

Electronic Supplementary Material to: Fluorescence Properties and Chemical Composition of Fine Particles in the Background Atmosphere of North China*

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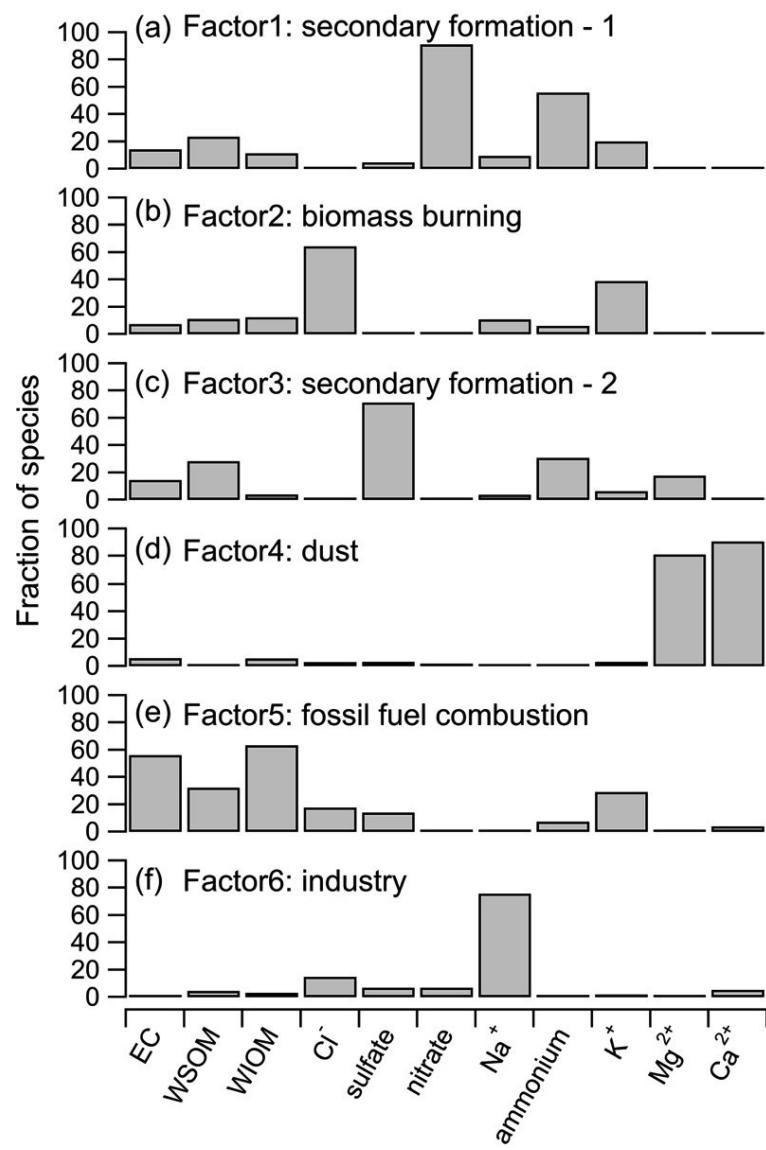


Fig. S1. Factor profile for the six-factor solution of the PMF analysis.

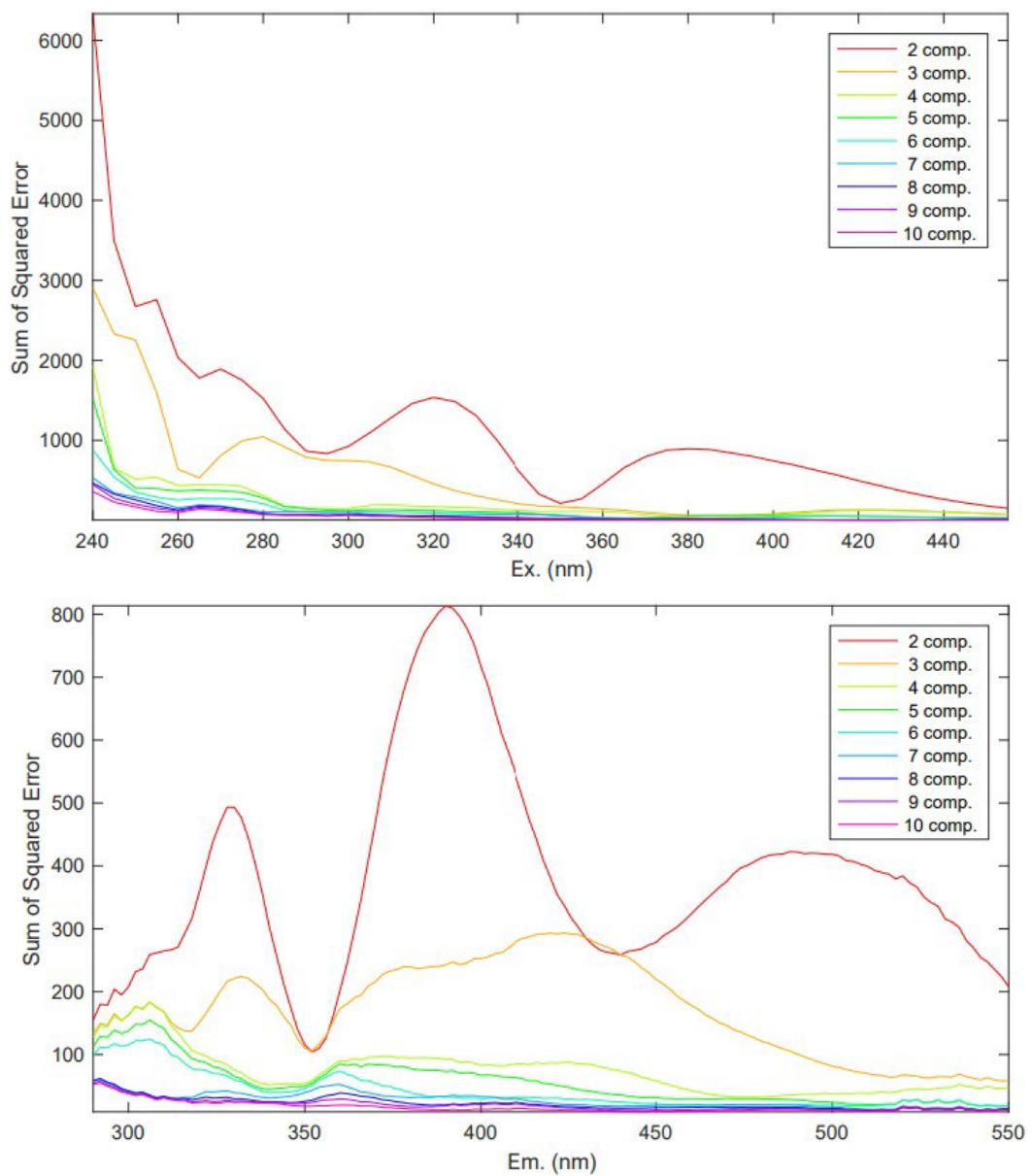


Fig. S2. Residual analysis of two- to ten-component PARAFAC models.

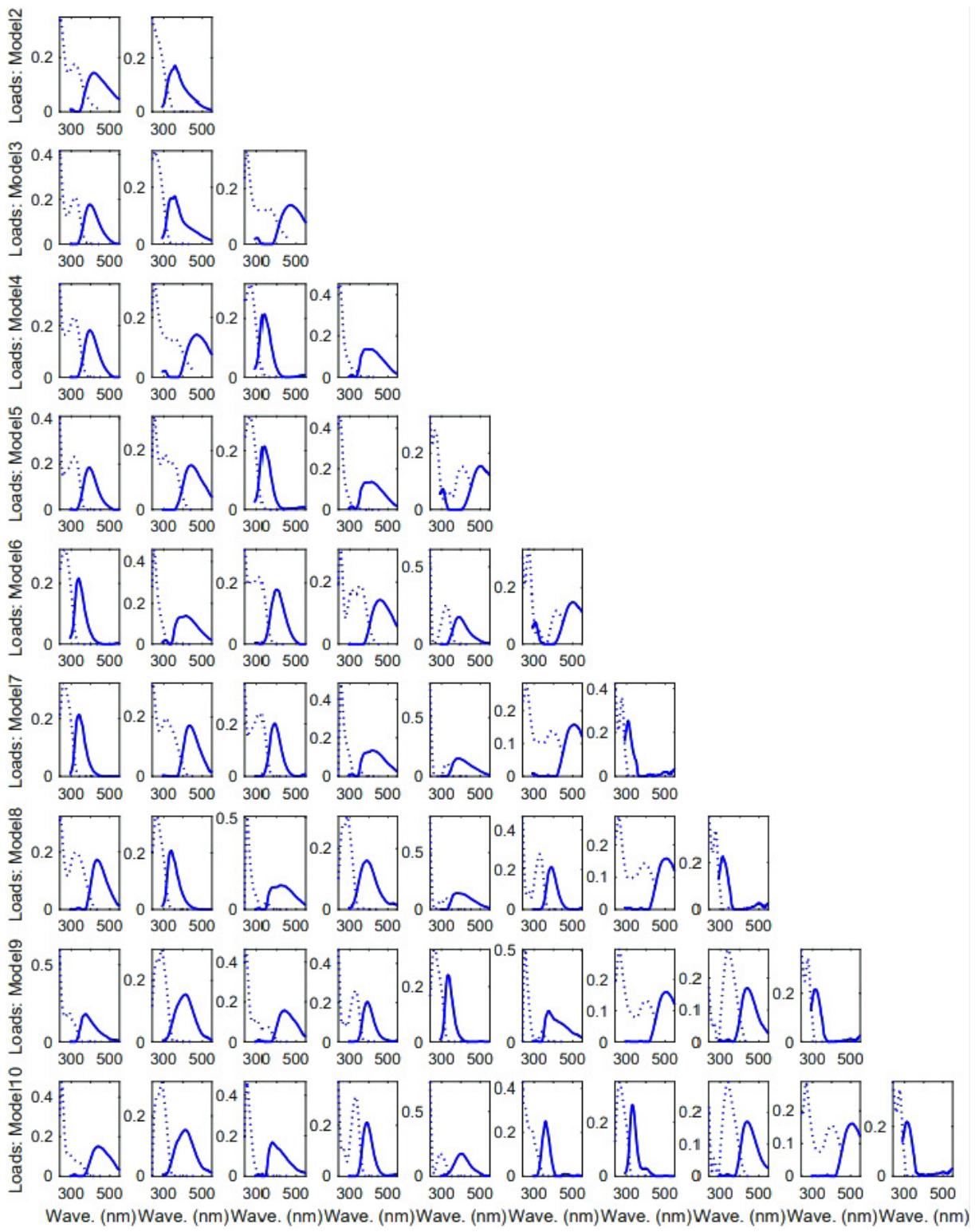


Fig. S3. Spectra comparison of two- to ten-component PARAFAC models.

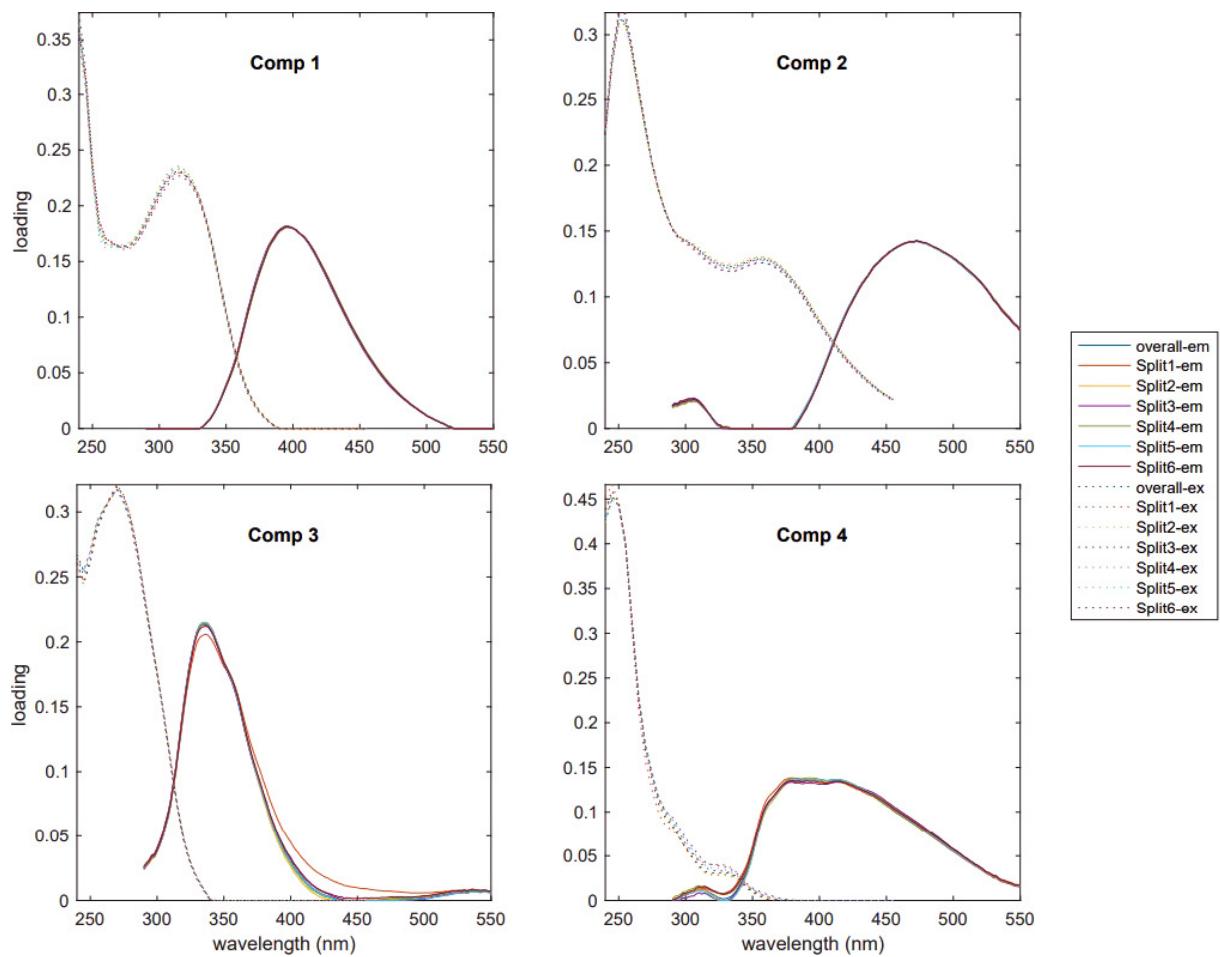


Fig. S4. Split half analysis of four-component PARAFAC model with the split style of “S4C6T3”.

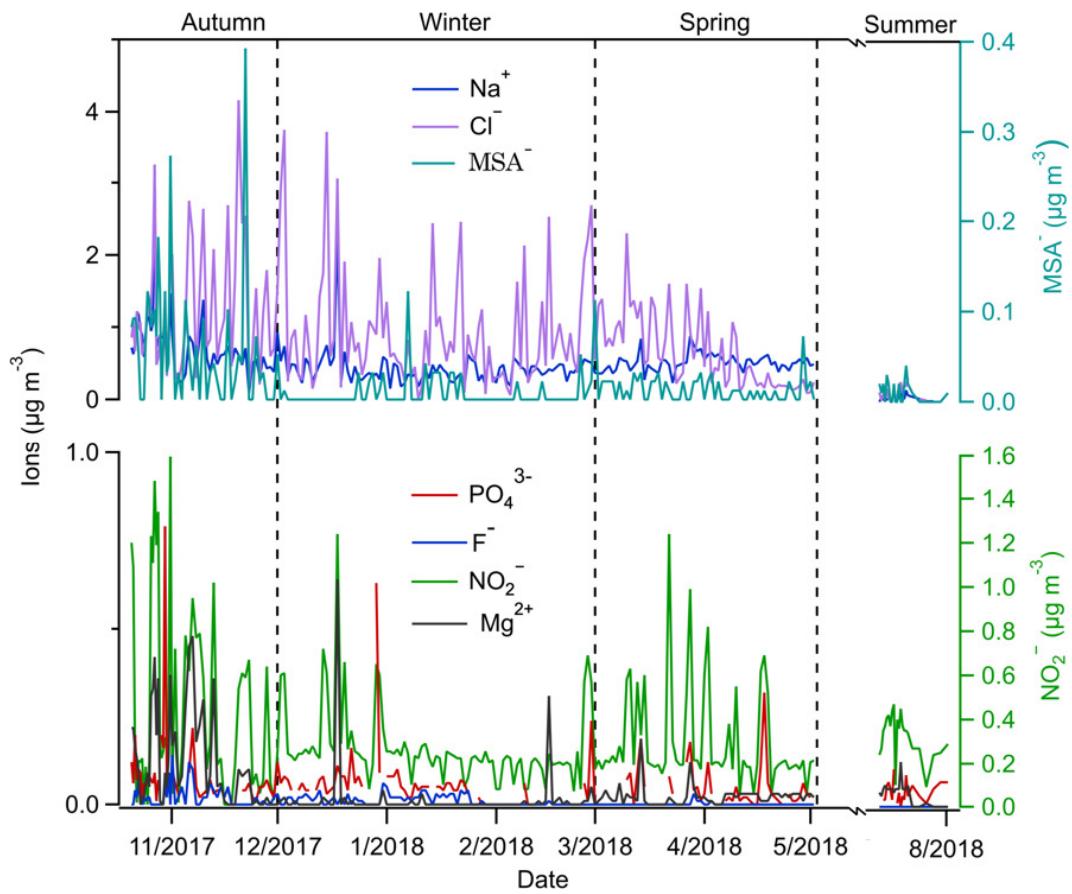


Fig. S5. Time series of the concentrations of the minor ions in PM_{2.5} at the SDZ site.

Table S1. Correlations between the measured and modeled concentrations of the species in the positive matrix factorization analysis.

Species	R ²	Slope
EC	0.98	0.98
WSOM	0.95	0.98
WIOM	0.94	0.97
Cl ⁻	0.96	1.0
SO ₄ ²⁻	0.98	0.96
NO ₃ ³⁻	0.98	0.98
Na ⁺	1.0	0.99
NH ₄ ⁺	0.97	0.95
K ⁺	0.61	0.59
Mg ²⁺	0.87	0.87
Ca ²⁺	0.90	0.85

Table S2. Seasonal variations of the fluorescence intensities of water-soluble organic matter (WSOM) in PM_{2.5} at SDZ.

Contents	Fluorescent components (10 ⁻⁵ RU L m ⁻³)									
	Autumn (n= 54)		Winter (n= 89)		Spring (n= 62)		Summer (n= 23)		Annual (n = 228)	
	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
HULIS-1	0.73–24	8.0 ± 5.6	1.7–30	7.3± 5.1	0.58–16	5.4 ± 3.9	0.14–5.1	2.1 ± 1.2	0.14–30	6.4 ± 5.0
HULIS-2	0.94–69	15 ± 13	2.6–63	21± 14	1.1–31	11 ± 7.1	0.23–6.4	3.3± 1.6	0.23–69	15 ± 13
HULIS-3	0.56–89	10 ± 14	3.5–46	21± 11	0.55–17	5.0 ± 3.9	0.0–0.80	0.21 ± 0.23	0.0–89	12 ± 13
PLOM	0.68–117	14± 18	3.5–64	25± 15	0.66–15	5.5± 3.6	0.06–1.9	1.1 ± 0.49	0.06–117	15 ± 16

Table S3. Correlation coefficients (r) among the chemical compositions, the fluorescent components, and the fluorescent indices in PM_{2.5} at the Shangdianzi (SDZ) site in (a) autumn, (b) winter, (c) spring, and (d) summer.

(a) autumn

	OC	EC	WSOC	Cl ⁻	SO ₄ ²⁻	NO ₃ ⁻	NH ₄ ⁺	K ⁺	HULIS-1	HULIS-2	HULIS-3	PLOM	HIX	FI	BIX
OC	1.0														
EC	0.96	1.0													
WSOC	0.96	0.89	1.0												
Cl ⁻	0.67	0.60	0.64	1.0											
SO ₄ ²⁻	0.63	0.52	0.76	0.29	1.0										
NO ₃ ⁻	0.76	0.67	0.87	0.40	0.91	1.0									
NH ₄ ⁺	0.74	0.63	0.86	0.40	0.95	0.99	1.0								
K ⁺	0.84	0.78	0.80	0.77	0.48	0.57	0.54	1.0							
HULIS-1	0.91	0.88	0.87	0.68	0.45	0.58	0.57	0.77	1.0						
HULIS-2	0.70	0.71	0.63	0.62	0.18	0.26	0.28	0.64	0.87	1.0					
HULIS-3	0.36	0.46	0.24	0.33	-0.13	-0.11	-0.09	0.32	0.55	0.84	1.0				
PLOM	0.36	0.45	0.24	0.28	-0.10	-0.09	-0.06	0.29	0.53	0.83	0.99	1.0			
HIX	0.32	0.25	0.40	0.02	0.53	0.51	0.50	0.27	0.26	-0.03	-0.37	-0.37	1.0		
FI	-0.13	-0.05	-0.13	-0.28	-0.11	-0.17	-0.16	-0.27	0.12	0.21	0.30	0.30	0.09	1.0	
BIX	-0.27	-0.14	-0.30	-0.21	-0.42	-0.44	-0.43	-0.30	0.02	0.26	0.45	0.44	-0.34	0.86	1.0

Notes: t -test is $p \leq 0.0001$ for the correction where $r \geq 0.50$.

(b) winter

	OC	EC	WSOC	Cl ⁻	SO ₄ ²⁻	NO ₃ ⁻	NH ₄ ⁺	K ⁺	HULIS-1	HULIS-2	HULIS-3	PLOM	HIX	FI	BIX
OC	1.0														
EC	0.94	1.0													
WSOC	0.92	0.79	1.0												
Cl ⁻	0.80	0.74	0.80	1.0											
SO ₄ ²⁻	0.65	0.53	0.86	0.59	1.0										
NO ₃ ⁻	0.84	0.69	0.96	0.71	0.86	1.0									
NH ₄ ⁺	0.82	0.68	0.97	0.71	0.92	0.98	1.0								
K ⁺	0.47	0.46	0.53	0.66	0.49	0.50	0.49	1.0							
HULIS-1	0.96	0.85	0.95	0.81	0.71	0.89	0.88	0.48	1.0						
HULIS-2	0.96	0.93	0.89	0.73	0.66	0.81	0.80	0.42	0.93	1.0					
HULIS-3	0.65	0.76	0.44	0.42	0.24	0.33	0.32	0.18	0.55	0.75	1.0				
PLOM	0.52	0.67	0.29	0.30	0.10	0.17	0.15	0.11	0.41	0.63	0.96	1.0			
HIX	0.34	0.13	0.54	0.38	0.53	0.58	0.60	0.30	0.46	0.22	-0.34	-0.51	1.0		
FI	-0.32	-0.17	-0.48	-0.37	-0.42	-0.53	-0.52	-0.28	-0.44	-0.18	0.33	0.50	-0.91	1.0	
BIX	-0.36	-0.20	-0.52	-0.42	-0.46	-0.54	-0.55	-0.34	-0.46	-0.22	0.31	0.47	-0.94	0.95	1.0

Notes: t -test is $p \leq 0.0001$ for the correction where $r \geq 0.50$.

(c) spring

	OC	EC	WSOC	Cl ⁻	SO ₄ ²⁻	NO ₃ ⁻	NH ₄ ⁺	K ⁺	HULIS-1	HULIS-2	HULIS-3	PLOM	HIX	FI	BIX
OC	1.0														
EC	0.97	1.0													
WSOC	0.98	0.96	1.0												
Cl ⁻	0.57	0.47	0.49	1.0											
SO ₄ ²⁻	0.88	0.89	0.93	0.33	1.0										
NO ₃ ⁻	0.94	0.93	0.96	0.52	0.91	1.0									
NH ₄ ⁺	0.87	0.85	0.91	0.48	0.87	0.94	1.0								
K ⁺	0.88	0.87	0.84	0.66	0.75	0.82	0.74	1.0							
HULIS-1	0.95	0.87	0.92	0.72	0.77	0.89	0.82	0.87	1.0						
HULIS-2	0.83	0.72	0.78	0.81	0.61	0.77	0.70	0.75	0.93	1.0					
HULIS-3	0.36	0.23	0.28	0.76	0.11	0.24	0.21	0.43	0.57	0.74	1.0				
PLOM	0.50	0.39	0.42	0.83	0.25	0.39	0.33	0.57	0.68	0.82	0.96	1.0			
HIX	0.62	0.66	0.68	-0.01	0.68	0.66	0.63	0.44	0.50	0.28	-0.30	-0.21	1.0		
FI	-0.43	-0.40	-0.47	-0.03	-0.43	-0.42	-0.38	-0.35	-0.40	-0.18	0.17	0.14	-0.73	1.0	
BIX	-0.45	-0.46	-0.50	0.11	-0.51	-0.44	-0.42	-0.30	-0.34	-0.08	0.34	0.28	-0.85	0.83	1.0

Notes: t -test is $p \leq 0.0001$ for the correction where $r \geq 0.50$.

(d) summer

	OC	EC	WSOC	Cl ⁻	SO ₄ ²⁻	NO ₃ ⁻	NH ₄ ⁺	K ⁺	HULIS-1	HULIS-2	HULIS-3	PLOM	HIX	FI	BIX	
OC	1.0															
EC	0.76	1.0														
WSOC	0.97	0.72	1.0													
Cl ⁻	0.68	0.56	0.64	1.0												
SO ₄ ²⁻	0.64	0.75	0.71	0.22	1.0											
NO ₃ ⁻	0.77	0.64	0.76	0.92	0.31	1.0										
NH ₄ ⁺	0.85	0.83	0.91	0.58	0.89	0.71	1.0									
K ⁺	0.72	0.77	0.78	0.38	0.93	0.47	0.92	1.0								
HULIS-1	0.94	0.70	0.98	0.69	0.65	0.83	0.90	0.73	1.0							
HULIS-2	0.95	0.64	0.94	0.68	0.52	0.80	0.79	0.59	0.96	1.0						
HULIS-3	-0.18	-0.08	-0.18	-0.06	-0.16	-0.05	-0.14	-0.06	-0.10	-0.15	1.0					
PLOM	0.72	0.45	0.74	0.60	0.24	0.74	0.56	0.30	0.81	0.85	0.16	1.0				
HIX	-0.03	-0.06	-0.03	-0.01	0.16	-0.02	0.11	0.19	-0.04	-0.16	-0.35	-0.47	1.0			
FI	-0.20	-0.26	-0.32	-0.19	-0.40	-0.30	-0.45	-0.43	-0.35	-0.18	0.15	-0.18	-0.41	1.0		
BIX	-0.60	-0.73	-0.66	-0.29	-0.89	-0.40	-0.84	-0.89	-0.60	-0.43	0.23	-0.15	-0.32	0.45	1.0	

Notes: the *t*-test is $p \leq 0.0001$ for the correction where $r \geq 0.71$. *t*-test is $0.0001 < p \leq 0.01$ for the correction where r is ≥ 0.50 to 0.72 .

Table S4. Average concentrations of chemical compositions in atmospheric aerosols at different global background stations and regional background stations, including (a) OC and EC and (b) major water-soluble inorganic ions.

(a) OC and EC

Location	Size	Season	Period	Concentrations ($\mu\text{g m}^{-3}$)		References
				OC	EC	
Global Background Stations						
Mt. Cimone	PM ₁₀	summer	2004	1.5	0.17	(Carbone et al., 2014)
Mt. Cimone	PM ₁	winter	2009–2011	0.61	0.068	(Carbone et al., 2014)
Mt. Cimone	PM ₁	spring	2009–2011	0.56	0.41	(Carbone et al., 2014)
Mt. Cimone	PM ₁	summer	2009–2011	1.9	0.31	(Carbone et al., 2014)
Mt. Cimone	PM ₁	autumn	2009–2011	0.61	0.10	(Carbone et al., 2014)
Regional Background Stations						
Akdale	PM ₁₀	annual	Jul. 2004–Mar. 2005	2.9	0.35	(Qu et al., 2009)
Akdale	TSP	summer-autumn	Jul.–Sep. 2004	4.4	0.38	(Qu et al., 2008)
Lin' an	TSP	summer	Aug. 2002	30	6.2	(Yang et al., 2006)
Lin' an	TSP	summer	Jul. 2003	14	2.5	(Yang et al., 2006)
Lin' an	PM _{2.5}	summer	Jun.–Aug. 2015	14	3.3	(Liang et al., 2018)
Lin' an	PM _{2.5}	winter	Jan. 2015	24	6.6	(Shi et al., 2017)
SDZ	TSP	summer	Jul. 2004	7.6	1.9	(Yan et al., 2012a)
SDZ	TSP	autumn	Sep. 2004	21	3.9	(Yan et al., 2012a)
SDZ	PM ₁₁	summer	Jul. 2004	6.8	1.7	(Yan et al., 2012a)
SDZ	PM _{2.5}	spring	Apr.–May 2009	9.7	3.8	(Zhao et al., 2013)
SDZ	PM _{2.5}	summer	Jul.–Aug. 2009	5.7	3.3	(Zhao et al., 2013)
SDZ	PM _{2.5}	autumn	Oct.–Nov. 2009	11	3.9	(Zhao et al., 2013)
SDZ	PM _{2.5}	winter	Jan.–Feb. 2010	17	4.4	(Zhao et al., 2013)
SDZ	PM _{2.5}	annual	2009–2010	11	3.9	(Li et al., 2016)
SDZ	PM _{2.5}	summer	Jun.–Aug. 2015	5.5	1.5	(Li et al., 2016)
SDZ	PM _{2.5}	winter	Jan., Feb., Dec. 2015	11	1.9	(Li et al., 2016)
SDZ	PM _{2.5}	annual	2015	8.6	1.6	(Li et al., 2016)
SDZ	PM _{2.5}	annual	2017–2018	5.6	0.70	This Study

(b) major water-soluble inorganic ions

Location	Size	Season	Period	Concentrations ($\mu\text{g m}^{-3}$)					References
				SO_4^{2-}	NO_3^-	NH_4^+	Cl^-	K^+	
Global Background Stations									
Mt. Waliguansan	TSP	autumn	Oct. 1994	0.22	0.24	0.33	0.20		(Yang et al., 1996)
Mt. Waliguansan	TSP	winter	Jan. 1995	0.19	0.012	0.24	0.37		(Yang et al., 1996)
Mt. Cimone	PM ₁₀	summer	2004	0.35	0.84	1.4			(Carbone et al., 2014)
Mt. Cimone	PM ₁	winter	2009–11	0.049	0.10	0.022			(Carbone et al., 2014)
Mt. Cimone	PM ₁	spring	2009–11	0.28	0.18	0.082			(Carbone et al., 2014)
Mt. Cimone	PM ₁	summer	2009–11	1.3	0.69	0.40			(Carbone et al., 2014)
Mt. Cimone	PM ₁	autumn	2009–11	0.25	0.11	0.063			(Carbone et al., 2014)
Regional Background Stations									
Mt. Longfengshan	TSP	autumn	Oct. 1994	0.52	0.62	0.66	0.35		(Yang et al., 1996)
Mt. Longfengshan	TSP	winter	Jan. 1995	1.2	0.75	1.1	0.55		(Yang et al., 1996)
Akdala	PM ₁₀	annual	Jul 2004–Mar 2005	3.3	0.58	0.60		0.10	(Qu et al., 2009)
Akdala	PM ₁₀	summer	Jul–Aug. 2004	1.5	0.23	0.32		0.094	(Qu et al., 2008)
Akdala	TSP	summer	Jul–Aug. 2004	2.0	0.88	0.24		0.098	(Qu et al., 2008)
Lin'an	TSP	autumn	Oct. 1994	1.0	0.88	0.91	0.62		(Yang et al., 1996)
Lin'an	TSP	winter	Jan. 1995	2.0	0.52	1.1	0.71		(Yang et al., 1996)
Lin'an	TSP	summer	Aug. 2004	18	2.9	5.8	0.71	1.5	(Yan et al., 2012b)
Lin'an	TSP	winter	Jan. 2005	17	12	7.6	1.3	1.8	(Yan et al., 2012b)
Lin'an	PM _{2.1}	summer	Aug. 2004	15	1.1	5.5	0.11	1.3	(Yan et al., 2012b)
Lin'an	PM _{2.5}	annual	2010	9.6	7.6	4.3	2.1	1.2	(Meng et al., 2012)
Lin'an	PM ₁	spring	Apr. 2011	8.5	5.3	6.1	0.60	1.8	(Li et al., 2015)
Lin'an	PM ₁	summer	Jul. 2011	7.5	3.3	3.6	0.30	0.70	(Li et al., 2015)
Lin'an	PM ₁	autumn	Oct. 2011	10	5.0	4.9	0.90	1.9	(Li et al., 2015)
Lin'an	PM ₁	winter	Jan. 2011	8.5	8.7	8.2	2.0	2.3	(Li et al., 2015)
Lin'an	PM _{2.5}	summer	Jun–Aug. 2015	8.7	2.0	3.3			(Liang et al., 2018)
Lin'an	PM _{2.5}	winter	Jan. 2015	15	19	11			(Shi et al., 2017)
SDZ	TSP	summer	Jul. 2004	27	7.0	13	0.26	1.4	(Yan et al., 2012b)
SDZ	PM _{2.1}	winter	Feb. 2004	14	9.8	6.2	0.25	3.2	(Yan et al., 2012b)
SDZ	PM _{2.1}	summer	Jul. 2004	24	5.8	13	0.11	1.3	(Yan et al., 2012b)
SDZ	PM _{2.5}	annual	2009–2010	14	12	4.5	0.80	1.2	(Li et al., 2016)
SDZ	PM _{2.5}	summer	Jun–Aug. 2015	9.6	3.3	3.4	0.10	0.20	(Li et al., 2016)
SDZ	PM _{2.5}	winter	Jan, Feb, Dec. 2015	7.4	7.5	3.7	0.40	0.60	(Li et al., 2016)
SDZ	PM _{2.5}	annual	2015	8.5	6.4	3.8	0.20	0.50	(Li et al., 2016)
SDZ	PM _{2.5}	annual	2017–18	4.0	8.4	3.8	0.85	0.31	This Study

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