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Meteorology - air quality interactions in large urban areas in Germany – An atmospheric modeling perspective

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Human activities lead to an increase of emissions of air pollutants influencing the chemical composition of urban air. Chemical reactions and aerosol formation processes in urban areas in turn are altered due to increased temperature, reduced humidity and modified urban-rural trace substance mixture. Urban-rural circulation patterns driven by the strength of the urban heat island (UHI) further promote the dispersion of pollutants into the rural vicinity, being able to modify local and regional air chemistry and meteorology. For this reason, numerical models describing urban climates need to represent both atmospheric dynamics and air chemistry in order to account for the complex interactions in these areas.

This study uses a state-of-the-art chemical transport model for analyzing the impact of urban aerosols originated from two large conurbations in western Germany on local and regional weather with particular focus on cloud formation and precipitation. For analyzing the links between aerosol transport and chemistry in and around clouds, we use the global chemistry climate model EMAC and its regional nested version MECO(n), which are based on the ECHAM (global) and the COSMO (regional) models. We show an improvement of modeling results when including the urban canopy parametrization TERRA-URB and further find a correlation between UHI-strength and urban-rural aerosol transport rates.

Focusing on a convection dominated summer time case with strong urban heat island formation we find remote impacts of urban aerosols originated from the Ruhr-Area, western Germany on cloud formation and precipitation in leeward regions over the Eiffel mountain range under particular flow conditions. The sign and magnitude of precipitation and cloud cover modification varies significantly for different emission scenarios and meteorological patterns. Model results for a case study in July 2007 show, that increasing the amount of emitted aerosols in dedicated urban areas by 70% results in an increase of cloud fraction over rural areas 100-200 km downwind by up to 60%. 10 hour accumulated rainfall does increase over these areas by up to 65% which we attribute to the additional amount of cloud condensation nuclei advected from remote urban source regions.

We summarize that linking chemical and meteorological features in a state-of-the art chemical transport model is crucial to account for combined effects of weather and air quality in urban regions. Findings from these model systems can be an important asset for science tools for cities in the framework of climate change adaption and mitigation strategies.