Supplementary information for
The effectiveness of coagulation sink of sub-10 nm particles

Runlong Cai¹,*, Ella Häkkinen¹, Chao Yan¹,², Jingkun Jiang³, Markku Kulmala¹,², Juha Kangasluoma¹,⁴

¹Institute for Atmospheric and Earth System Research / Physics, Faculty of Science, University of Helsinki, Helsinki, 00014, Finland
²Aerosol and Haze Laboratory, Beijing Advanced Innovation Center for Soft Matter Science and Engineering, Beijing University of Chemical Technology, Beijing, 100029, China
³State Key Joint Laboratory of Environment Simulation and Pollution Control, School of Environment, Tsinghua University, Beijing, 100084, China
⁴Karsa Ltd., A. I. Virtasen aukio 1, Helsinki, 00560, Finland

Correspondence to: Runlong Cai (runlong.cai@helsinki.fi)
Figure S1. The theoretical survival probability of 1.5-10 nm new particles versus the measured frequency of new particle formation events in urban Beijing as a function of the condensation sink. The particle survival probability is calculated assuming an effective coagulation sink. The condensation sink characterizes the size-dependent coagulation sink during each new particle formation event. The NPF frequency is determined as the ratio of NPF days to all the measurement days within the given condensation sink range. The lower limits of the vertical survival probability axis in this figure and Figure 7 in the main text are determined according to the measured median survival probability of new particles and particle formation rate in urban Beijing.

Figure S2. Schematic diagram for illustrating the underestimation of particle grow rate (GR) retrieved using the mode-fitting method. The mode-fitting method tracks the increase in a representative particle diameter \(d_p\) of a growing aerosol population (e.g., \(P_1\)) as a function of time \(t\). The representative \(d_p\) is usually the peak diameter of aerosol number size distribution \(dN/d\log d_p\). For instance, the peak diameter of aerosol population \(P_1\) grows by \(\Delta d_p\).
after $\Delta t$, and GR can be estimated using $\Delta d_p/\Delta t$. This estimated GR can be further corrected to disentangle the influences of coagulation.

However, a particle source, e.g., nucleation, may cause a significant underestimation in the retrieved GR. As shown in this figure, assuming a new aerosol population $P_2$ is formed during $\Delta t$. The measured aerosol size distribution at $t_2$ is the sum of the distributions of $P_1$ and $P_2$. As a result, the apparent $\Delta d_p$ calculated using the measured distributions is smaller than the $\Delta d_p$ of $P_1$, causing an underestimated GR. A more complicated scenario with continuous particle formation and growth is given in Figure S2, which also shows an underestimation of the mode-fitting method due to the influence of particle source.

**Figure S3.** (a) Simulated particle size distribution ($dN/d\log d_p$) and diameter-time ($d_p$-t) relationship used for growth rate (GR) calculation. (b) Growth rates retrieved using the appearance time method and the mode-fitting method. The evolution of particle size distribution is simulated using a discrete aerosol model (Li and Cai, 2020). The input nucleation rate is time-dependent and the input particle growth rate ($GR_{\text{input}}$) is time-and-size dependent. The influences of coagulation on the GR retrieved using the appearance time method ($GR_{\text{app}}$) are corrected. The $GR_{\text{input}}$ shown in panel (b) is calculated following the $d_p$-t relationship of the appearance time method. Due to the time-dependence of $GR_{\text{input}}$, the $GR_{\text{input}}$ following $d_p$-t relationship of the mode-fitting method (not shown) is higher than that for the appearance time method, yet the difference is minor (5 % on average) for this simulation.

As shown in panel (b), $GR_{\text{app}}$ is consistent with $GR_{\text{input}}$, indicating good accuracy of the appearance method for this simulation. The GR retrieved using the mode-fitting method ($GR_{\text{mode}}$) is significantly underestimated because of the influence of nucleation. This underestimation increases as the particle size decreases towards the critical cluster size, at which new particles are added to the simulation system.

**Reference**