Black carbon (BC) is formed by incomplete combustion of fossil fuels, biofuels, and biomass, and is the second most important anthropogenic contributor to global warming after CO2. Climate impact of BC aerosols is poorly qualified due to the systematic discrepancy between model and observation estimates of BC light absorption enhancements ($E_{abs}$) after aging which transfer directly into large uncertainties in model estimates of BC radiative forcing. Until now, a proper description of $E_{abs}$ varying with BC aging has not been validated, leading to a crucial question of BC climate impact. In this study, BC absorption enhancements are qualified using a theoretical model considering their realistic particle morphologies and mixing states dependent on aging scales. The fractal aggregated morphologies with bare, partly coated, partially encapsulated, and heavily coated states of BC-containing particles are simulated dependent on the mass ratio of non-BC and BC components in the individual BC-containing particles, and their optical properties are validated by the comprehensive laboratory and field ambient data. Our results indicate that previous conflicting results of $E_{abs}$ were possibly observed in different BC aging states, which lie in the range of modelling descriptions. The observed $E_{abs}$ can be simulated by the model considering particle morphology if BC aging states are exactly obtained. The small observed values of $E_{abs}$ correspond to a partly aging stage with the BC particles that have inclusions and are thinly coated. The large results of $E_{abs}$ are mainly produced by heavily coated BC particles in their fully aged stage. It is suggested that the predictions of $E_{abs}$ varying with BC aging can be largely improved by considering their realistic particle morphologies and mixing states dependent on aging scales.

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