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Markedly enhanced direct radiative forcing of black carbon particles under polluted urban environments

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Black carbon (BC) particles, produced from incomplete fossil fuel combustion and biomass burning, are ubiquitous in the atmosphere and have profound impacts on air quality, human health, weather, and climate. For example, in areas identified as aerosol hotspots, which include many urban centers and megacities worldwide, solar heating by BC particles has been shown to be comparable to warming due to the greenhouse gases2. Although BC represents a key short-lived climate forcer, its direct radiative forcing remains highly uncertain. In particular, the available results of absorption enhancement of BC particles during atmospheric aging are conflicting from the previous studies, leading to a large uncertainty in global radiative transfer calculation. Here, we quantified the aging and variation in the optical properties of BC particles under ambient conditions in Beijing, China and Houston, US, using a novel chamber approach. BC aging exhibits two distinct stages - initial transformation from a fractal to spherical morphology with little absorption variation and the subsequent growth of fully compact particles with a maximum absorption enhancement factor of 2.4. The variation in BC direct radiative forcing is highly dependent of the rate and timescale of aging, with an estimated increase of 0.45 (0.21 - 0.80) W m-2 from fresh to fully aged particles. Our results reveal a high climatic impact in polluted environments due to rapid aging and a clear distinction between urban cities in developed and developing countries for BC particles, highlighting a larger than recognized co-benefit in air quality improvement and climate protection by BC mediation.