Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

EXZELLENZCLUSTER
CLIMATE, CLIMATIC CHANGE, AND SOCIETY (CLICCS)

Model study on the influence of aerosol-cloud interaction processes on precipitation in urban areas

Friederike Bär[1], Ronny Petrik[1], Markus Quante[1], Bernd Heinold[2]
[1]Helmholtz-Zentrum hereon, Geesthacht, Germany
[2]Leibniz Institute for Tropospheric Research (TROPOS), Leipzig, Germany
friederike.baer@hereon.de

Motivation

High aerosol concentrations in urban regions from industry, traffic, and residential heating play an important role in the dynamics and microphysical properties of convective systems. Changes in dynamics and cloud microphysics can trigger large-scale changes in storm morphology and precipitation patterns and thus play a significant role in precipitation formation. The **modifications by the urban area** can lead to **intensification**, **delay**, or even **suppression of convective precipitation**.

This urban influence depends not only on size and chemical composition of aerosols, but also which synoptic conditions prevail. A combination of both will result in many different cloud and precipitation outcomes. Consequently, this project aims to investigate the role of urban emissions in the formation of clouds and precipitation by investigating which cloud systems can be influenced by the city and which aerosol concentrations are required to see an effect and thereby contribute to a better understanding of urban influence on precipitation.

Method

Model description

For this study, we use the COSMO model **online-coupled** with the urban canopy parameterization DCEP and the chemistry transport model MUSCAT.

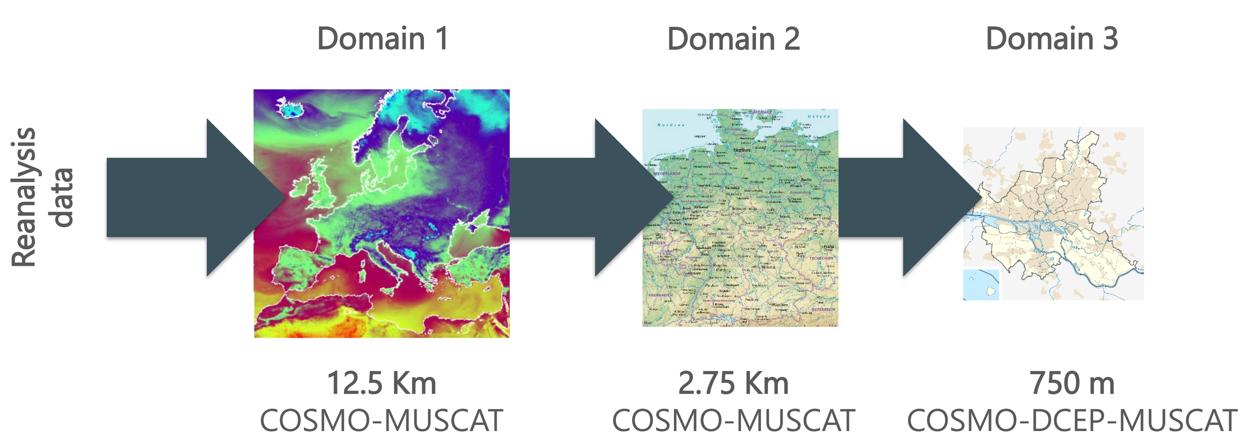
-**COSMO** (COnsortium for Small scale MOdelling): regional meteorological model, which has been the operational forecast model of the German Weather Service (DWD) until 2020 and solves the atmospheric equations on the basis of a terrain-following grid.

-**MUSCAT** (MUltiScale Chemistry Aerosol Transport): handles chemical transformations and atmospheric transport for different gas phase species and aerosol particles, driven by the meteorological model. The transport processes take account of advection, turbulent diffusion, sedimentation, dry and wet deposition.

-**DCEP** (Double Canyon Effect Parametrization): allows to consider how airflow and radiation are effected by the urban morphology. (an extension of Martilli's BEP scheme)

Model setup

We apply a 3-way nesting strategy for the simulations, where the highest resolution area is centered over the Leipzig metropolitan area with a 750m grid spacing.



The coarse simulation is initialized with ERA5 reanalysis data and the atmospheric chemical composition reanalysis product (CAMS (Copernicus Atmosphere Monitoring Service)). Natural primary Aerosols like dust and sea salt aerosols are calculated within the MUSCAT model using the meteorological fields from COSMO combined with information from the surface properties. Emissions of anthropogenic primary particles and precursors of secondary aerosols are given by emission fields from MACC (Monitoring Atmospheric Composition and Climate).

A 24h spin-up of the COSMO model is followed by 48h coupled chemistry and meteorology runs. To keep the meteorology close to the analysis fields, the system is reinitialized after every 48h cycle.

Extension of the 2-moment microphysical scheme

In order to simulate a direct aerosol-cloud-precipitation coupling the 2-moment microphysics scheme from COSMO was modified to allow cloud condensation nuclei to be calculated directly from aerosols simulated with MUSCAT.

Aerosol species considered in this calculation are: ammonium sulfate, ammonium nitrate, sulfate, organic, and elemental carbon, as well as for sea salt and 5 dust classes.
The number size distribution for each species is calculated and then used to calculate the number of activated particles. This calculation is done similar to the parametrization of Abdul-Razzak and Ghan (2000) for multimodal aerosol distributions and the work from Genz et al. 2020. Using the Köhler theory, the particle number size distribution and number of activated particles are related as a function of maximum supersaturation.

The total number of activated particles N is then:

$$N = \sum_{i=1}^{I} N_i \frac{1}{2}[1 - erf(u_i)]$$

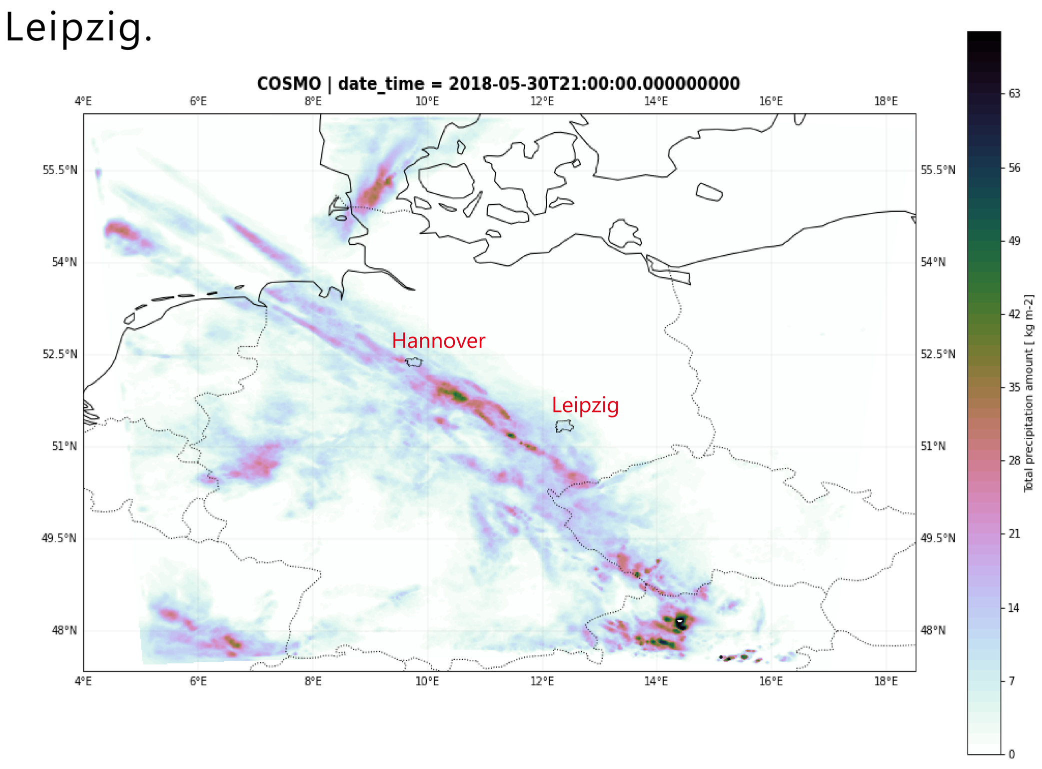
where

$$u_i \equiv \frac{2\ln(S_{mi}/S_{max})}{3\sqrt{2}\ln\sigma_i}.$$

For each aerosol species only the hygroscopicity parameter κ is necessary for the treatment of internal mixtures of aerosol material. The κ values used in this study are similar to Genz et al. 2020.

Results

A first suitable weather system we found for this study is a **convergence line**, which occurred 30. Mai 2018. In the area of the convergence zone, an additional uplift drive developed, which was responsible for the heavy showers and thunderstorms. As the upper-level flow was quite weak, the **thunderstorm cells hardly moved**. This makes this convergence line particularly interesting for our study, since the stationary position makes it possible to study the continuous influence of the cities below, for example Hannover and Leipzig.



Total precipitation amount simulated with COSMO from 2018-05-29T00:00:00 until 2018-05-30T21:00:00 with grid resolution 0.025°.

Unfortunately, progress has been slow due to problems with the high performance computer. Plans for the future include investigating further into details how the precipitation caused by the convergence line is influenced by the urban areas and aerosols. Additionally we plan to examine other weather situations, as well as simulations resolving individual cities with a resolution of 750m.