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On the impact of urban canopy forcing on summer photochemistry over central Europe

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The regional climate model RegCM4.4, including the surface model CLM4.5, was offline coupled to the chemistry transport model CAMx6 in order to investigate the impact of the urban canopy induced meteorological changes on the long-term summer photo-chemistry over central Europe for the 2001-2005 period. First, the urban canopy impact on the meteorological conditions was evaluated performing a reference experiment without urban landsurface considered and an experiment with urban surfaces modeled using the urban parameterization within the CLM4.5 model. In accordance with the expectations, strong increases of urban surface temperatures (up to 2-3 K), increases of wind speed (up to -1 m/s) and increases of vertical turbulent diffusion coefficient (up to 60-70 m2/s) were modeled.

For the impact on chemistry, these three components were considered. Several experiments were performed by adding them one-by-one to the total impact: i.e. first, only the urban temperature impact was considered driving the chemistry model; secondly, the wind impact was added and finally the impact on turbulence was accounted for as well. We further looked at the effect of temperature enhanced biogenic emission increase.

We found that the impact on biogenic emission account for minor changes in species concentrations. On the other hand, the dominating component acting is the increased vertical mixing, resulting in up to 5 ppbv increase of urban ozone concentrations while causing -2 to -3 ppbv decreases and around 1 ppbv increases of NO_x and nitric acid (HNO_3) surface concentrations, respectively. The temperature impact alone results in reduction of ozone, increase in NO, decrease in NO_2 and increase of nitric acid. The wind impact leads, over urban areas, to ozone decreases, increases of NO_x and a slight increase in HNO_3. The overall impact is similar to the impact of increased vertical mixing alone. The Process Analysis (PA) technique implemented in CAMx was adopted to investigate the causes of the modeled impacts in more detail. It is shown that the main process contributing to the temperature impact on ozone is the enhanced dry-deposition, while, as assumed, the dominating process controlling the wind impact on ozone over cities is the reduced advection. In case of the impact of enhanced turbulence, PA suggests that ozone increases are, again as assumed, the result of increased downward vertical mixing supported by reduced chemical loss. Comparing the model concentrations with measurements over urban areas, a slight improvement of the model performance was achieved during afternoon hours if urban canopy forcing on chemistry via meteorology was accounted for.