Response to reviewer 1

Thanks for your great efforts and valuable comments, which helps to improve our manuscript. We have addressed the reviewers' comments on a point-to-point basis as below for consideration. Referee comments are in black. Author responses are in red.

The revised manuscript is greatly improved over the original one. However, there are still a few minor issues that need to be considered before I can recommend the paper to be accepted for publication:

The overall structure of section causes some confusion, which should be clarified. While section 3.1 discusses all the observed dust events, sections 3.2-3.5 evidently concentrated on a single dust event. This is not clear when reader the paper for the first time 1) because only the title of section 3.2 refers to a case study and sections 3.3-3.5 do not, and 2) because the contents of sections 3.3-3.5 have very little information on to which dust event(s) the data in them refers to (except a few dates without a year here and there). I recommend combining these sections into a single one (e.g. 3.2 Case study of a dust storm), and sections 3.3-3.5 put under the same title as sub-sections 3.2.1-3.2.3.

Reply: Thanks for your comment. We re-organized the structure of this manuscript. The original section 3.2 and 3.5 was combined into section 3.2, and this section was sub-divided into the following parts:

3.2 Case study of a dust-related NPF event
3.2.1 A severe dust storm case
3.2.2 Secondary aerosol formation during dust storm
3.2.3 Variations of particle hygroscopicity
3.2.4 Impact on the cloud condensation nuclei by the dust storm

The authors say that they have removed their statements on the role of anthropogenic emission from abstract and discussion. However, there are still claims in section 3.1 that are not solid in this respect (e.g. lines 235-236, lines 241-244). Please check out and revised if necessary.

Reply: As compared with the original submitted manuscript, we removed the statements of the quantitative description of the influence of anthropogenic emissions on NPF events from the abstract and conclusions, as this evaluation method is not scientifically sound as the reviewer suggested. This kind of statements was probably not robust, which could not be presented in the abstract or conclusion part. However, we still believe the influence of anthropogenic emissions on dust-related NPF events could be different from that on the normal NPF events. For this purpose, we prefer to have some discussions about anthropogenic emission effect on NPF in this section. In line 235-236, it was revised to "N_{3-10} and N_{3-25} were generally lower on dust-related NPF days than on other NPF days, which was probably due to a considerable contribution by anthropogenic emissions on non-dust NPF days."

For line 241-244, we added a reference to support our discussion. The sentence has been revised to “This suggested that the influence of anthropogenic emitted precursors on non-dust days when nucleated particles growing into the sizes above 10 nm could be more significant. It has been also reported the nitrogen-containing oxygenated organic molecules related with anthropogenic emissions in urban Beijing can contribute over 50% to the particle growth (Qiao et al., 2021). However, the influence by anthropogenic emissions was difficult to be estimated, as even during the growth process of dust-related NPF events, freshly-emitted precursors could also participate.”

Qiao, X., Yan, C., Li, X., Guo, Y., Yin, R., Deng, C., Li, C., Nie, W., Wang, M., Cai, R., Huang, D., Wang, Z., Yao, L., Worsnop, D. R., Bianchi, F., Liu, Y., Donahue, N. M., Kulmala, M. and Jiang, J.: Contribution of Atmospheric Oxygenated Organic Compounds to Particle Growth in an Urban Environment, Environmental science & technology, 55(20): 13646-13656, DOI: 10.1021/acs.est.1c02095, 2021.

Line 172: should this be vis > 10 km?

Reply: Even on floating dust days, the visibility should be below 10 km, according the dust case identification method suggested by Wang et al., (2005). Floating dust is the weakest as compared with dust storm and blowing dust, and is generally characterized with fine dust particles suspending in the lower troposphere with horizontal visibility of o10,000 m.

Wang, S., Wang, J., Zhou, Z. and Shang, K.: Regional characteristics of three kinds of dust storm events in China, Atmospheric Environment, 39(3): 509-520, DOI: 10.1016/j.atmosenv.2004.09.033, 2005.

Lines 193-194: this is a bit strange statement. I suppose you mean that NPF was not observed until the dust event was over (now you kind of claim contrary to this).

Reply: The sentence has been corrected to “NPF event can not be observed until the whole dust process finished.”

Lines 225-227: I do not feel that referring to fractions when comparing particle growth rates between the two types of days is a proper term here. Maybe it would be better to talk about ratios.

Reply: this sentence has been corrected to “The ratio of GR_{dust_NPF} to GR_{other_NPF} ranged from 0.50 to 0.86, with a mean value of approximately 0.67.”

Response to reviewer 2

Thanks for your great efforts and valuable comments, which helps to improve our manuscript. We have addressed the reviewers' comments on a point-to-point basis as below for consideration. Referee comments are in black. Author responses are in red. All corrections have been conducted according to reviewer's comments in the manuscript and supplementary materials.

While the authors addressed several of the comments raised by the reviewers in the first round, I believe there is still room for improvement and some claims that are either false or unjustified throughout the manuscript that need to addressed prior to publication in ACP. I highlight the major points here:

1. The authors consider dusty days are the 'background' conditions of the atmosphere in Beijing given the low average CS compared to other NPF-event day. In practice, dust events are extreme events and cannot be considered a norm or background. Instead, Beijing is recurrently subject to clean air-masses arriving from the north and west, not carrying any dust, but are low in CS. One can note based on the violin plots in Figure 2, that there are data points in the 'other NPF' category which are low in CS. Therefore, for an improved understanding of the dust episodes, and other episodes, a comparison between NPF characteristics (CS, J, GR) on 'dust days' and 'clean-other days' and 'polluted-other days' can be added.

Reply: The hourly mean *CS* values ranged from 0.002 to 0.163 s^{-1} during our study period, with statistical mean, median, 25% and 75% value of 0.034, 0.027, 0.014 and 0.047 s^{-1}, respectively. The potential source contribution function (PSCF) analysis was conducted based on the back trajectories calculation, with the *CS* criterion value of 0.027 s^{-1}, which was the median *CS* value during the measurement and the conditions with *CS* above this value was regarded as the polluted conditions. The PSCF result has also revealed that the higher *CS* values usually corresponded to the southerly regional air mass, containing high concentration of anthropogenic pollutants. The violin plot of *CS* in the manuscript has been revised to be Fig. S2. The comparison of formation rate and growth rate was also supplemented as shown in Fig. S3.

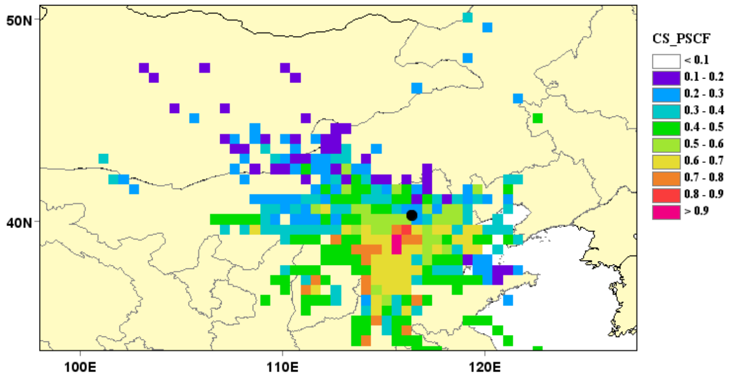

Fig. S1. Air mass classification of back trajectories arriving at the CAMS site in March, April and May, 2021. The color bar indicates the number concentration weighted potential source contribution function (PSCF) value of condensation sink.

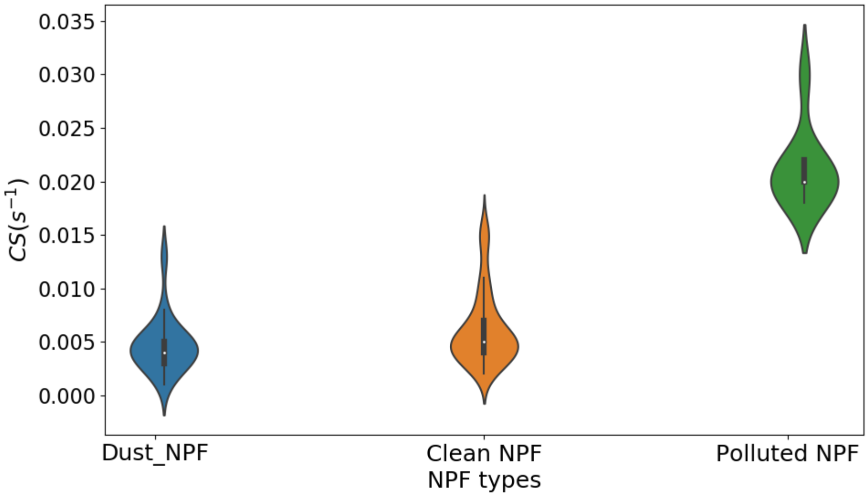

Fig. S2 The violin plot of condensation sink (*CS*) of dust-related NPF (Dust_NPF) and other NPF events under clean (Clean NPF) and polluted conditions (Polluted NPF). The marker represents the median value; a box indicating the interquartile range, and the shaded area represents the distribution probability of the *CS*.

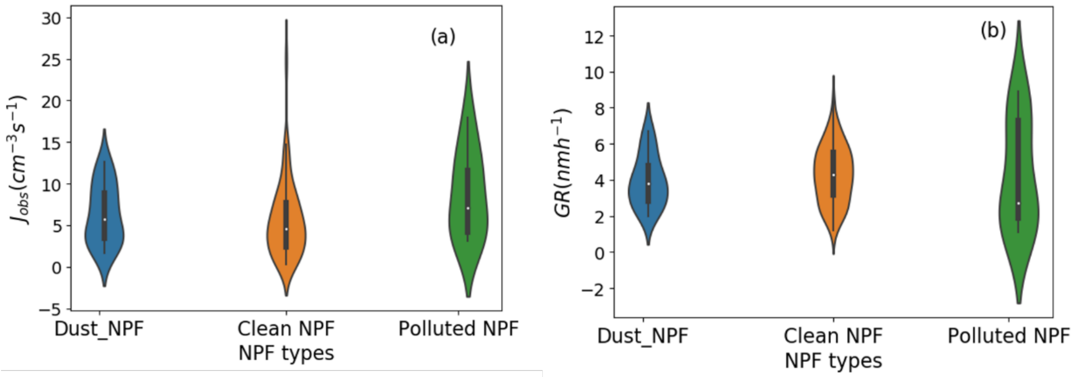

Fig. S3 The violin plot of formation rate, J_{obs} (a) and growth rate, GR (b) of dust-related NPF (Dust_NPF) and other NPF events under clean (Clean NPF) and polluted conditions (Polluted NPF). The marker represents the median value; a box indicating the interquartile range, and the shaded area represents the distribution probability of J_{obs} and GR.

2. Sentence on line 194 reads: ‘On May 7 and May 8, NPF events were observed with extremely low CS values of approximately 0.0025 – 0.003 s^{-1}, indicating the concentration level of precursors participating nucleation and growth were comparable for these two cases.’ In this sentence, the authors claim that they are able to ‘estimate’ the precursor concentration based on the CS level. This is an incorrect way of addressing atmospheric observations as the emissions, oxidants and meteorology are ignored. It is important to note here that May 7, 2021 is a workday, while May 8, 2021 is a weekend, which means that the emissions are definitely not comparable. See for example: https://doi.org/10.1007/s11430-008-0088-2. Here, the authors could check the changes in SO2 which is a precursor of the main vapor driving nucleation in Beijing

(sulfuric acid).

Reply: The authors all agreed with the reviewer's comment that we should look into the reactive gases, condensation sink (*CS*), and sulfuric acid data on May 7 and 8 further. The reactive gases (SO_2, NO_2, and O_3) were derived as the average of the values at four air quality monitoring sites, including Guanyuan (GY), Wanshou Temple (WST), Dongsi (DS), and Chaoyang (CY), in urban Beijing, as mentioned in the manuscript. It showed before NPF start, around 8:00 LT, the concentration of SO_2 and NO_2 on May 7 and 8 was quite close, which did not show a clear difference between workday and weekend. Furthermore, the *CS* before NPF start was also comparable on these two days, around 0.003 s^{-1}, indicating the available condensable vapor was close.

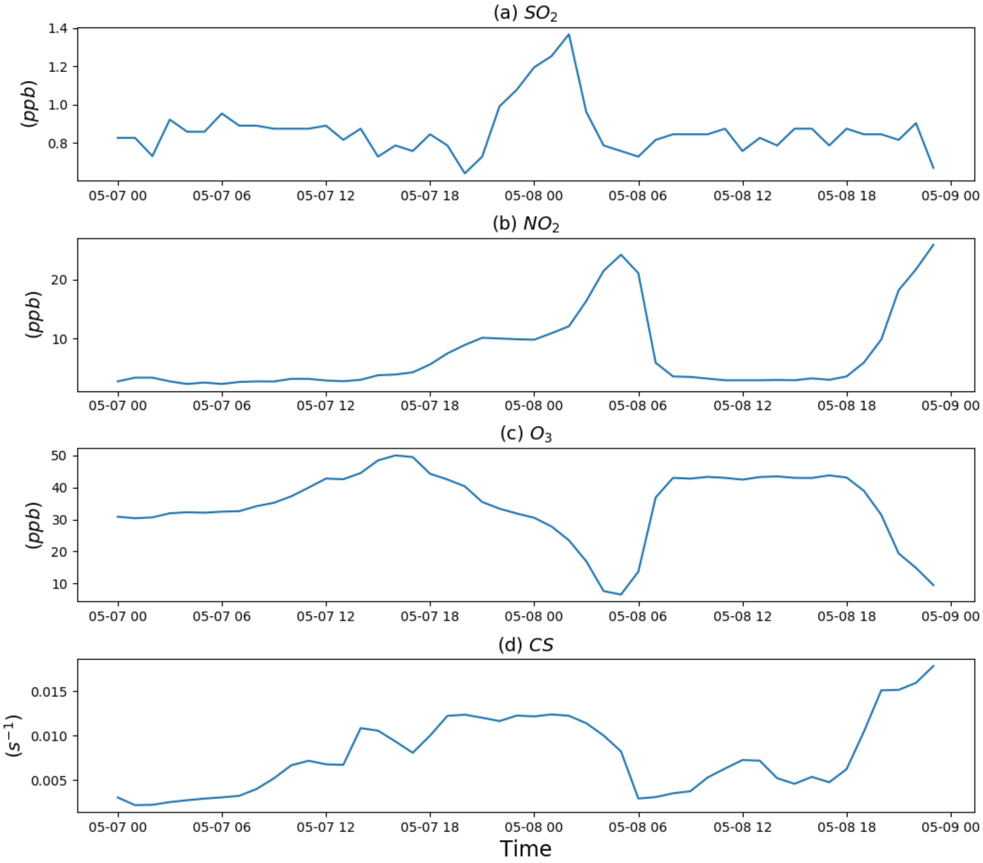

Fig. S4. Time series of hourly volume mixing ratio of SO_2, NO_2, O_3 and condensation sink (*CS*) on May 7 and 8, 2021.

As there is no direct H_2SO_4 measurement data available in this work, we used two methods to estimate sulfuric acid concentration. In the calculation of [H_2SO_4] in Beijing, we chose proxy equation number 2 as Proxy 1 in this study (Eq. 1) and 7 (Eq. 2) as Proxy 2 in this study as recommended by Lu et al. (2019), to represent the simplest and most accurate method, respectively.

$$[H_2SO_4] = 280.05 \times UVB^{0.14} \times [SO_2]^{0.40} \quad (1)$$

$$[H_2SO_4] = 0.0013 \times UVB^{0.13} \times [SO_2]^{0.40} \times CS^{-0.17} \times ([O_3]^{0.44} + [NO_x]^{0.41}) \quad (2)$$

And the UVB was derived by 0.008% × Glob_R, based on the previous study that the monthly average of the ratio of UVB to global radiation (Glob_R) ranged from 0.007

to 0.017% in Beijing (Hu et al., 2013). The average ratio of January and February (0.008%) was applied.

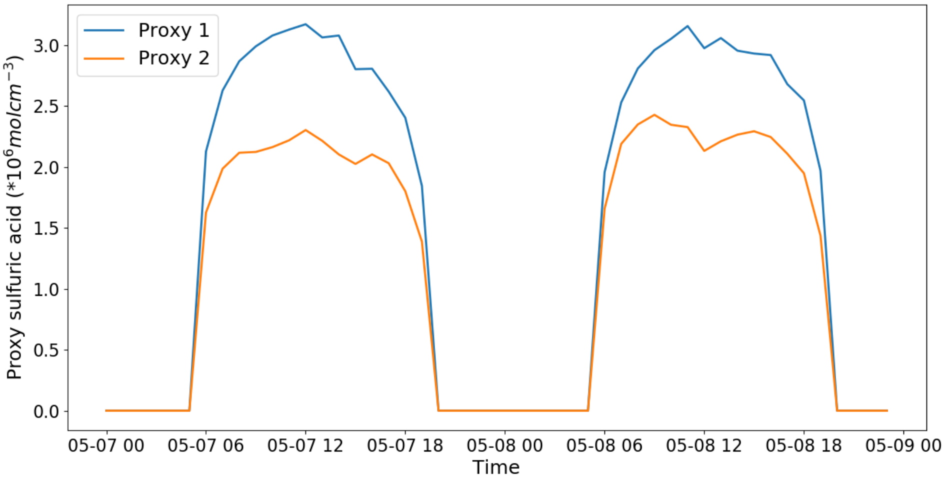

Fig. S4. The sulfuric acid concentrations derived by different proxy equations. The blue and orange lines indicate the result by N2 (Proxy 1) and N7 (Proxy 2) method by Lu et al., 2019

Hu, B., Zhang, X. H. and Wang, Y. S.: Variability in UVB radiation in Beijing, China, Photochem Photobiol, 89(3): 745-750, DOI: 10.1111/php.12051, 2013.

Lu, Y., Yan, C., Fu, Y., Chen, Y., Liu, Y., Yang, G., Wang, Y., Bianchi, F., Chu, B., Zhou, Y., Yin, R., Baalbaki, R., Garmash, O., Deng, C., Wang, W., Liu, Y., Petäjä, T., Kerminen, V. M., Jiang, J., Kulmala, M. and Wang, L.: A proxy for atmospheric daytime gaseous sulfuric acid concentration in urban Beijing, Atmos. Chem. Phys., 19(3): 1971-1983, DOI: 10.5194/acp-19-1971-2019, 2019.

Tang, W., Zhao, C., Geng, F., Peng, L., Zhou, G., Gao, W., Xu, J. and Tie, X.: Study of ozone “weekend effect” in Shanghai, Science in China Series D: Earth Sciences, 51(9): 1354-1360, DOI: 10.1007/s11430-008-0088-2, 2008.

3. An in depth analysis of the particle formation and growth rates as well as CS can still be performed, for instance is there a difference between particle formation rates on the different types of dust events? Or was the formation rate on the severe dust storm higher than the rest? The same applies to the growth rates and condensation sink. A plot of J vs GR/CS can also be useful here to show where the dust points fall compared to others.

Reply: As the reviewer recommended, we supplemented a scatterplot of J_{obs}, *GR* and *CS* and also categorized by different NPF event types, which included the NPF events occurred under clean and polluted conditions and influenced by blowing dust (BD), floating dust (FD) and dust storm (DS). There is no clear relationship between J_{obs} and *GR* as shown in Fig. S5. J_{obs} ranged from 0.3 to 23.6 cm^{-3}s^{-1}, with the mean value of 6.1 cm^{-3}s^{-1}. *GR* ranged from 1.1 to 8.9 nm h^{-1}, with the mean value of 4.18 nm h^{-1}. The mean J_{obs} of NPF events under clean (96), polluted (10), BD (9) and FD (11) conditions was 5.7, 8.7, 6.6 and 6.8 cm^{-3}s^{-1}, respectively. The corresponding mean *GR* value was 4.2, 4.3 4.1 and 3.7 nm h^{-1}, respectively, and mean *CS* was 0.006, 0.020, 0.005 and

0.005 s^{-1}. Formation rate under polluted conditions was significantly higher than those under other conditions, suggesting there were abundant condensing vapours participating nucleation and overcame the competition with the pre-existing particles (as indicated by high *CS* value). The J_{obs} at 3 nm and *GR* reported in this study was comparable with the values of previous studies, 0.5-20 cm^{-3}s^{-1} and a few nm h^{-1} to 20 nm h^{-1}, respectively, as summarized by Chu et al. (2019) based on several NPF studies in China. However, due to the limited cases of NPF with moderate accurate J_{obs} and *GR* influenced by BD (number of cases = 9), FD (11) and DS (1), a confident comparison results among different dust NPF events could not be derived. The related figure and discussion have been supplemented in the manuscript.

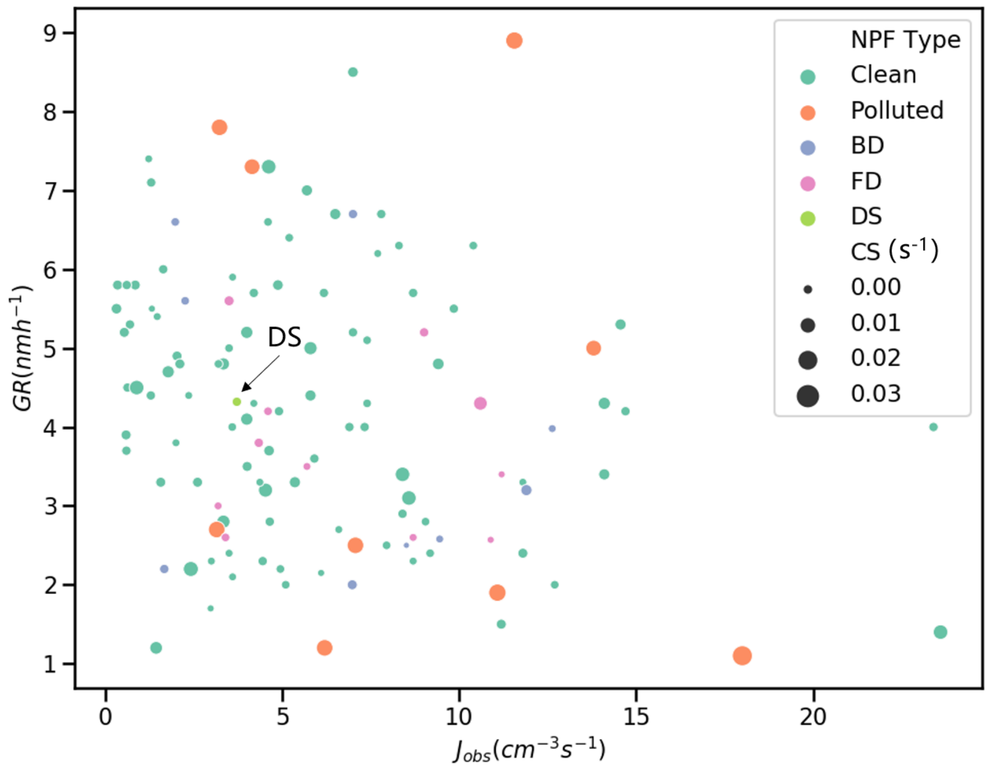

Fig. S5, Scatter plot of formation rate (J_{obs}), grow rate (GR) and condensation sink (CS) as categorized by different NPF event types, including the cases occurring under clean, polluted conditions and influenced by blowing dust (BD), floating dust (FD) and dust storm (DS).

4. I am also surprised that the authors do not compare their results to any other study in Beijing, or China or worldwide. For example how does the J, GR and CS observed during those measurements compare to others? The work already done on new particle formation in Beijing is comprehensive and could be useful for the authors to improve their story, especially the part related to anthropogenic emissions.

Reply: Thanks for the reviewer's suggestion. The NPF studies have been conducted extensively since 1990 worldwide and 2000 over China. Kerminen et al., (2018) and Chu et al., (2019) have summarized the particle nucleation and growth based on filed campaigns worldwide and over China, respectively. In this work, we only focused on the NPF event in spring time. In the previous studies, the long-term datasets are limited, especially in China. The formation and growth rates showed clear seasonal variation, and also varied depending on the environments. The lower limit of the particle size distribution should also be considered, as it influences the formation rate calculation. So, we focused on the comparison between this wok and the previous work conducted in Beijing in spring time or at least above 1 year with the particle detection limit of 3 nm. Based on the one-year study of NPF events at Peking University (PKU) site in Beijing in 2004, it has been reported that the formation rate (J_3) ranged from 3.3 to 81.4 $cm^{-3}s^{-1}$, and growth rate (GR) ranged from 0.1 to 11.2 nm h^{-1}, respectively (Wu et al., 2007). Wang et al. (2013) has also reported J_3 at PKU site ranged from 2.2 to 34.5 $cm^{-3}s^{-1}$, and growth rate ranged from 2.5 to 15.3 nm h^{-1} from March to November in 2008. PKU site locates 5 km to the north of CAMS site, which is a representative urban site in Beijing with long-term study of NPF events. Based on the long-term study at PKU site (2013-2019), it has been recently reported the annual average of J_3 decreased from 12 $cm^{-3}s^{-1}$ in 2013 to 3 $cm^{-3}s^{-1}$ in 2017, whereas increased to 5 $cm^{-3}s^{-1}$ in 2019, and GR values kept stable around 2-4 nm h^{-1} during these years (Shang et al., 2022). The mean values of J_3 and GR in our study was 6.10 $cm^{-3}s^{-1}$ and 4.18 nm h^{-1}, which was comparable with the values reported by Shang et al., (2022).

Although the precursors from anthropogenic emissions have been proved to participating the particle nucleation and growth processes, it is difficult to quantify its contribution, especially in megacities like Beijing (Kulmala et al., 2021). The complex primary emissions, for example, traffic emissions with plentiful nanoparticles, can mix with the freshly nucleated particles, making it difficult to resolve the particles from primary emissions and secondary formation. However, based some long-term studies of NPF event, it has reported that the decrease of the precursors due to the emission control strategies in China has caused formation rate reduction from 2013 to 2017 both in Beijing (Shang et al., 2022) and rural site in Yangtze River Delta region (Shen et al., 2022).

The comparison between this work and the previous studies has been added in the manuscript.

Wu, Z., Hu, M., Liu, S., Wehner, B., Bauer, S., Ma ßling, A., Wiedensohler, A., Petäjä, T., Dal Maso, M. and Kulmala, M.: New particle formation in Beijing, China: Statistical analysis of a 1-year data set, Journal of Geophysical Research, 112(D9), DOI: 10.1029/2006jd007406, 2007.

Chu, B., Kerminen, V.-M., Bianchi, F., Yan, C., Petäjä, T. and Kulmala, M.: Atmospheric new particle formation in China, Atmospheric Chemistry and Physics, 19(1): 115-138, DOI: 10.5194/acp-19-115-2019, 2019.

Kerminen, V.-M., Chen, X., Vakkari, V., Petäjä, T., Kulmala, M. and Bianchi, F.: Atmospheric new particle formation and growth: review of field observations, Environ. Res.Lett., 13(10), DOI: 10.1088/1748-9326/aadf3c, 2018.

Shang, D., Tang, L., Fang, X., Wang, L., Yang, S., Wu, Z., Chen, S., Li, X., Zeng, L., Guo, S. and Hu, M.: Variations in source contributions of particle number concentration under long-term emission control in winter of urban Beijing, Environ Pollut, 304: 119072, DOI: 10.1016/j.envpol.2022.119072, 2022.

Kulmala, M., Dada, L., Daellenbach, K. R., Yan, C., Stolzenburg, D., Kontkanen, J., Ezhova, E., Hakala, S., Tuovinen, S., Kokkonen, T. V., Kurppa, M., Cai, R., Zhou, Y., Yin, R., Baalbaki, R., Chan, T., Chu, B., Deng, C., Fu, Y., Ge, M., He, H., Heikkinen, L., Junninen, H., Liu, Y., Lu, Y., Nie, W., Rusanen, A., Vakkari, V., Wang, Y., Yang, G., Yao, L., Zheng, J., Kujansuu, J., Kangasluoma, J., Petaja, T., Paasonen, P., Jarvi, L., Worsnop, D., Ding, A., Liu, Y., Wang, L., Jiang, J., Bianchi, F. and Kerminen, V. M.: Is reducing new particle formation a plausible solution to mitigate particulate air pollution in Beijing and other Chinese megacities?, Faraday Discuss, 226: 334-347, DOI: 10.1039/d0fd00078g, 2021.

Shen, X., Sun, J., Ma, Q., Zhang, Y., Zhong, J., Yue, Y., Xia, C., Hu, X., Zhang, S. and Zhang, X.: Long-term trend of new particle formation events in the Yangtze River Delta, China and its influencing factors: 7-year dataset analysis, Science of the Total Environment: 150783, DOI: https://doi.org/10.1016/j.scitotenv.2021.150783, 2022.

5. The same applies to all other results in the paper. The authors do not acknowledge the work of previous colleagues who measured long-term aerosol mass composition in China. How do the results in Figure 8 compare to those studies? The same applies for the hygroscopicity analysis and the SOR/NOR results. Where do these results stand in comparison to other literature?

Reply: The chemical composition and hygroscopicity analysis was only conducted for the dust storm study from March 15-16, 2021, due to the limited dataset. In the previous studies in Beijing, it has been reported the NR-PM_1 derived from AMS could reach ~200 μg m^{-3} during polluted episode and decreased to several μg m^{-3} under clean conditions (Zhang et al., 2018). In this work, the PM_1 mass concentration ranged from approximately 5.0 μg m^{-3} during dust and post dust period and to 83.2 μg m^{-3} during a moderate polluted conditions before dust. During the dust and post dust period, organics was the dominant contributor to the chemical composition, which was consistent with the previous studies that organics could contributed 40-60% to PM_1 in Beijing (Zhang et al., 2018; 2019). However, the mass fraction of nitrate and ammonium increased during polluted condition before dust, which has been also reported a recent study in Beijing in January - February, 2021 (Zhang et al., 2023). The limited sample of chemical composition and hygroscopicity measurement could introduce uncertainties in the comparison between the results of this study with other previous work.

The hygroscopicity parameter (κ) of 50 nm ranged from 0.05 to 0.17, and 0.15-0.30 for 100 nm particles, which was consistent with the long-term study in Beijing as reported by Wang et al. (2018) and Zhang et al. (2023). Although the chemical composition of ultrafine particles can not be derived in this work, based on a recent study in Beijing, it has been revealed that organics dominated the mass concentration of particles below 100 nm, whereas the mass fraction of nitrate increased depending on the size (Li et al., 2023).

The SOR and NOR results have been compared with the previous studies in Beijing. It has been reported that the SOR was 0.18 in clean air conditions, whereas it was 0.27 under polluted conditions in Beijing in 2016 wintertime, indicating that SO2 secondary transformation was a major pathway of sulfate production with a higher conversion efficiency under the polluted episode, whereas NOR was approximately 0.08, under both clean and polluted conditions (Wu et al., 2019).

The discussion of chemical composition and hygroscopicity have been supplemented in the manuscript.

Li, X., Chen, Y., Li, Y., Cai, R., Li, Y., Deng, C., Yan, C., Cheng, H., Liu, Y., Kulmala, M., Hao, J., Smith, J. N. and Jiang, J.: Seasonal variations in composition and sources of atmospheric ultrafine particles in urban Beijing based on near-continuous measurements, Atmos. Chem. Phys. Diss., DOI: 10.5194/egusphere-2023-809, 2023.

Wang, Y., Wu, Z., Ma, N., Wu, Y., Zeng, L., Zhao, C. and Wiedensohler, A.: Statistical analysis and parameterization of the hygroscopic growth of the sub-micrometer urban background aerosol in Beijing, Atmospheric Environment, 175: 184-191, DOI: 10.1016/j.atmosenv.2017.12.003, 2018.

Zhang, Y., Wang, Y., Zhang, X., Shen, X., Sun, J., Wu, L., Zhang, Z. and Che, H.: Chemical Components, Variation, and Source Identification of PM1 during the Heavy Air Pollution Episodes in Beijing in December 2016, Journal of Meteorological Research, 32(1): 1-13, DOI: 10.1007/s13351-018-7051-8, 2018.

Zhang, Y., Vu, T. V., Sun, J., He, J., Shen, X., Lin, W., Zhang, X., Zhong, J., Gao, W., Wang, Y., Fu, T. M., Ma, Y., Li, W. and Shi, Z.: Significant Changes in Chemistry of Fine Particles in Wintertime Beijing from 2007 to 2017: Impact of Clean Air Actions, Environ Sci Technol, 54(3): 1344-1352, DOI: 10.1021/acs.est.9b04678, 2019.

Zhang, Y., Tian, J., Wang, Q., Qi, L., Manousakas, M. I., Han, Y., Ran, W., Sun, Y., Liu, H., Zhang, R., Wu, Y., Cui, T., Daellenbach, K. R., Slowik, J. G., Prévôt, A. S. H. and Cao, J.: High-time-resolution chemical composition and source apportionment of $PM_{2.5}$ in northern Chinese cities: implications for policy, Atmos. Chem. Phys. Diss., DOI: 10.5194/egusphere-2023-457, 2023.

Zhang, S., Shen, X., Sun, J., Che, H., Zhang, Y., Liu, Q., Xia, C., Hu, X., Zhong, J., Wang, J., Liu, S., Lu, J., Yu, A. and Zhang, X.: Seasonal variation of particle hygroscopicity and its impact on cloud-condensation nucleus activation in the Beijing urban area, Atmospheric Environment, 302, DOI: 10.1016/j.atmosenv.2023.119728, 2023.

6. Figure 4 is not readable, the dust and other NPF N_{25} line colors are the very similar. The comparison to other locations, intercomparison between dust event types could be added.

Reply: We have removed figure 4 and 5 in the manuscript and supplemented a modified figure describing the mean diurnal variation of number concentration of particles in the size range of 3-25 nm (N_{3-25}) and geometric mean diameter ($D_{p,g}$) of NPF events occurred under clean, polluted conditions and influenced by blowing dust (BD), floating dust (FD) and dust storm (DS), respectively. N_{3-25} showed similar diurnal pattern, which peaked around noon time governed by NPF event. The lower N_{3-25} was found on DS-related NPF event, with lower $D_{p,g}$ at the initial growth stage below 20 nm, indicating less precursors participating nucleation and growth processes. It should be also addressed that only one DS-related NPF event occurred (March 16, 2021) in this study, which could not represent overall characteristics of NPF events influenced by dust storm. $D_{p,g}$ on the dust-related NPF events (including BD, FD and DS type) in Fig. 5b was generally lower than that on the clean and polluted NPF events with nucleated particles below 20 nm. A quick growth of nucleated particles at round 19-20 LT was probably associated with the wind direction change as given in the supplementary materials (Fig. S9). The previous studies in Beijing have revealed that the southerly air masses containing plentiful anthropogenic precursors, facilitating the nucleation and growth processes of NPF events (Wang et al., 2013; Shen et al., 2018). It was also found polluted-NPF events usually started later, at around 10 LT, with N_{3-25} quickly peaked at around 12 LT, indicating a shorter nucleation process with higher formation rate as shown above.

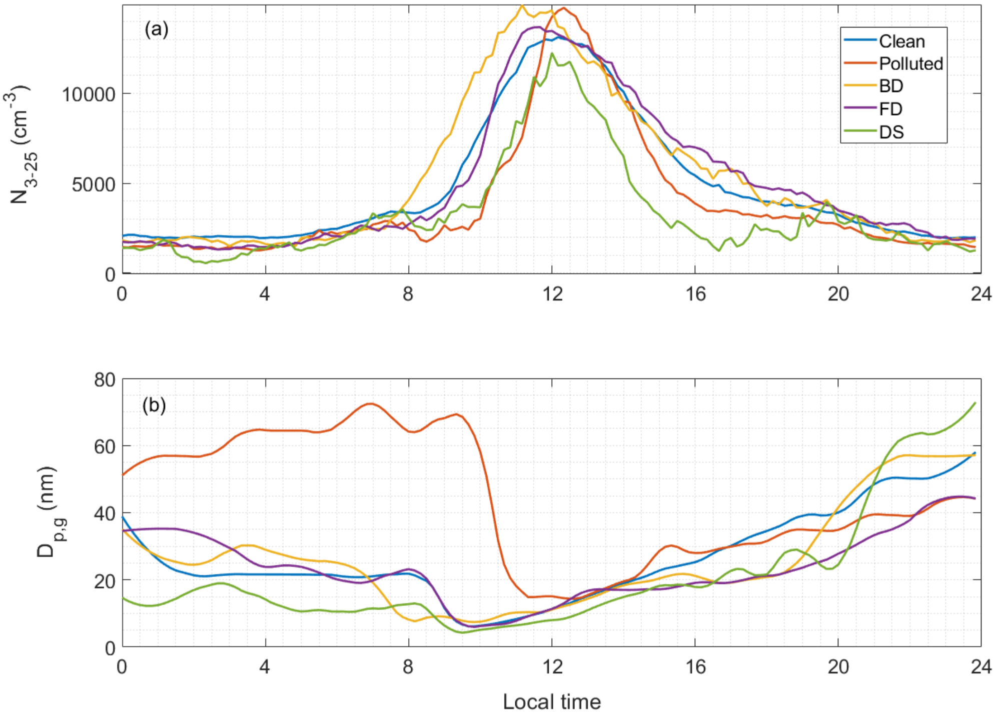

Fig. S6. the mean diurnal variation of number concentration of particles in the size range of 3-25 nm (N_{3-25}) (a) and geometric mean diameter ($D_{p,g}$) (b) of NPF events occurred under clean, polluted conditions and influenced by blowing dust (BD), floating dust (FD) and dust storm (DS), respectively.

7. There are several claims that remain in the text, not justified by the observation nor backed-up by previous literature. I give some examples here, but the entire manuscript benefits from being revised:

Reply: We have revised the discussions with not robust confidence as the reviewer mentioned below and also checked through all the manuscript.

i) 'The variation in NO_2 sharply increased in the early morning (5:00–6:00 LT) on March 15, which could be attributed to the downward mixing of NO_2 rich air in the residual layer where NO_2 was trapped during the pollution episode on March 14.' Do the authors have proof of this? Neither a citation of a previous similar observation, nor a discussion is added.

Reply: We looked into the time series of wind distribution depending on air pressure level (800-1000 hpa) on March 14th and 15th based on the reanalysis meteorological data (https://cds.climate.copernicus.eu/). The wind (u- and v-component) data for the Beijing region (latitude:39-42°N, longitude: 115-117°E) was averaged and given in Fig. S1. Before March 15, the air pollutants accumulated in Beijing, with stable upward wind. The wind changed on 3:00 LT March 15, with the wind direction from upward to downward. Although quite small wind below 900 hpa (corresponding to below ~1000 m geopotential height) near ground surface was observed before 06:00 on March 15, the wind direction switched to downward at around 3:00 LT and could bring the pollutants to the ground, resulting in the elevated NO_2 and condensation sink as given in Fig. 8 in the manuscript. The air pollutants decreased sharply after 6:00 LT as the wind speed increased. We have revised the discussion in the manuscript and the figure was added in the supplementary materials.

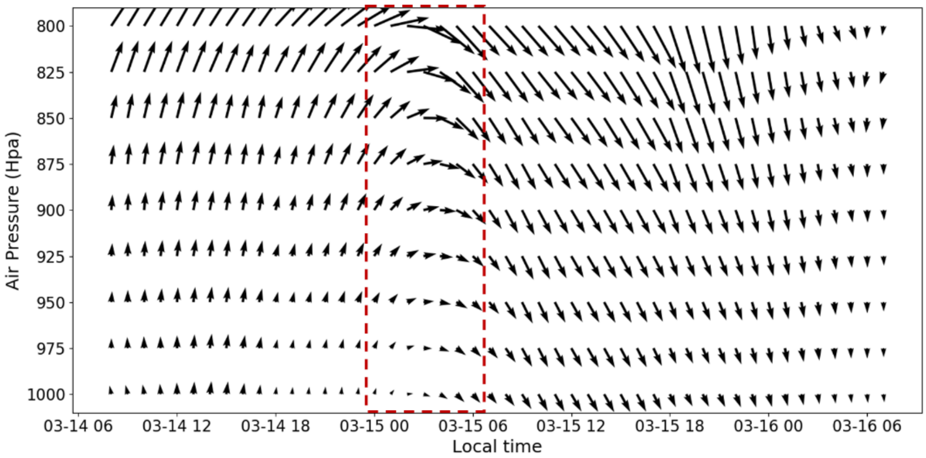

Fig. S7. Time series of wind variation depending on the air pressure level from March 14 to 15, the arrows represent the wind direction and the length of the arrow indicates the wind speed (m/s)

ii) 'The concentration of SO_2 remained stable before 6:00 LT, probably because its distribution was uniform in the boundary layer', same as the previous sentence.

Reply: As illustrated above, the wind field remained stable before 3:00 on March 15 when the air pollutants accumulated. The wind direction switched from upward to downward since 3:00 LT and the wind speed increased significantly since 6:00 LT. The mixing ratio of SO_2 remained stable decreased sharply until 6:00 LT due to the strong wind, indicating the vertical distribution of SO_2 was uniform in the boundary layer.

iii) 'The concentration of O_3 increased during dust storms, probably because the O_3 budget was influenced by mineral dust.' Can the authors prove this based on observations or previous literature?

Reply: It has been revised to "The volume mixing ratio of NO_2 decreased, while that of O_3 increased, indicating that the removal of NO_2 was helpful for the elevated O_3 concentration, as NO_x-titration photochemistry process could influence the production and loss of O_3 (Lu et al., 2010). It has been also reported by the previous study in

Beijing-Tianjin-Hebei region, the decrease in NO_x increased ozone and enhanced the atmospheric oxidizing capacity (Huang et al., 2020).”

Huang, X., Ding, A., Gao, J., B. Zheng, D. Zhou, X. Qi, R. Tang, J. Wang, C. Ren, W. Nie, X. Chi, Z. Xu, L. Chen, Y. Li, F. Che, N. Pang, H. Wang, D. Tong, W. Qin, W. Cheng, W. Liu, Q. Fu, B. Liu, F. Chai, S.J. Davis, Q. Zhang and K. He. Enhanced secondary pollution offset reduction of primary emissions during COVID-19 lockdown in China, National Sci Rev, nwaa137, 2020.

Lu, K., Zhang, Y., Su, H., Brauers, T., Chou, C. C., Hofzumahaus, A., Liu, S. C., Kita, K., Kondo, Y., Shao, M., Wahner, A., Wang, J., Wang, X. and Zhu, T.: Oxidant (O3 +NO2) production processes and formation regimes in Beijing, J. Geophys. Res., 115: D07303, DOI: 10.1029/2009JD012714, 2010.