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Size-resolved effective density of submicron aerosol particles in the North China Plain

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Effective density is one of the most important physical properties of atmospheric aerosol particles, and is linked to particle formation and aging process. Combined characterization of aerosol density, chemical composition, emission and aging processes may provide crucial information for better understanding their interactions and effects on environment and climate. In autumn of 2019, the effective density of sub-micrometer aerosol particles was measured in-situ at a heavily polluted rural site in the North China Plain (NCP). A tandem technique coupling a Centrifugal Particle Mass Analyzer (CPMA) with a differential mobility analyzer (DMA) and a Condensation Particle Counter (CPC) were used to determine the effective density of ambient aerosol particles with diameters of 50, 100, 150, 220 and 300 nm. The probability distribution of effective density exhibits double peak modes in majority cases, with a higher density mode (main-density) and a lower density mode (sub-density). The existence of sub-density particles normally ascribed to freshly emitted or partial aged black carbon (BC) with non-spherical morphology. The number fraction of sub-density mode varies from 4% to 67%, with mean of 22-27% at five particle sizes. Due to the higher aging degree of larger particles, the main-density exhibits an evident ascending trend with particle size. However, the sub-density decreases as mobility size increases, from 0.89 g/cm^3 at 50 nm to 0.62 g/cm^3 at 300 nm, since larger fresh soot particles usually present a more agglomerated morphology than small particles. A comparison was carried out between the mean effective density at 300 nm and ACSM-derived density using different approximations of BC density. The best agreement is achieved when assuming a BC density of 0.6 g/cm^3, indicating that BC typically exists as non-spherical particles with fractal-like or porous morphology in the NCP in cold season.