LM-ART – Aerosols and Reactive Trace Gases within LM

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Abstract

We developed a fully online coupled model system composed of a numerical weather forecast model and a chemical transport model. With this model system we want to quantify feedback processes between aerosols and the state of the atmosphere and the interaction between trace gases and aerosols both on the regional scale.

1 Introduction

Atmospheric aerosol particles are modifying the radiative transfer in the atmosphere and they have an impact on the cloud formation. Therefore, they alter the weather and they have an impact on climate. The anthropogenic part of this modification of the state of the atmosphere is currently not well understood and raises the largest uncertainties with respect climate change (see the IPCC report 2007).We developed a new online model system to investigate the aerosol-radiation-interaction in the regional scale.

2 The Method

Based on the mesoscale model system KAMM/DRAIS/MADEsoot/dust (Riemer et al., 2004, Vogel, B. et al., 2006) we developed an enhanced model system to simulate the spatial and temporal distribution of reactive gaseous and particulate matter. The meteorological driver of the old model system (KAMM) was replaced by the operational weather forecast model **L**okal-**M**odell (LM, Steppeler et al., 2003) of the German Weather Service (DWD). The name of the new model system is LM-ART **(**ART stands for **A**erosols and **R**eactive **T**race gases, Vogel, H. et al., 2006). The CTM module was online coupled with the operational version of the LM. That means that in addition to the transport of a non reactive tracer the dispersion of chemical reactive species and aerosols can be calculated. Secondary aerosols which are formed from the gas phase, directly emitted components like soot, mineral dust, sea salt and biological material are represented by log normal distributions. Processes as coagulation, condensation and sedimentation are taken into account. The emissions of biogenic VOCs, dust particles, sea salt and pollen are calculated also online, taking into account the dependencies on the meteorological variables. To calculate efficiently the photolysis frequencies a new method was developed using the GRAALS radiation scheme (Geleyn and Ritter, 1992) that is already implemented in LM. With this model system we want to quantify feedback processes between aerosols and the state of the atmosphere and the interaction between trace gases and aerosols both on the regional scale. To enable fully coupled model runs, the aerosol optical properties have been parameterized since online Mie computations were too time-consuming. In the parameterization that is based on off-line Mie calculations, the aerosol optical properties for the eight spectral bands of the LM radiation scheme are calculated separately for the five modes of the aerosol model as a function of dry mass density, water content and soot content in each mode. For the simulations, the climatologically aerosol optical properties, which are used in the standard LM version, are replaced by these parameterized ones that take into account current modal aerosol mass densities. By comparing different simulation results obtained with parameterized and climatological aerosol optical properties, the impact of the aerosol not only on the radiation, but also on other meteorological variables as the temperature can be quantified.. The model system can be embedded by one way nesting into individual global scale models as the GME model (Global model of the DWD) or the ECMWF model. Fig. 1 gives an overview about new model system.

3 Results

In the following two case studies where the model was used to quantify the impact of natural and anthropogenic aerosol particles on the regional weather will be explained.

3.1 The interaction of mineral dust with radiation

The first application is the simulation of a mineral dust event over West Africa in March 2004. During this event there were high wind speeds and low temperature observed in the Sahara and heavy precipitations over Libya (Knipperts and Fink, 2006). Figure 2 shows the simulated dust loading for March, 4th, 2004 at 12 UTC. To investigate the impact of the dust aerosols on radiation two simulations were performed; one with no interaction between the actual aerosol concentration and radiation and one that takes into account the interaction. Figure 3 shows the results for the shortwave radiation balance at the surface for both cases. The high dust load of the atmosphere leads to a strong modification of the shortwave radiation balance. In contrast to the simulation without interaction between aerosols and radiation the simulation using the actual values of the dust concentrations in the radiation scheme shows a reduced shortwave radiation balance up to a factor of 2 over western Africa, which has also an effect on the cloud formation and the dynamics (not shown here).

3.2 The interaction of anthropogenic aerosols with radiation

The model system was also applied to study the direct effect of anthropogenic aerosols on radiation. In addition the ageing process of the emitted soot particles was taken into account for this investigation. The model domain for this study was the south western part of Germany with adjacent area. The simulation period was 16.08.05 - 22.08.05. The emission data were available for this period with a temporal resolution of 1 h and a horizontal resolution of 7 km. Again two model runs were carried out, one with the interaction of the actual aerosol concentration and the radiation and one without. Figures 4 and 5 show the result of these simulations. In contrast to the case study of the dust event the aerosol concentration is rather low. Nevertheless, the influence on the shortwave radiation balance is quite large due to the effect that the cloud formation is also influenced by the modifications in the radiation field caused by the aerosols. Although the aerosol concentration is much lower in the western part of the domain than in the eastern part (Fig. 4 left), an effect on the shortwave radiation balance can be seen all over the model domain (Fig. 5 left). In the less cloudy western part, there is a cooling effect of several tenth degrees dominating, whereas in the western part both areas with warming and cooling effects can be seen (Fig. 5 right).

4 Conclusions

A new online coupled model system named COSMO LM-ART was developed. This model system contains for example a variety of natural and anthropogenic aerosols. The ageing process of soot is explicitly described. The treatment of their impact on the atmospheric radiation allows the quantification of feedback mechanisms. The simulation of a dust event occurring over West Africa gives rather high aerosol concentrations and consequently a strong effect on the shortwave radiation balance which leads also to differences in the cloud formation and the dynamics. The study concerning the anthropogenic aerosol-radiation-interaction shows that despite of rather low aerosol concentrations the modification of the radiation balance causes a surprisingly strong effect on the cloud pattern (semi-indirect effect) that needs further investigations.

Acknowledgements

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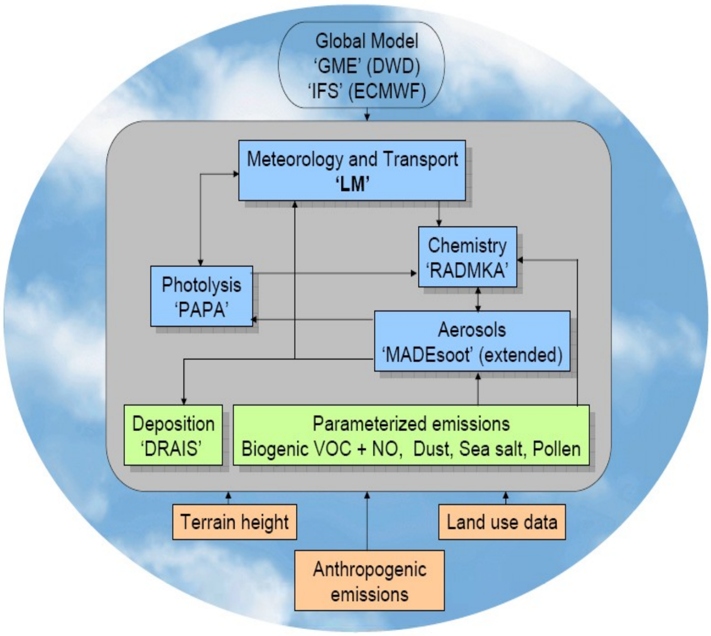


Figure 1. The model system COSMO LM-ART

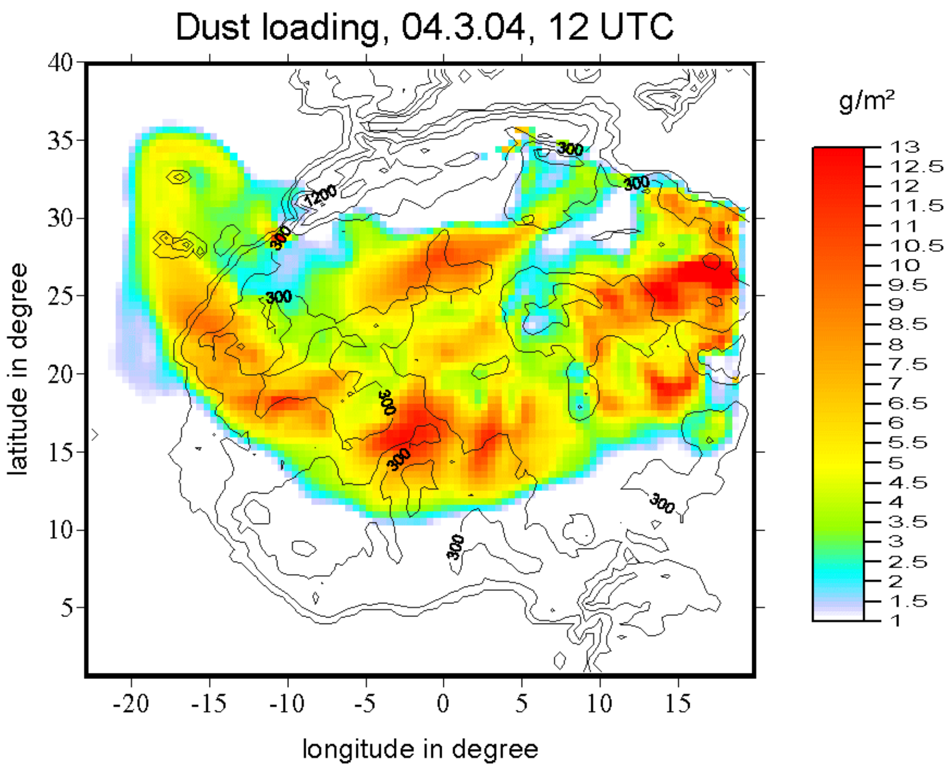


Figure 2. Horizontal distribution of the simulated dust loading over western Africa

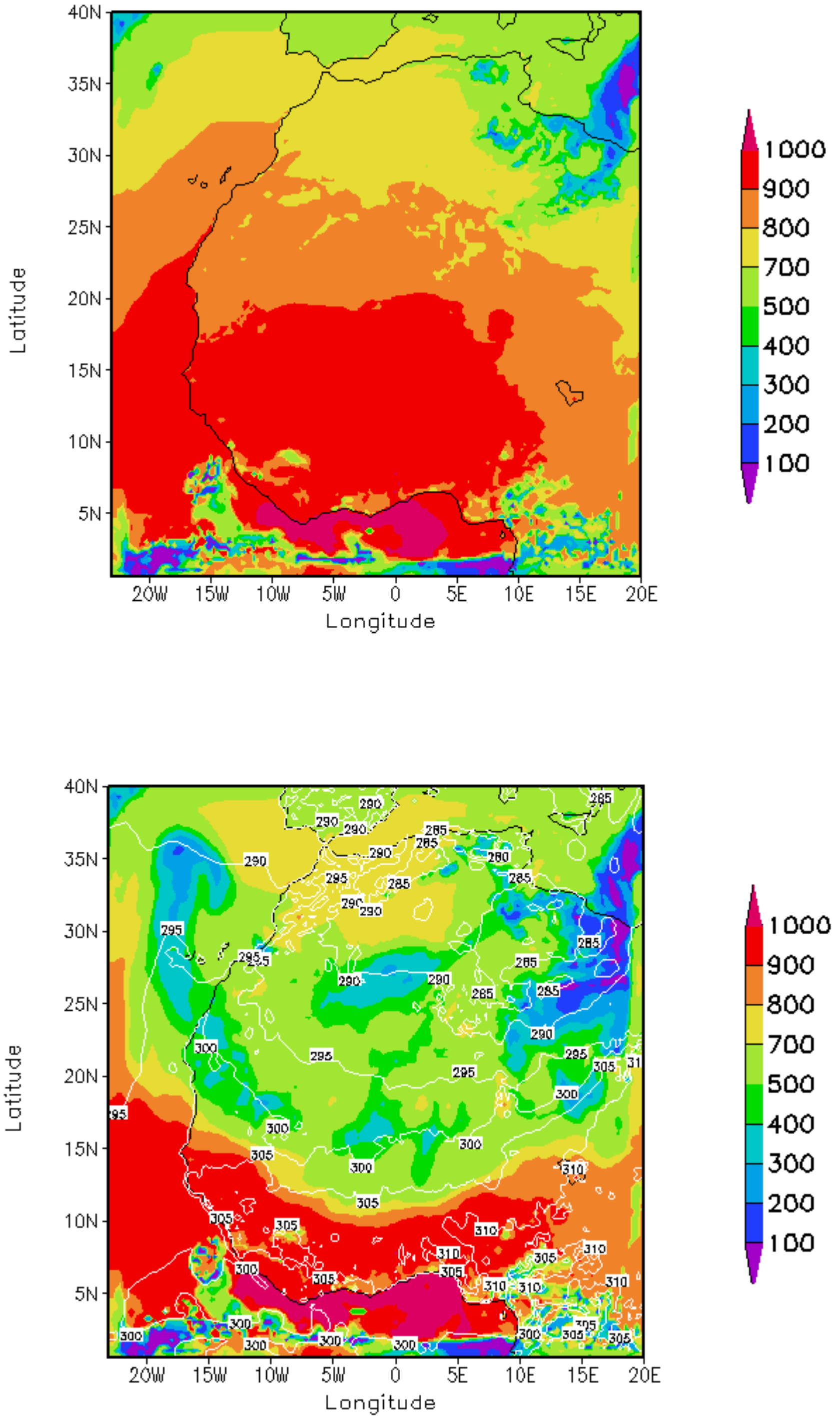
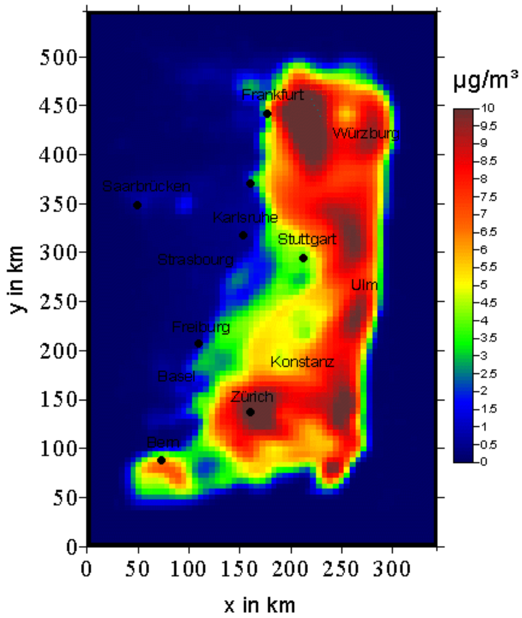


Figure 3. Horizontal distribution of the according shortwave radiation balance for the simulation taken into account the actual dust concentration (left) and the simulation using the climatological values (right), both for 04.03.2004, 12 UTC.



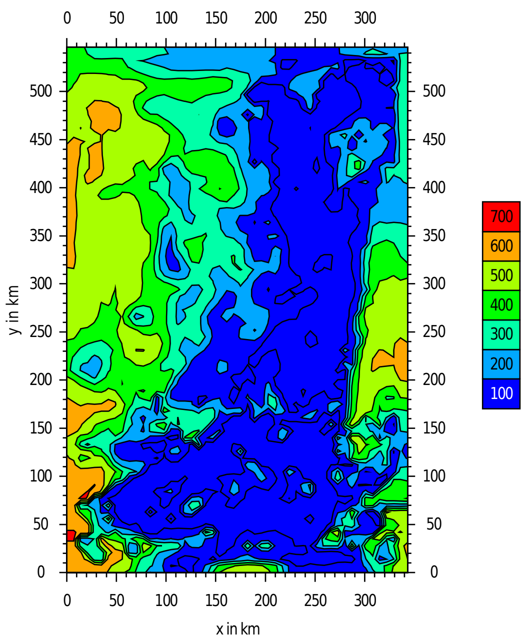
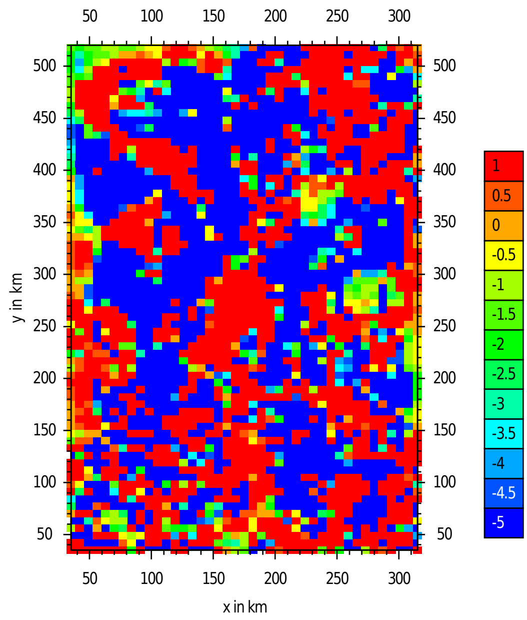


Figure 4. Horizontal distribution of the dry aerosol mass (20 m above ground, left) and the according shortwave radiation balance (right), both for 04.03.2004, 12 UTC.



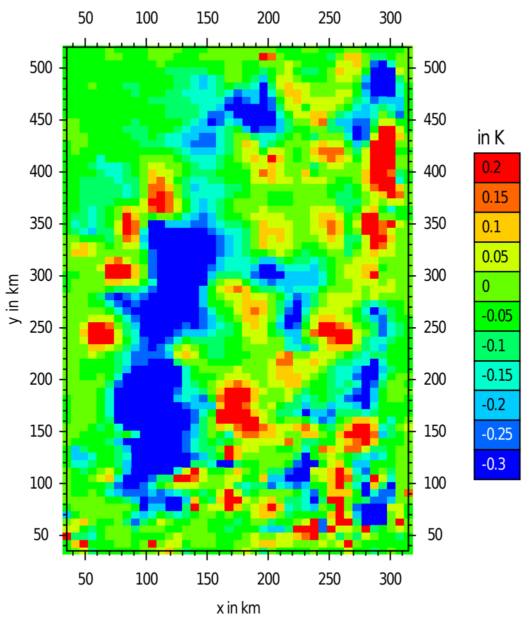


Figure 5. Difference of the shortwave radiation balance (left) and the temperature (right) between the model run with aerosol-radiation interaction and the run without aerosol-radiation interaction.