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.[1]	Vol. Conc.[2]	Observations by CMA [3]	Concentration of Al element ($\mu g\ m^{-3}$) [4]	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 [5]
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	False	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 μm): '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 μm) at three different temperatures.

Type	Temperature (℃) & Average concentration proportion		
	-10℃	-15℃	-20℃
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 ($D_{50} = 10.0, 5.6, 3.2, 1.8\ and\ 1.0$ μm) 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 (℃)	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

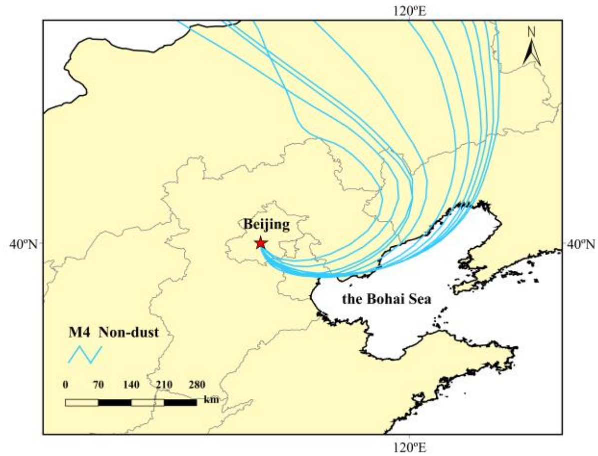

Figure S1. Back trajectory of the air mass for sample M4 (solid blue lines), which went through the Bohai Sea before arriving in Beijing.

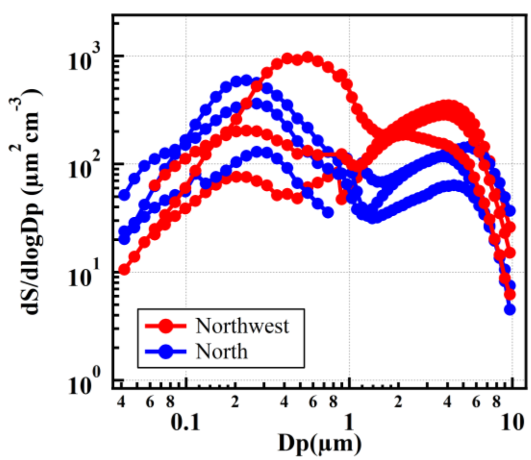

Figure S2. Surface area distributions of the northwest (M6, M7, M8, D7) and north (M3, M5, D6) transport pathways averaged over the respective sampling periods. D_p is the aerodynamic diameter of the particles. The surface area spectrum of the sample D7 is partially missing, and is not shown here.

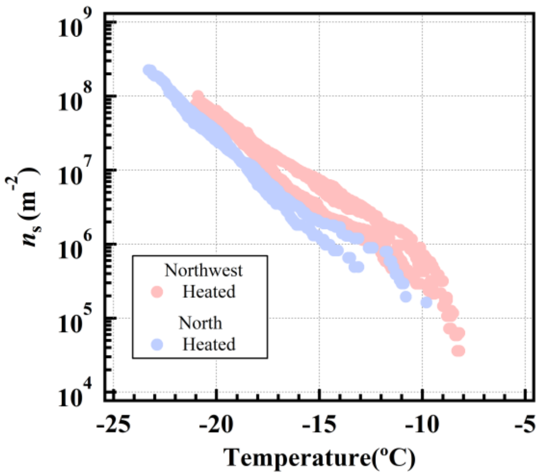

Figure S3. Comparison of nucleation activity of northwest and north samples after heat treatment. Northwest and north samples are named "Heated", and marked as solid light red and light blue circles, respectively.