully coupled to the comprehensive mesoscale model system KAMM/DRAIS (Vogel *et al.*, 1995). This model configuration is applied to study the visibility degradation on the regional scale depending on the mixing state of the soot particles.

## METHODS

The aerosol model MADE has been included in the comprehensive mesoscale model system KAMM/DRAIS in order to allow for a treatment of the aerosols in the regional scale. We extended the concept of MADE and introduced three additional modes in order to treat the transformation of soot from the external to the internal mixture. Modes  $i_f$  and  $j_f$  now describe the soot-free particles which contain sulfate, nitrate, ammonium and water in an internal mixture. Modes  $i_c$  and  $j_c$  contain the same species together with soot. Mode  $s$  is reserved for externally mixed, pure soot. To assess the optical properties of the aerosol population, the individual mixed particles are assumed to consist of an insoluble core and a soluble shell. Recent measurements of the refraction index of diesel soot made in the AIDA chamber are used (Kamm *et al.*, 1999, Schnaiter, 2001). The extinction coefficients of the soluble particles and the pure soot particles are calculated according to Binkowski (2001). For the mixed particles (soot and soluble material) a Mie code after Bohren and Huffman (1983) is used to determine the extinction coefficients. In order to investigate the relative importance of coagulation and condensation as the responsible aging processes for the soot particles, we carried out simulations using a 1-D version of the model system. Beyond this, a 3-D simulation for the region of the south-western part of Germany was carried out to study the effects of the mixing state of the soot particles on visibility.

## RESULTS

Figures 1 to 3 present results of the 1-D simulations which were carried out to analyze the role of coagulation and condensation for the mixing process of soot. At first, only coagulation was considered whereas condensation was excluded. Figure 1 and Figure 2 show the diurnal development of the vertical profiles of the pure soot and the fraction of soot which is internally mixed under the assumption that only coagulation is responsible for the transfer of soot from the external into the internal mixture. In the

morning we find high soot concentrations near the ground because soot is emitted at this height and the vertical mixing is suppressed due to stable stratification. During the day, the concentration becomes almost constant with height caused by turbulent mixing. Comparing the soot mass of the pure soot mode and of the soot containing modes it results that after two days of simulation less than 50% of the soot is internally mixed. Figure 3 presents the fraction of soot which is internally mixed assuming that both coagulation and condensation account for the aging of soot. In this case pure soot can mainly be found close to the sources. During daytime over 80% of the soot is internally mixed.

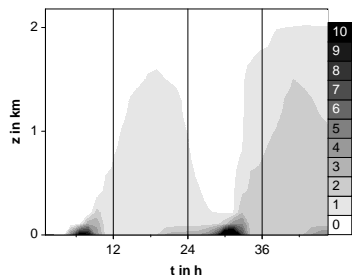


Fig. 1. Diurnal development of vertical profiles of mass of soot in  $\mu\text{g m}^{-3}$ .

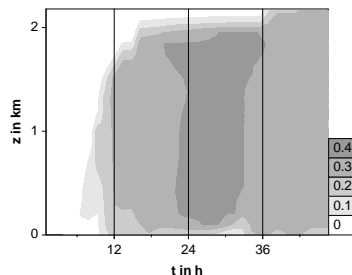


Fig. 2. Fraction of soot which is internally mixed (only coagulation).

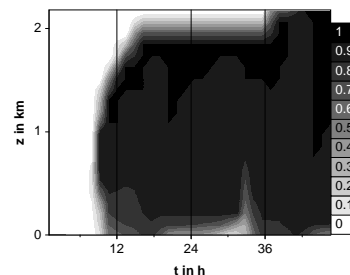


Fig. 3. Same as Fig. 2 but for coagulation and condensation.

With this model configuration we carried out a 3-D simulation for the region of South-West Germany. Figure 4 shows the topography and the wind field close to the surface at 9:00 CET. Figure 5 displays the corresponding horizontal distribution of the total particle number concentration. Due to the low wind speeds and the high emissions large number concentrations occur in the area of Stuttgart whereas in the mountainous regions only low number concentrations are reached. For this simulation the visibility reduction caused by aerosol particles will be presented.

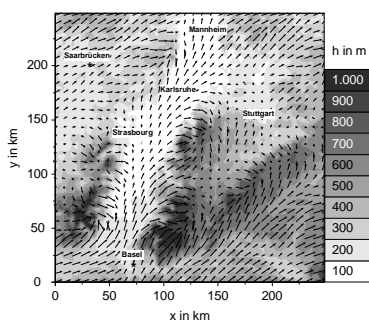


Fig. 4. Topography and the wind field close to the surface at 9:00 CET.

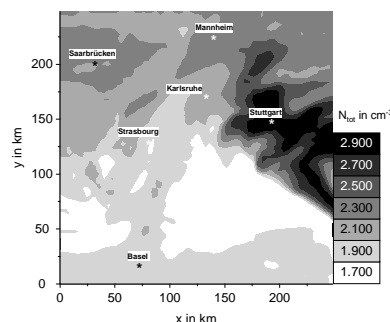


Fig. 5. Horizontal distribution of the total particle number concentration in  $\text{cm}^{-3}$ .

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