Supplementary Information for
Size-Resolved Atmospheric Ice Nucleating Particles during East Asian Dust Events

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**Table S1.** The criteria used to distinguish between dust and non-dust events for 14 sets of samples.

The two weather conditions, i.e., dust and non-dust events, were defined based on PM$_{10}$ mass concentration (PM$_{10}$ Mass Conc.), the volume concentration of coarse mode particles (Vol. Conc.), phenomenological dust storm observations operated by China Meteorological Administration (Observations by CMA), and the concentration of aluminium (Al).

| Sample ID | PM$_{10}$ Mass Conc. | Vol. Conc. | Observations by CMA | Concentration of Al element ($\mu g m^{-3}$) | Weather condition |
|-----------|----------------------|------------|---------------------|---------------------------------------------|------------------|
| M1        | True                 | True       | True                | 5.65                                        | Dust             |
| M2        | True                 | True       | True                | 1.68                                        | Dust             |
| M3        | True                 | True       | True                | 0.72                                        | Dust             |
| M4        | True                 | False      | False               | 0.04                                        | Non-dust         |
| M5        | True                 | False      | True                | 0.12                                        | Dust             |
| M6        | True                 | True       | True                | 1.45                                        | Dust             |
| M7        | True                 | True       | True                | 1.07                                        | Dust             |
| M8        | True                 | True       | True                | 1.01                                        | Dust             |
| D2        | True                 | True       | True                | 0.14                                        | Dust             |
| D3        | True                 | True       | True                | 0.77                                        | Dust             |
| D4        | True                 | True       | True                | 0.39                                        | Dust             |
| D5        | True                 | True       | True                | 0.59                                        | Dust             |
| D6        | True                 | False      | True                | 0.13                                        | Dust             |
| D7        | True                 | False      | True                | 0.17                                        | Dust             |

Note: The weather condition of each sample was defined by a combination of the above four factors.

1 PM$_{10}$ mass concentration: ‘True’ is defined as PM$_{10}$ mass concentration larger than 200 $\mu g m^{-3}$ for more than 2 hours.

2 The volume concentration of the coarse mode particles (> 1 $\mu m$): ‘True’ is defined for mean concentration higher than 75 $\mu m^3 cm^{-3}$. The threshold was developed based on the measurements of 2004-2006 in Beijing. Asian dust loading has declined in recent years. Thus, this threshold is not mandatory.

3 Phenomenological dust storm observations: China Meteorological Administration (CMA) provides predictions and observations on dust storm events that occurred in China. The dust events in Beijing identified in this study have been reported as the largescale dust storm events.

4 Aluminium (Al) is usually selected to be an indicator of mineral dust because it is one of the most abundant constant elements in deserts. Thus, the concentration of Al is considered as an important factor to define dust events.

5 Sample M4 was collected from the end of a continuous dust storm (M1, M2, and M3), i.e., during the removal process after a dust storm. High wind speeds can blow up large particles from the roads and other surfaces in the city. In addition, the air...
mass of M4 passed through the Bohai Sea before arriving in Beijing (Fig. S1), possibly bringing large marine particles. Although the average concentration of PM$_{10}$ for sample M4 was higher than those of samples M5 and D6, the concentration of Al in sample M4 was much lower compared to sample M5 and D6. Therefore, we classify sample M4 as a non-dust event, since it’s not dominated by mineral dust.
Table S2. The INP concentrations for 8 particle sizes at different temperatures. Three criteria (average concentration (Average), standard deviation (STD), and valid sample number (Sample Num)) based on 13 dust dominated samples are presented for each particle size. Large size particles start and complete freezing at warmer temperatures than small particles. At a given temperature, not all 13 samples may begin to freeze, while some samples may be completely frozen. Therefore, the valid sample number for the 8 particle sizes presented here at various temperatures is less than or equal to 13.

| Particle size (µm) | Type | Temperature (℃) & INP concentrations (L⁻¹) |   |   |   |   |   |
|-------------------|------|-------------------------------------------|---|---|---|---|---|
|                   |      | -8            | -10       | -13     | -15     | -18     | -20     | -23     |
| 10.0              |      | Average       | 0.055     | 0.150   | 0.481   | 0.786   | 2.244   | 3.904   | 7.577   |
|                   | STD  | 0.066         | 0.198     | 0.627   | 0.890   | 1.673   | 2.297   | 4.527   |
|                   |      | Sample Num    | 9         | 11      | 11      | 11      | 11      | 8       | 3       |
| 5.6               |      | Average       | 0.117     | 0.247   | 0.615   | 1.030   | 2.395   | 3.913   | 4.542   |
|                   | STD  | 0.212         | 0.437     | 1.004   | 1.553   | 1.987   | 2.943   | 3.621   |
|                   |      | Sample Num    | 9         | 13      | 13      | 13      | 12      | 9       | 3       |
| 3.2               |      | Average       | 0.064     | 0.184   | 0.552   | 0.993   | 2.830   | 4.228   | 8.722   |
|                   | STD  | 0.117         | 0.211     | 0.537   | 1.031   | 2.300   | 2.916   | /       |
|                   |      | Sample Num    | 11        | 12      | 13      | 13      | 13      | 9       | 1       |
| 1.8               |      | Average       | 0.042     | 0.119   | 0.329   | 0.618   | 2.059   | 3.289   | 4.121   |
|                   | STD  | 0.064         | 0.147     | 0.340   | 0.540   | 1.714   | 2.518   | 3.373   |
|                   |      | Sample Num    | 9         | 12      | 12      | 12      | 13      | 10      | 5       |
| 1.0               |      | Average       | 0.028     | 0.065   | 0.156   | 0.289   | 1.005   | 2.610   | 4.017   |
|                   | STD  | 0.025         | 0.053     | 0.145   | 0.272   | 0.867   | 2.206   | 3.388   |
|                   |      | Sample Num    | 6         | 10      | 12      | 12      | 13      | 12      | 5       |
| 0.56              |      | Average       | 0.012     | 0.025   | 0.048   | 0.096   | 0.429   | 1.574   | 3.686   |
|                   | STD  | 0.004         | 0.016     | 0.036   | 0.076   | 0.297   | 1.092   | 3.768   |
|                   |      | Sample Num    | 2         | 10      | 13      | 13      | 13      | 12      | 5       |
| 0.32              |      | Average       | 0.010     | 0.021   | 0.040   | 0.059   | 0.275   | 1.143   | 1.481   |
|                   | STD  | 0.006         | 0.018     | 0.045   | 0.066   | 0.359   | 1.821   | 0.920   |
|                   |      | Sample Num    | 2         | 4       | 10      | 11      | 13      | 12      | 5       |
| 0.18              |      | Average       | 0.010     | 0.009   | 0.016   | 0.022   | 0.081   | 0.226   | 0.286   |
|                   | STD  | 0.006         | 0.005     | 0.014   | 0.028   | 0.090   | 0.280   | 0.125   |
|                   |      | Sample Num    | 2         | 3       | 7       | 9       | 11      | 10      | 4       |
Table S3. The average percentage of heat-resistant and heat-sensitive INPs of the overall INP populations ($D_{50} \geq 1.0 \, \mu m$) at three different temperatures.

| Type             | Temperature (°C) & Average concentration proportion |
|------------------|-----------------------------------------------------|
|                  | -10°C | -15°C | -20°C |
| Heat-sensitive INPs | 81 ± 12% | 70 ± 15% | 38 ± 21% |
| Heat- resistant INPs | 19 ± 12% | 30 ± 15% | 62 ± 21% |

Table S4. The average percentage of heat-resistant and heat-sensitive INPs of the size-resolved INPs ($D_{50} = 10.0, 5.6, 3.2, 1.8$ and $1.0 \, \mu m$) at different temperatures. The valid sample number (Sample Num) presented in the table is less than or equal to 12 because the results are based on 12 samples.

| Temperature (°C) | Type            | Particle size (μm) & Concentration proportion |
|------------------|-----------------|---------------------------------------------|
|                  |                 | 10.0 | 5.6 | 3.2 | 1.8 | 1.0 |
| -10              | Heat-sensitive INPs | 80% | 78% | 82% | 89% | 84% |
|                  | Heat- resistant INPs | 20% | 22% | 18% | 11% | 16% |
|                  | Sample Num      | 10  | 12  | 11  | 11  | 9  |
| -15              | Heat-sensitive INPs | 75% | 64% | 71% | 75% | 70% |
|                  | Heat- resistant INPs | 25% | 36% | 29% | 25% | 30% |
|                  | Sample Num      | 10  | 12  | 12  | 11  | 11  |
| -20              | Heat-sensitive INPs | 33% | 27% | 34% | 35% | 66% |
|                  | Heat- resistant INPs | 67% | 73% | 66% | 65% | 34% |
|                  | Sample Num      | 10  | 12  | 12  | 12  | 12  |
Figure S1. Back trajectory of the air mass for sample M4 (solid blue lines), which went through the Bohai Sea before arriving in Beijing.

Figure S2. Surface area distributions of the northwest (M6, M7, M8, D7) and north (M3, M5, D6) transport pathways averaged over the respective sampling periods. $D_p$ is the aerodynamic diameter of the particles. The surface area spectrum of the sample D7 is partially missing, and is not shown here.
Figure S3. Comparison of nucleation activity of northwest and north samples after heat treatment. Northwest and north samples are named “Heated”, and marked as solid light red and light blue circles, respectively.