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Study of the direct aerosol effect in the Paris metropolitan area using a coupled meteorological – chemical transport model

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The radiative effects of atmospheric aerosols have been recognised as the main modes of interaction, coupling meteorological phenomena and atmospheric pollution. Aerosol radiative forcings on the surface radiation budget include the combined effect of scattering and absorption of solar radiation and have a profound impact on the total amount of absorbed radiation as well as in the increase of low-level static stability. In recent years, two-way coupling of mesoscale and urban-scale numerical weather prediction and chemical transport models has been an area of active research, aiming to an improved description of aerosol-induced feedbacks in these scales. In an online coupled mesoscale model system, the interaction between pollutant fields and the meteorology is usually implemented through the use of specialised submodules that aim to account for the contribution of aerosol feedbacks on the main radiative processes. In the present work, a coupled model system consisting of the mesoscale Eulerian meteorological model MEMO and the chemical transport model MARS-aero is applied to the study of impact of the aerosol direct effect on the urban meteorology and the evolution of air pollution in an urban area. During the coupled model's operation, the aerosol concentration fields calculated by the dispersion model are introduced back as input in the enhanced radiation module of a three-dimensional non-hydrostatic mesoscale meteorological model by means of the OPAC (Optical Properties of Aerosols and Clouds) software library. For the assessment of the system's performance, simulations of meteorological fields and dispersion of atmospheric pollutants were performed for the Paris metropolitan area during the MEGAPOLI study period of summer 2005. The performance of the new formulation was assessed by evaluating the response of the primary meteorological variables governing the transport and dispersion of pollutants, as well as trends in particulate matter concentrations. The introduction of the direct effect leads to a consistent reduction of calculated mean wind speeds over most of the domain, while a notable decrease of the turbulent kinetic energy production at the first layer of the model is also evident, indicating a significant reduction of thermal forcings on the surface. At the same time, PM10 concentration fields calculated by the coupled model system reveal a significant increase over almost the entire domain covering the Paris metropolitan area, compared to the stand-alone calculations, as well as higher pollution loads in the southern part of the computational domain which can be attributed to the prevailing wind flows during the simulation period. Further evaluation of the coupled model's predictive skill was performed by comparing calculated PM10 concentrations with time series of measurements at several AIRPARIF stations, which indicated an improved ability of the coupled system in reproducing the evolution of particulate concentrations throughout the area of study.