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The present and future of secondary organic aerosol direct forcing on climate

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Secondary organic aerosols (SOA), a subset of organic aerosols that are chemically produced in the atmosphere, are included in climate modeling calculations using very simple parameterizations. Estimates on their shortwave forcing on climate span almost two orders of magnitude, being potentially comparable to sulfate direct forcing. In the longwave, a neglected part of the spectrum when it comes to SOA, the direct SOA forcing could exceed that of sulfate and black carbon, although in absolute values it is much weaker than the shortwave forcing. Critical for these estimates is the vertical distribution of the climate active agents, pointing to SOA temperature-dependent volatility. Over the last few years, research also revealed the highly oxidized character of organic aerosol and its chemical aging in the atmosphere that partially leads to the formation of brown carbon, an absorbing form of organic aerosol. This review summarizes critical advances in the understanding of SOA behavior and properties relevant to direct climate forcing and puts them in perspective with regard to primary organic aerosol and brown carbon. These findings also demonstrate an emerging dynamic picture of organic aerosol that has not yet been integrated in climate modeling. The challenges for the coming years in order to reduce uncertainties in the direct organic aerosol climate impact are discussed. High priority for future model development should be given to the dynamic link between “white” and “brown” organic aerosol and between primary and secondary organic aerosol. The SOA temperature-dependent volatility parameterizations and wavelength-dependent refractive index should be also included.