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Wildfire particulate matter in Europe during summer 2003: meso-scale modeling of smoke emissions, transport and radiative effects

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Abstract. The present study investigates effects of wildfire emissions on air quality in Europe during an intense fire season that occurred in summer 2003. A meso-scale chemistry transport model CHIMERE is used, together with ground based and satellite aerosol optical measurements, to assess the dispersion of fire emissions and to quantify the associated radiative effects. The model has been improved to take into account a MODIS-derived daily smoke emission inventory as well as the injection altitude of smoke particles. The simulated aerosol optical properties are put into a radiative transfer model to estimate (off-line) the effects of smoke particles on photolysis rates and atmospheric radiative forcing. We have found that the simulated wildfires generated comparable amounts of primary aerosol pollutants (130 kTons of $PM_{2.5}$, fine particles) to anthropogenic sources during August 2003, and caused significant changes in aerosol optical properties not only close to the fire source regions, but also over a large part of Europe as a result of the long-range transport of the smoke. Including these emissions into the model significantly improved its performance in simulating observed aerosol concentrations and optical properties. Quantitative comparison with MODIS and POLDER data during the major fire event (3–8 August 2003) showed the ability of the model to reproduce high aerosol optical thickness (AOT) over Northern Europe caused by the advection of the smoke plume from the Portugal source region. Although there was a fairly good spatial agreement with satellite data (correlation coefficients ranging from 0.4 to 0.9), the temporal variability of AOT data at specific AERONET locations was not well captured by the model. Statistical analyses of model-simulated AOT data at AERONET ground stations showed a significant decrease in the model biases suggesting that wildfire emissions are responsible for a 30% enhancement in mean AOT values during the heat-wave episode. The implications for air quality over a large part of Europe are significant during this episode. First, directly, the modeled wildfire emissions caused an increase in average $PM_{2.5}$ ground concentrations from 20 to 200%. The largest enhancement in $PM_{2.5}$ concentrations stayed, however, confined within a 200 km area around the fire source locations and reached up to 40 µg/m³. Second, indirectly, the presence of elevated smoke layers over Europe significantly altered atmospheric radiative properties: the model results imply a 10 to

30% decrease in photolysis rates and an increase in atmospheric radiative forcing of 10–35 W m^{-2} during the period of strong fire influence throughout a large part of Europe. These results suggest that sporadic wildfire events may have significant effects on regional photochemistry and atmospheric stability, and need to be considered in current chemistry-transport models.

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