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Simulation of aerosol and clouds on the regional scale

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The interaction of aerosol and clouds is a multi-scale problem. Modelling studies followed a variety of approaches to improve the understanding of this interaction. Most studies had their focus either on the interaction with single clouds or on the global forcing of the aerosol. On these scales the inhomogeneous and variable distribution of the aerosol and of the clouds can not be sufficiently represented. To investigate the interaction between the aerosol and the atmosphere on the regional to continental scale the variations in the distribution of aerosol particles caused by the spatial and temporal variation of the emissions the ongoing physical, and chemical processes have to be considered.

To fulfil these requirements we developed the model system COSMO-ART. It is based on the non-hydrostatic weather forecast model COSMO (Consortium for Small-scale Modeling, Doms & Schättler, 2002) of the German Weather Service (DWD) and is online coupled with comprehensive modules for gas phase chemistry and aerosol dynamics. ART stands for Aerosols and Reactive Trace gases. COSMO-ART includes complex photochemistry to calculate the temporal and spatial distribution of the gaseous precursors of the secondary aerosol particles. For submicron particles five internally mixed modes with log-normal size distributions are used. All modes are subject to condensation and coagulation. A detailed description of the model formulation and of the representation of the natural and the anthropogenic emissions can be found in Vogel et al. (2009).

The activation of particles is calculated by integrating the size distribution of the individual modes. The critical radius for the integration is determined with the Köhler theory and the parameterization of Abdul-Razzak & Ghan (2000) with respect to the size distribution and the chemical composition of the individual modes. The cloud scheme is an extended version of the operational scheme used for the weather forecast with the COSMO model. For the representation of autoconversion, accretion, and selfcollection of cloud drops the double-moment parameterization of Seifert & Beheng (2001) is used for cloud water and droplet number.

In this study the influence of the aerosol particles on cloud properties and precipitation formation was simulated for Central Europe with a spatial resolution of 7 km.

The simulated distribution of the available CCN is very variable and depends strongly on the properties of the aerosol particles. The results of the simulations show that in the area of a forming cloud the availability of CCN is higher than in the surrounding area because of local vertical transport processes and high humidity. Therefore the distributions of CCN and clouds are related to each other on the regional scale.

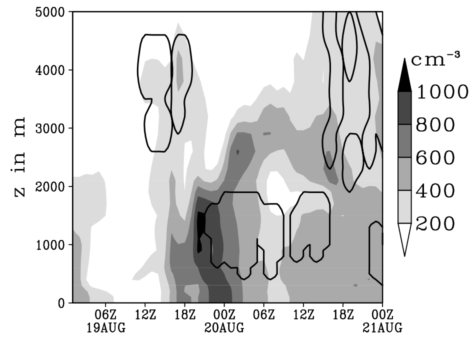

Figure 1. Evolution in time of CCN for 0.1% supersaturation (greyscale) and clouds (contours) at Karlsruhe.

The comparison with a simulation that was performed with a fixed homogenous aerosol distribution shows that the simulation allowing variable aerosol distributions leads to changes in cloud droplet number density. Consequently, this has also an influence on the warm rain process. High CCN-concentrations weaken the initial formation of rain and tend to delay the rain initiation in warm clouds. Depending on the lifetime of the cloud system the net precipitation amount can be the same, but with temporal and spatial shifts in the distribution of precipitation.

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