Effects of physical and chemical nonlinearities on evolution of the optical properties of biomass burning aerosol

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Motivation

- Biomass burning (BB) aerosol has a strong impact on the Earth's radiation budget
- Accurate knowledge of the BB aerosol optical properties and their evolution is a key prerequisite for accurate estimates of the impact of BB emissions on climate
- Field and laboratory studies of atmospheric transformations (aging) of BB aerosol have yielded a wide diversity of observed effects but they are not explained in the corresponding model simulations

The study objectives

- To investigate the evolution of the BB aerosol optical properties – such as the mass absorption and scattering efficiencies (MAE and MSE) – within an isolated BB plume using a dynamic box model coupled with a Mie optical code
- To identify and analyze the nonlinearities in the dependencies of MAE and MSE on BB plume parameters – the initial BB aerosol concentration and initial size – due to the oxidation and gas-particle partitioning processes, thereby extending the previous analysis of the nonlinear behavior of BB aerosol [1]
- To investigate the sensitivity of MAE and MSE in the box model simulations to the differences between organic aerosol (OA) oxidation VBS schemes proposed in the literature

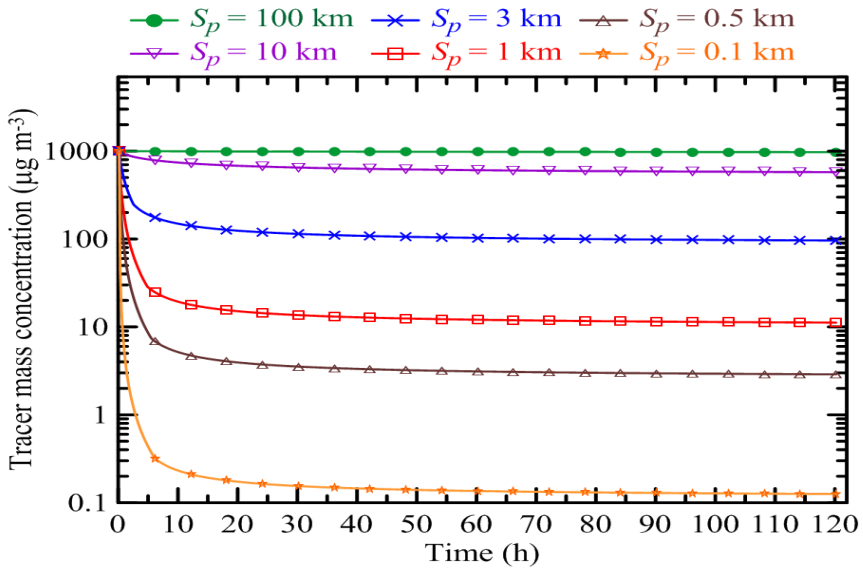
1. Konovalov, I. B., Beekmann, M., Golovushkin, N. A., and Andreae, M. O.: Nonlinear behavior of organic aerosol in biomass burning plumes: a microphysical model analysis, Atmos. Chem. Phys., 19, 12091–12119, https://doi.org/10.5194/acp-19-12091-2019, 2019.

Methods

The evolution of aerosol in BB plumes is simulated with MDMOA (Microphysical Dynamic Model of Organic Aerosol) that involves a schematic parameterization of the dilution process and represents the oxidation and gas-particle partitioning processes within the volatility basis set (VBS) framework. The Mie-theory-based simulations of the optical properties of aging BB aerosol were performed with the OPTSIM module coupled with MDMOA. The MAE and MSE values are computed by assuming that an absorbing BC core is surrounded by a non-absorbing organic shell.

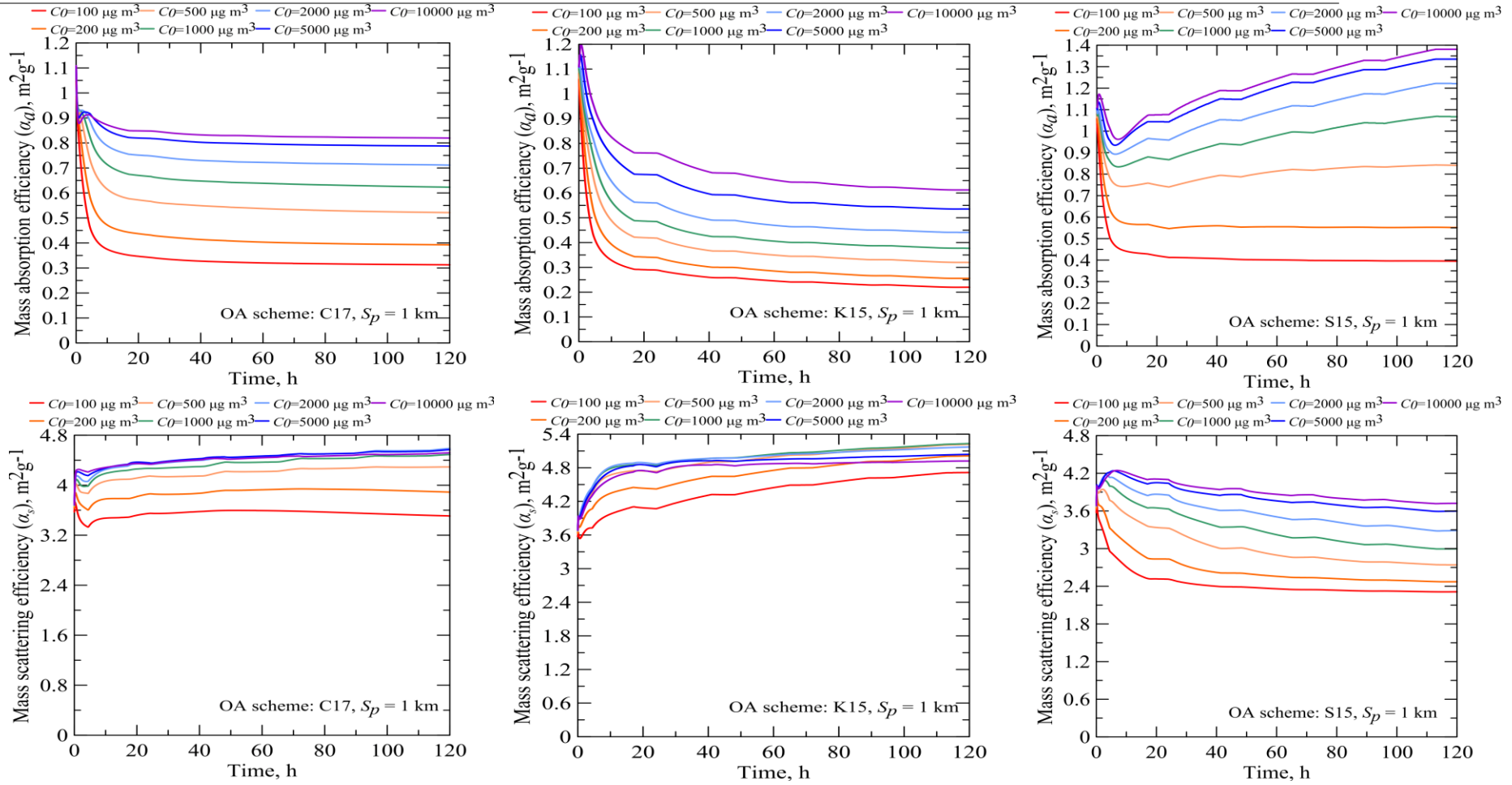
Dilution is simulated based on a Gaussian dispersion model as a function of the initial horizontal (across-wind) size of a BB plume, S_p.

Examples of the simulated evolution of the mass concentration of an inert tracer for different values of S_p:



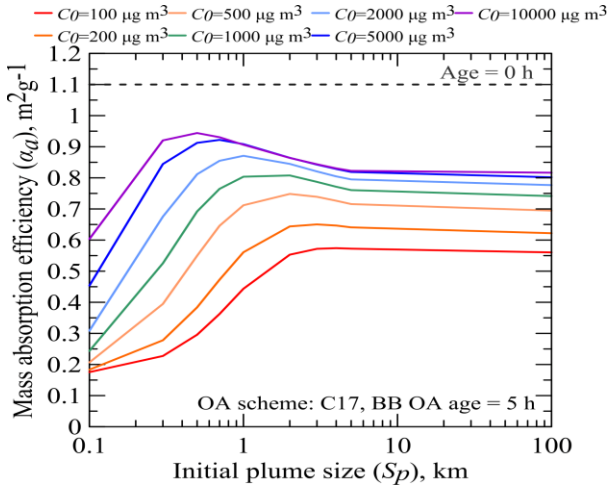
Results

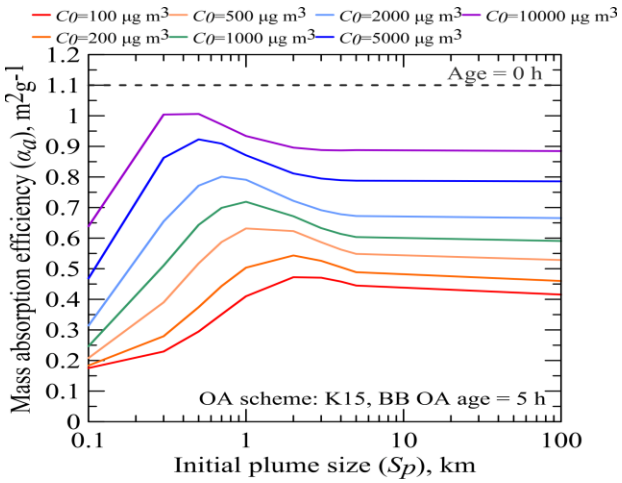
Evolution of the BB aerosol mass absorption efficiency (top) and mass scattering efficiency (bottom), according to the simulations performed with the three different OA schemes (see Konovalov et al., 2019) and with different values of the initial mass concentration (C_0). The initial BB plume size, S_p, has a fixed value of 1 km in all the simulations shown.

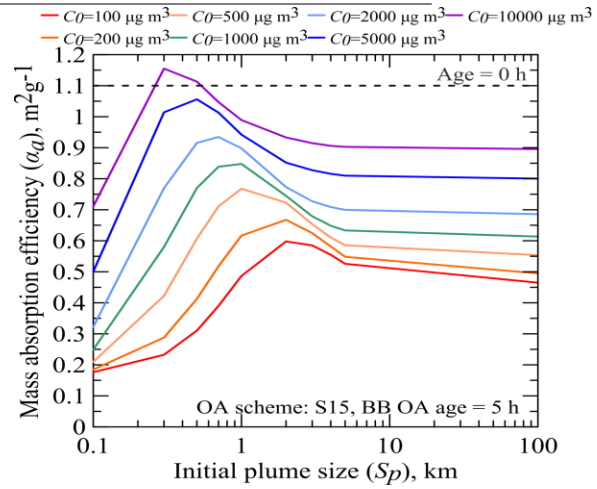


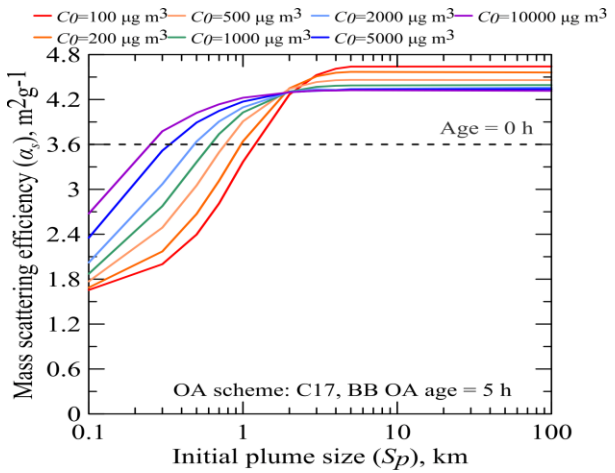
Results

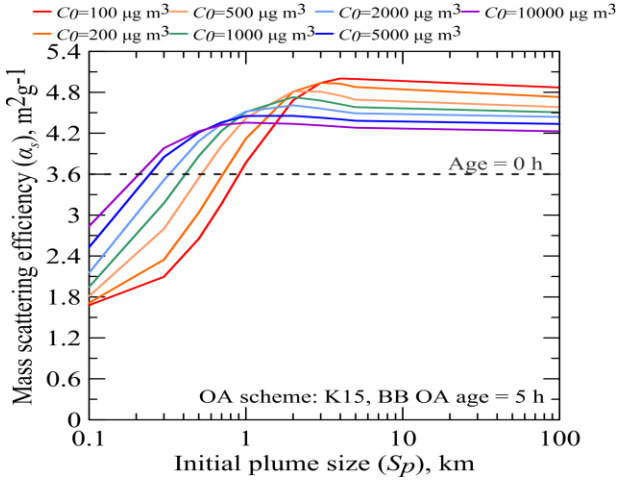
Simulated dependencies of MAE (top) and MSE (bottom) after 5 hours of evolution on the initial plume size, S_p. Dashed lines show the initial values of MAE or MSE.

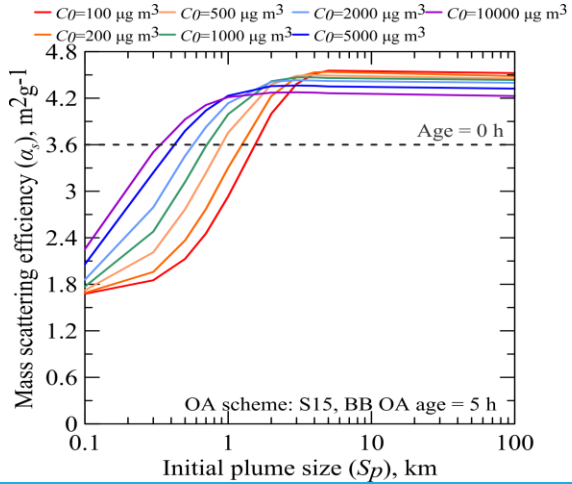






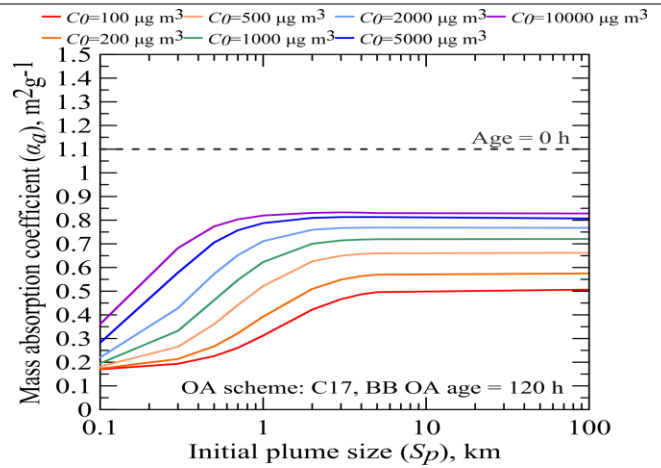


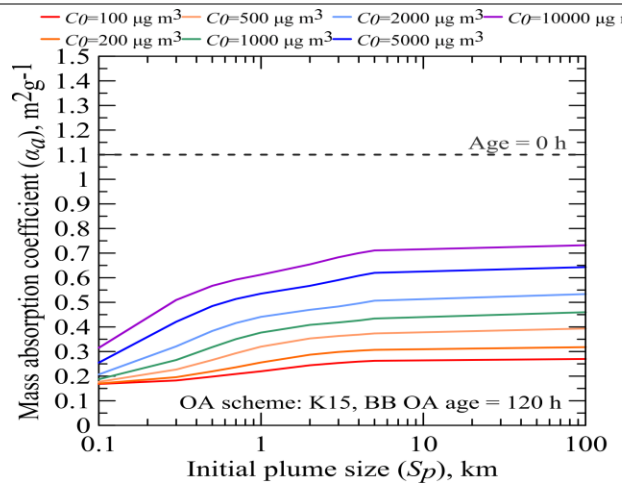


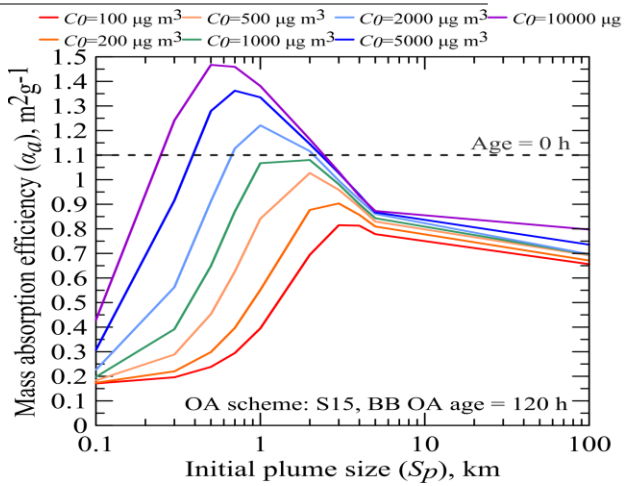


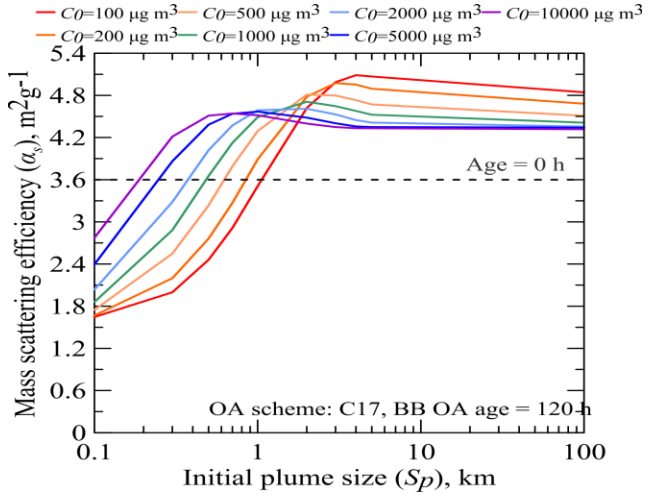
Results

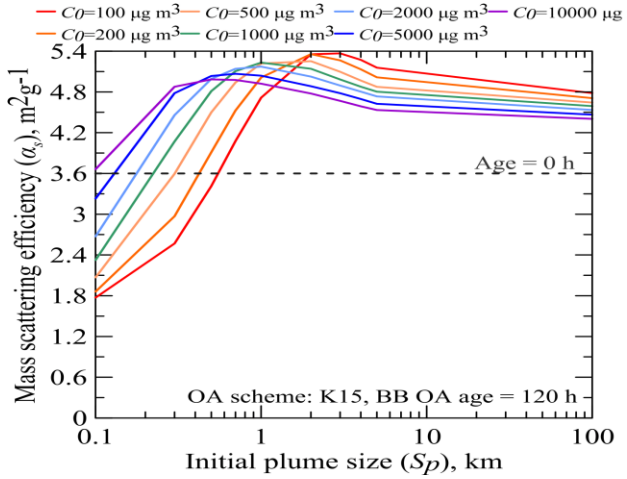
The same as in the previous slide but after 120 hours of evolution

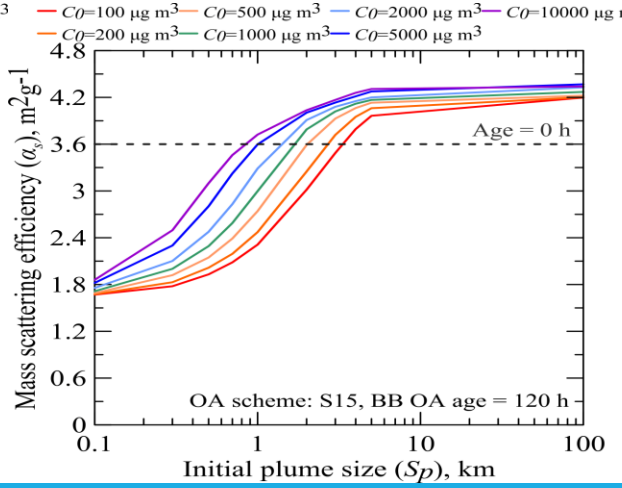












Conclusions

MAE and MSE show strong changes during BB aerosol evolution within an isolated BB plume

The simulated values of MAE and MSE demonstrate strongly nonlinear dependencies on the parameters of a BB plume

The simulated changes in MAE and MSE are sensitive to the choice of a VBS scheme used to model the BB OA evolution

Thank you for your interest

Any questions?