



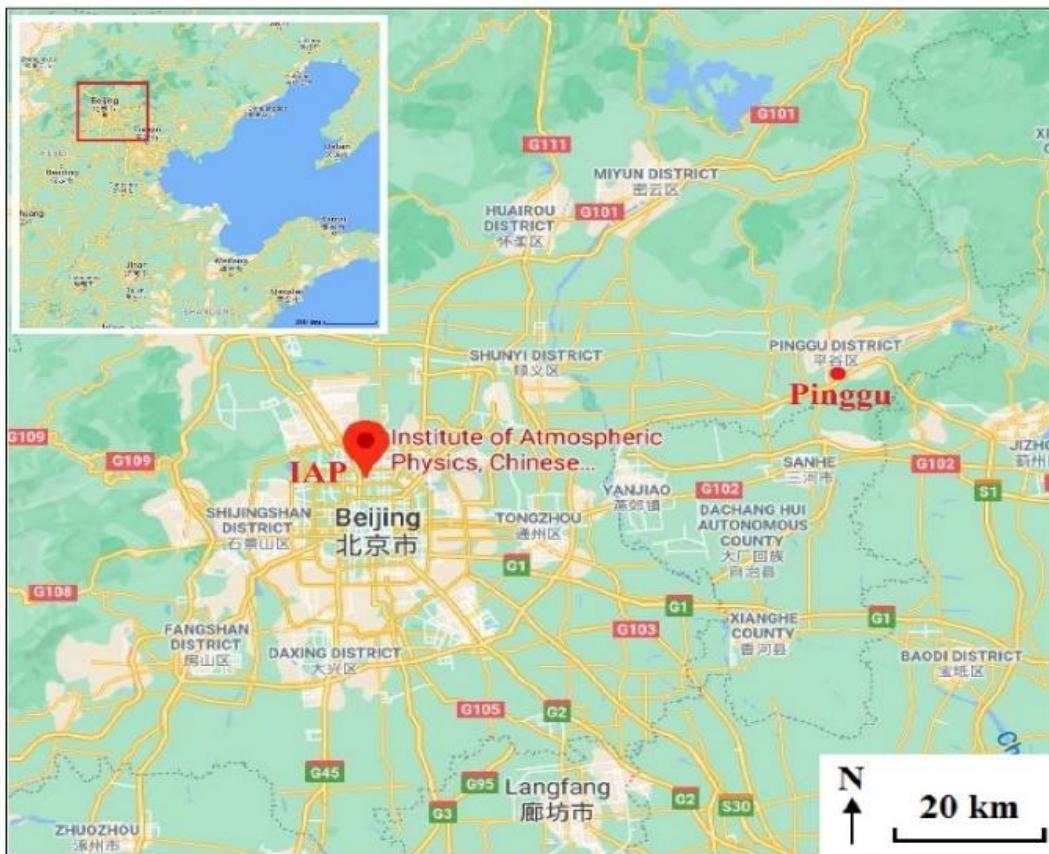
Supplement of

Insight into PM_{2.5} sources by applying positive matrix factorization (PMF) at urban and rural sites of Beijing

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8 **Figure S1.** Map of the sampling sites in Beijing (IAP - urban site: Institute of Atmospheric Physics of
 9 the Chinese Academy of Sciences; Pinggu - rural site) (source: Xu et al., 2020).

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11 **Table S1.** Detection limits of the species used in the PMF model.

Species	Detection limit (ng m ⁻³)
PM _{2.5}	50
OC	30
EC	50
K ⁺	10
Na ⁺	32
Ca ²⁺	10.8
NH ₄ ⁺	76
NO ₃ ⁻	240
SO ₄ ²⁻	142
Cl ⁻	138
Ti	3.2
V	4.3
Mn	0.5
Ni	5.2
Zn	2.0
Pb	3.0
Cu	26.4
Fe	43.6
Al	220.6
C26	0.004
C29	0.004
C31	0.004
17 α (H)-22,29,30-Trisnorhopane	0.009
17 β (H),21 α (H)-30-norhopane	0.009
Chrysene	0.008
Benzo(b)fluoranthene	0.008
Benzo(a)pyrene	0.008
Picene	0.009
Coronene	0.008
Levoglucosan	0.0197
Stearic acid	0.004

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14 **Table S2.** Comparison between modeled and measured species.

Species	Correlation coefficient(r^2)
PM _{2.5}	0.90
OC	0.69
EC	0.80
K ⁺	0.90
Na ⁺	0.79
Ca ²⁺	0.41
NH ₄ ⁺	0.97
NO ₃ ⁻	0.92
SO ₄ ²⁻	0.79
Cl ⁻	0.98
Ti	0.66
V	0.66
Mn	0.95
Ni	0.78
Zn	0.89
Pb	0.96
Cu	0.54
Fe	0.94
Al	0.71
C26	0.52
C29	0.47
C31	0.65
17 α (H)-22,29,30-Trisnorhopane	0.57
17 β (H),21 α (H)-30-norhopane	0.51
Chrysene	0.56
Benzo(b)fluoranthene	0.63
Benzo(a)pyrene	0.55
Picene	0.55
Coronene	0.63
Levoglucosan	0.77
Stearic acid	0.43

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17 **Table S3.** Results from bootstrap runs.

	Coal combustion	Road dust	Traffic emissions	Oil combustion	Secondary inorganics	Biomass burning	Soil dust
Coal combustion	98	0	0	0	0	0	0
Road dust	0	98	0	0	0	0	0
Traffic emissions	0	0	98	0	0	0	0
Oil combustion	0	0	1	97	0	0	0
Secondary inorganics	0	0	0	0	98	0	0
Biomass burning	0	0	0	0	0	96	0
Soil dust	0	0	0	0	0	0	98

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20 **Table S4.** Observed P-value for each factor obtained using t-test.

	Coal combustion	Road dust	Traffic emissions	Oil combustion	Secondary inorganics	Biomass burning	Soil dust
P<0.05	0.17191	0.12272	0.27713	0.10883	0.22586	0.16272	0.07998

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24 **Table S5.** List of the studies conducted in the Beijing metropolitan area to evaluate PM sources.

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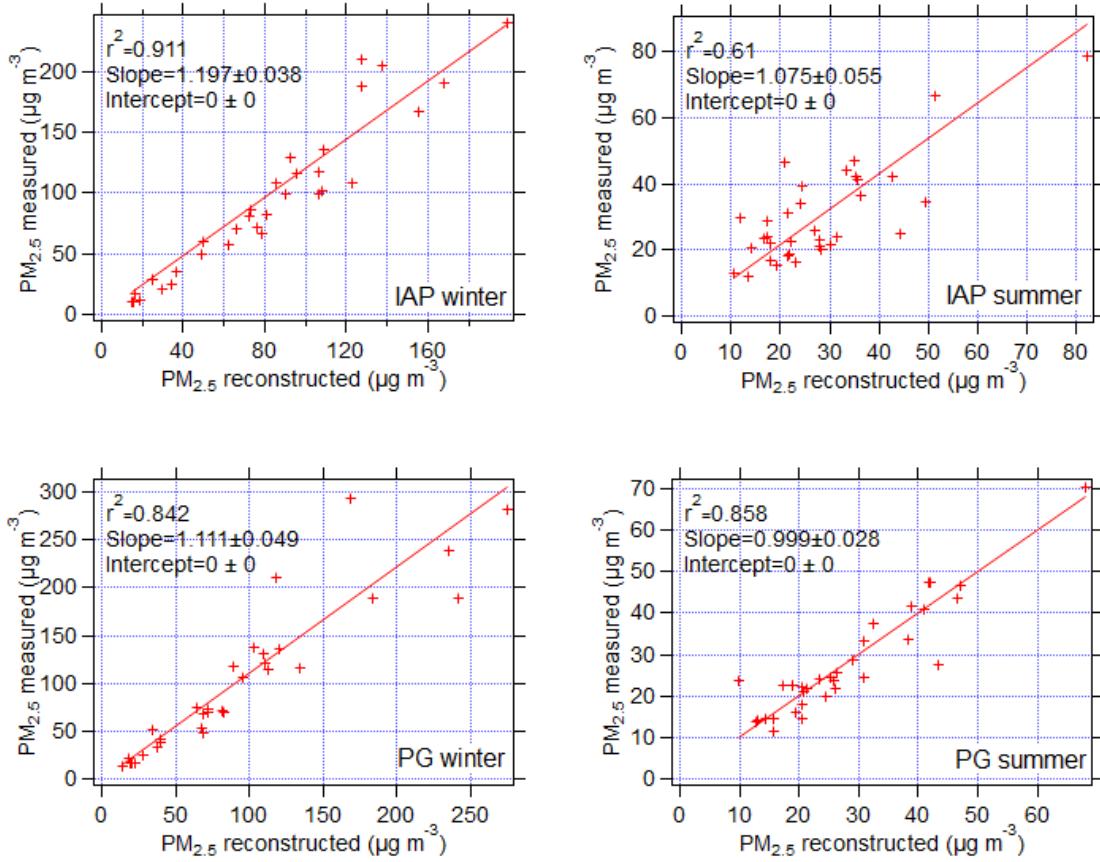
Reported Studies	PM size fraction	Sampling site	Study period	Identified PMF factors (% contribution)						Input species
				Dust/soil dust*/road dust ^S /mineral dust ^a /local ^b /non-local [∞]	Traffic/fossil fuel ^x	Coal combustion	Biomass burning	Secondary inorganics	Industrial	
Li et al. (2019)	PM _{2.5}	Urban- IAP	15 th Sep – 12 th Nov 2014	-	-	-	-	-	-	Mg, Al, K, Ca and Fe, V, Cr, Mn, Co, Cu, Zn, Ag, Cd, Pb and As
		Suburban- UCAS	15 th Sep – 12 th Nov 2014	-	-	-	-	-	-	
Liu et al. (2019)	PM _{2.5}	PKU	Nov-Dec 2016	5	18	16	9	44	8	OC, EC, NO ₃ ⁻ , SO ₄ ²⁻ , NH ₄ ⁺ , Cl ⁻ , Na ⁺ , Mg, Al, K, Ca, Ba, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, and Pb
Ma et al. (2017a)	PM _{2.5}	Urban- IAP	24 th Feb - 12 th Mar 2014	10*	6	18 ^e	18 ^e	46	20	Na ⁺ , K ⁺ , Mg ²⁺ , Ca ²⁺ , NO ₃ ⁻ , SO ₄ ²⁻ , NH ₄ ⁺ , Cl ⁻ , Al, Fe, Ti, Mn, Cu, Zn, Sb, Pb, Cr, PM _{2.5} , EC, OC
Tian et al. (2016)	PM _{2.1}	Urban- IAP	Mar 2013 – 28 th Feb 2014	8.4 ^S	19.6	17.7	8.6	25.1	12.1	Na, Mg, Al, K, Ca, Mn, Fe, Co, Ni, Cu, Zn, Mo, Cd, Ba, Tl, Pb, Th, U, Na ⁺ , NH ₄ ⁺ , K ⁺ , Mg ²⁺ , Ca ²⁺ , Cl ⁻ , SO ₄ ²⁻ , NO ₃ ⁻ , OC and EC.
			Mar 2013 – 28 th Feb 2014	10.9 ^S , 22.6 ^a	-	7.8	6.9	9.8	5.1	
Yu et al. (2013)	PM _{2.5}	Urban- BNU	1 st Jan – 31 st Dec 2010	12.7 ^S , 10.4*	17.1, 16 ^x		11.2	26.5 ^e	6	Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Br, Ba and Pb
Zhang et al. (2013)	PM _{2.5}	PKU	April, July, Oct 2009 and Jan 2010	15*	4 ⁺	18	12	26	25	Na ⁺ , K ⁺ , Mg ²⁺ , Ca ²⁺ , NO ₃ ⁻ , SO ₄ ²⁻ , NH ₄ ⁺ , Cl ⁻ , Al, Fe, Na, Mg, K, Ca, Ba, Co, Mo, Cd, Sn, As, Se, Rb, Ti, Mn, Cu, Zn, Sb, Pb, Cr, PM _{2.5} , EC, OC
Wang et al. (2008)	PM _{2.5}	Urban- BNU	Summer and winter 2001 to 2006	8.8 ^B , 6.7 [∞]	5.9	16.7	11.8	12.7 ^e , 14.7 ^y	8.8	Na, K ⁺ , Mg ²⁺ , NO ₃ ⁻ , SO ₄ ²⁻ , NH ₄ ⁺ , Cl ⁻ , Al, Fe, Na, Mg, K, Ca, Co, Cd, As, Ti, Mn, Cu, Zn, Sb, Pb, S, Cr, BC, OC, C ₂ O ₄ ²⁻
	PM ₁₀		Summer and winter 2001 to 2006	23 ^B	8.4	13.3	10.2	18.9	14.9	
	PM _{2.5}	Duolun [®]	Summer and winter 2001 to 2006	36.2 ^B , 23.1 [∞]	-	-	15.6	7.1 ^y	-	
	PM ₁₀		Summer and winter 2001 to 2006	61.7 ^B , 11 [∞]	-	-	18.1	4.1	-	
Song et al. (2007)	PM _{2.5}	Urban- PKU, OLC, SJS, TZ, and LX; Rural-MT	Jan 2004	7.8 ^S	8.5	40.6	16.4	9.2 ^e , 10.5 ^y	-	OC, EC, NO ₃ ⁻ , SO ₄ ²⁻ , NH ₄ ⁺ , Cl ⁻ , Na, Mg, Al, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, and Pb
			Aug 2004	4.4 ^S	7.8	5.9	6.7	12.6 ^e , 4.2 ^y	-	

Song et al. (2006)	PM _{2.5}	OT, NB, BJ, XY, CH	6-day intervals in Jan, Apr, Jul, and Oct 2000	9 ^s and yellow dust	6	19	11	17 ^t ,14 ^y	6	OC, EC, NO ₃ ⁻ , SO ₄ ²⁻ , NH ₄ ⁺ , Na, Al, Si, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Br, Pb, and Mg
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27 ⁺ Reported as traffic and waste incineration emissions; ^tSecondary sulphur/^ysecondary nitrate; ^π Fossil fuel; [€] Reported as combined coal and
 28 biomass burning contribution; [©] Background site; University of Chinese Academy of Sciences-UCAS; Peking University-PKU; Beijing
 29 Normal University-BNU; Ming Tombs -OT, the airport-NB, Beijing University-BJ, Dong Si EPB-XY, and Yong Le Dian-CH.

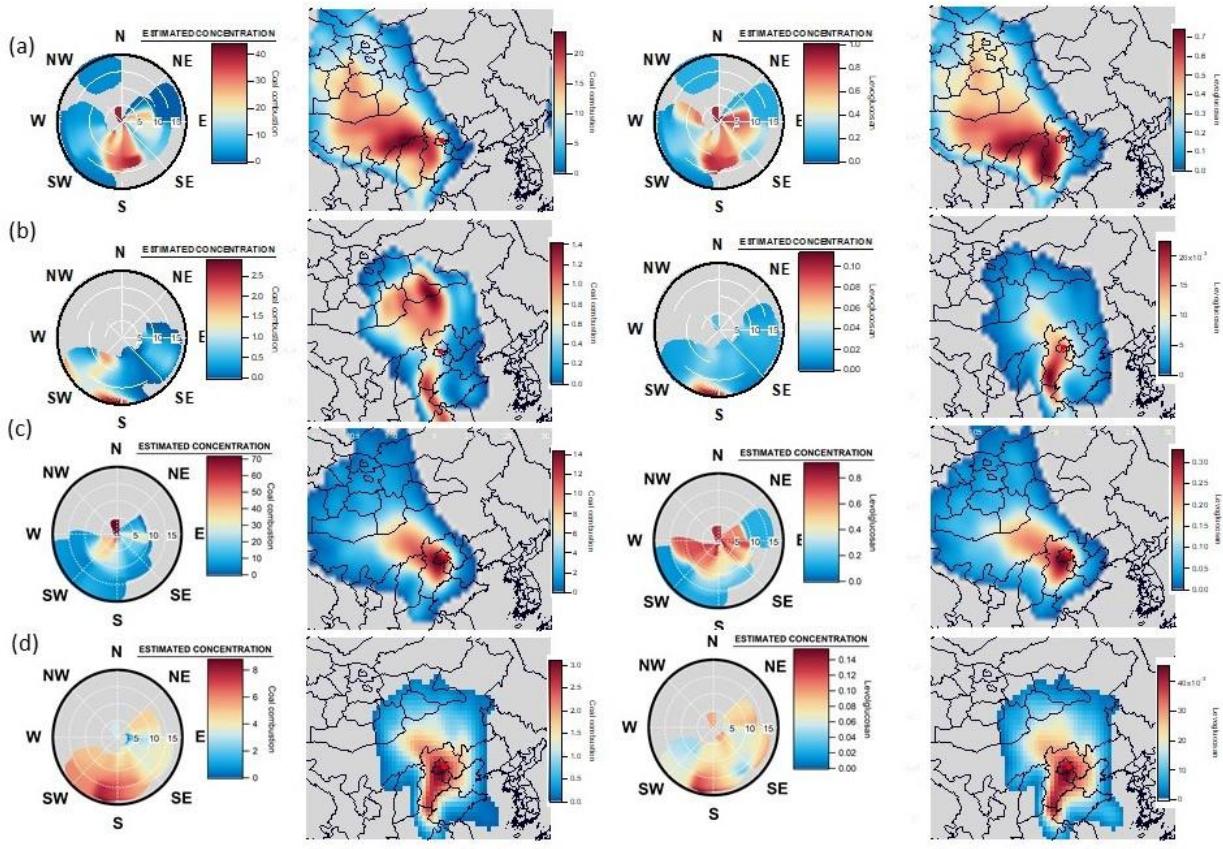
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32 **Figure S2.** Comparison of reconstructed PM_{2.5} mass using PMF model with PM_{2.5} measurements at both
33 sites, IAP and PG, respectively.

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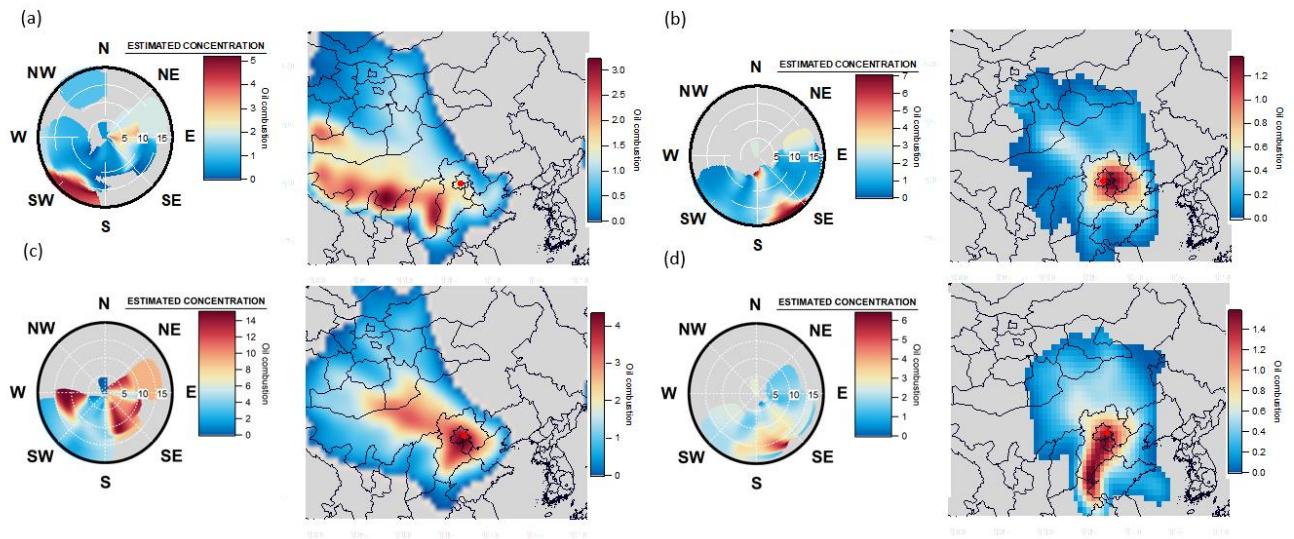
Figure S3. NWR (non parametric wind regression) and CWT (concentrated weighted trajectories) results for Coal combustion source and Levoglucosan (a) IAP winter (b) IAP summer (c) PG winter (d) PG summer.

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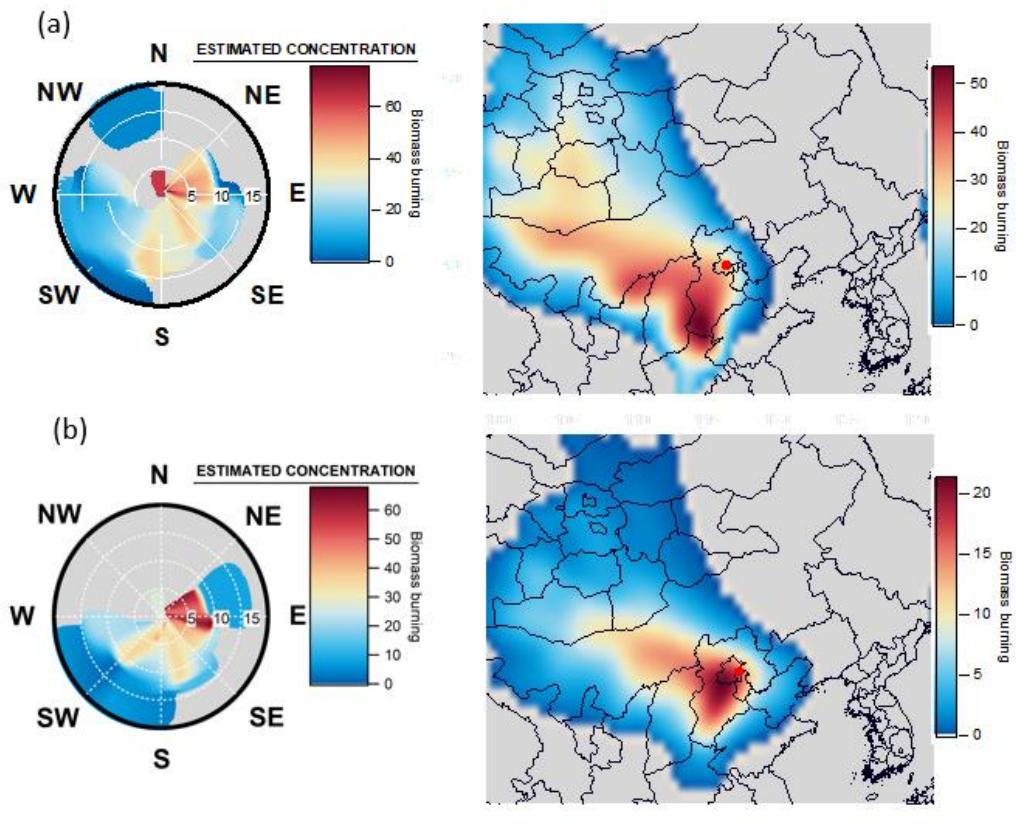
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45 **Figure S4.** NWR (non parametric wind regression) and CWT (concentrated weighted trajectories) results
46 for oil combustion source (a) IAP winter (b) IAP summer (c) PG winter (d) PG summer.
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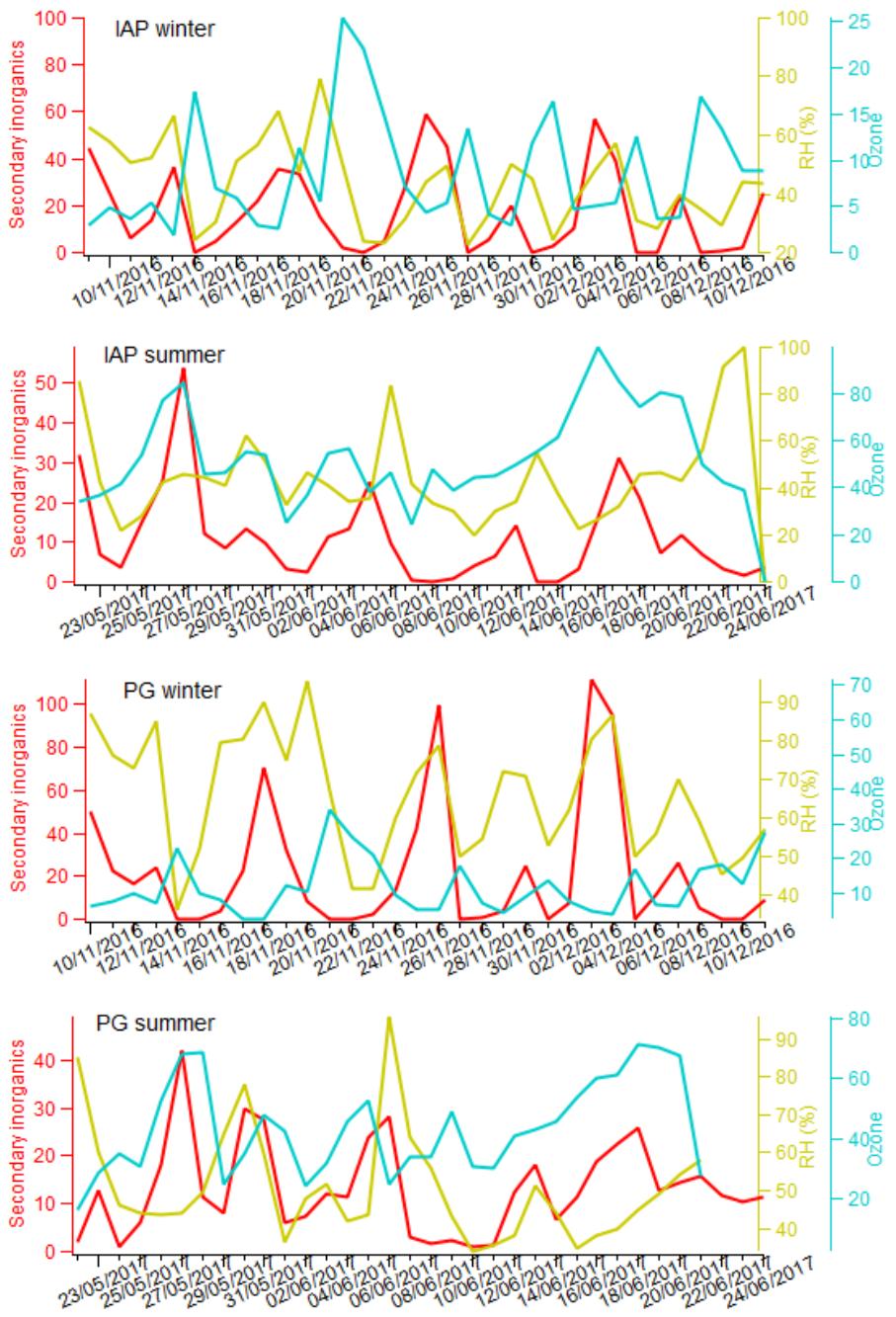
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67 **Figure S5.** NWR (non parametric wind regression) and CWT (concentrated weighted trajectories) results
68 for biomass burning (a) IAP winter (b) PG winter.

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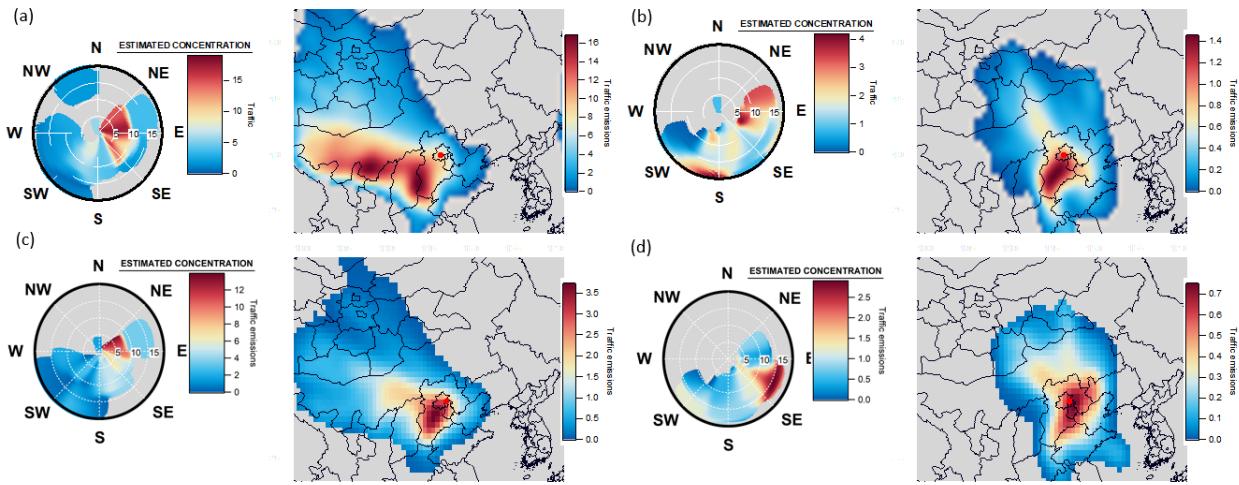
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73 **Figure S6.** Temporal evolution of the secondary inorganics factor ($\mu\text{g m}^{-3}$), relative humidity (RH) and
74 ozone ($\mu\text{g m}^{-3}$).

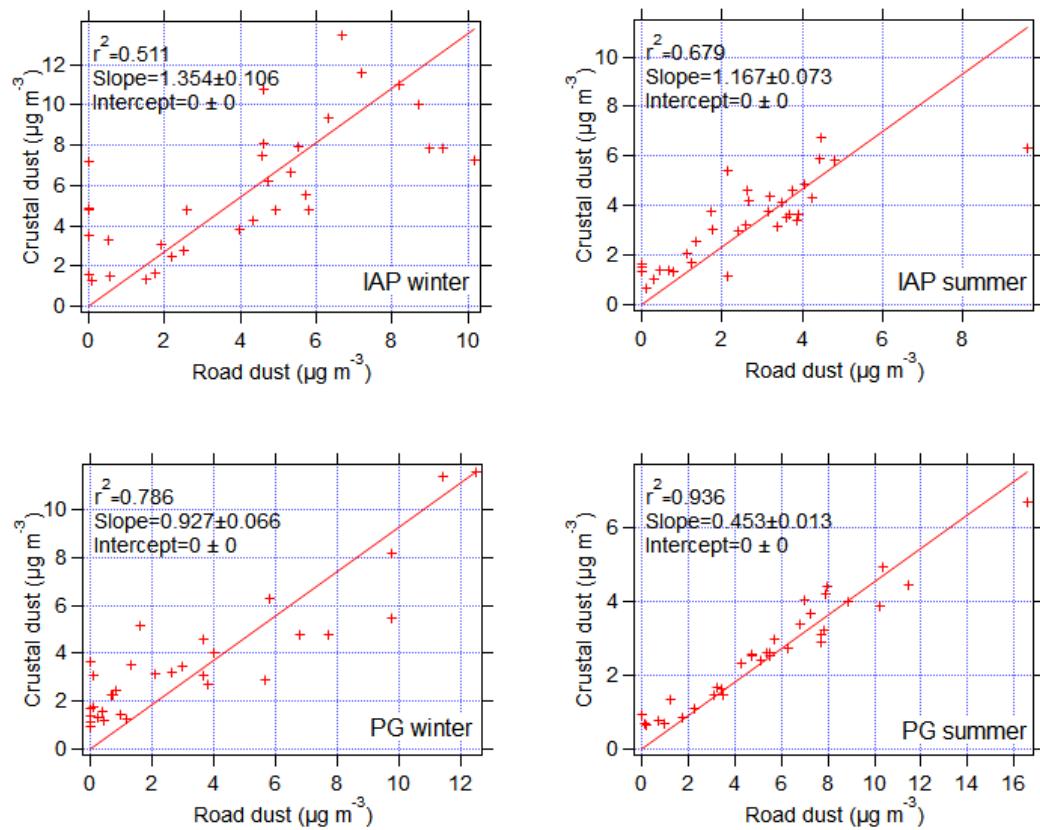


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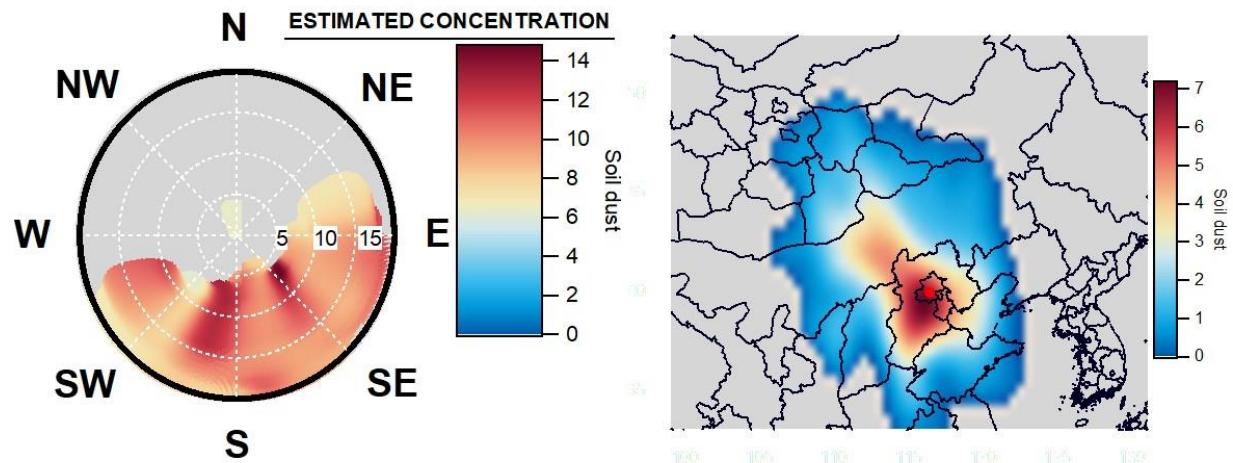
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77 **Figure S7.** NWR (non parametric wind regression) and CWT (concentrated weighted trajectories) results
 78 for traffic emissions (a) IAP winter (b) IAP summer (c) PG winter (d) PG summer.

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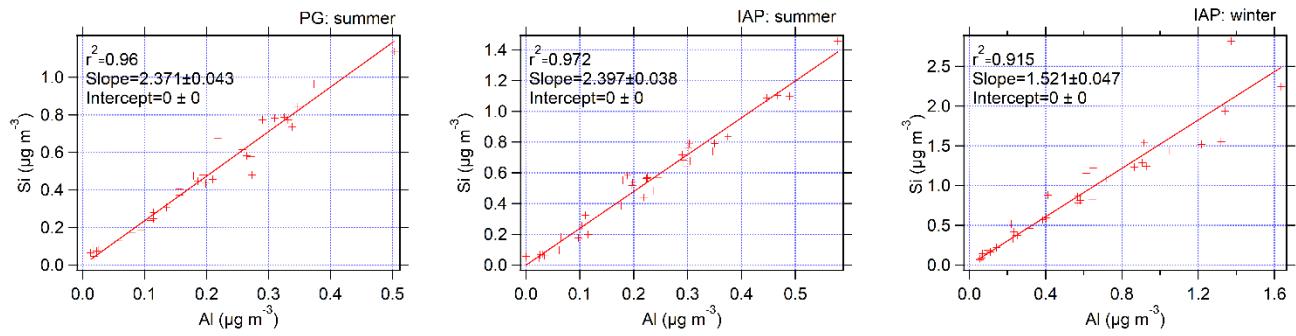


82 **Figure S8.** Comparison of estimated Crustal Dust with Road Dust factor resolved at both sites, IAP and
83 PG, respectively.

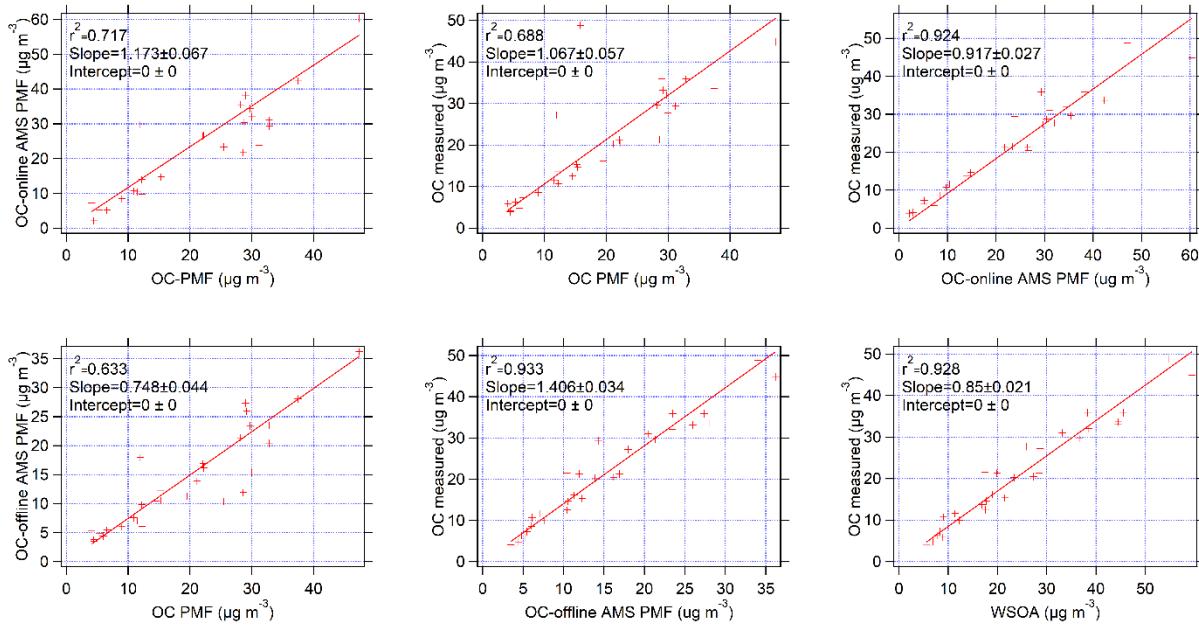


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85 **Figure S9.** NWR (non parametric wind regression) and CWT (concentrated weighted trajectories) results
 86 for Soil dust- IAP summer



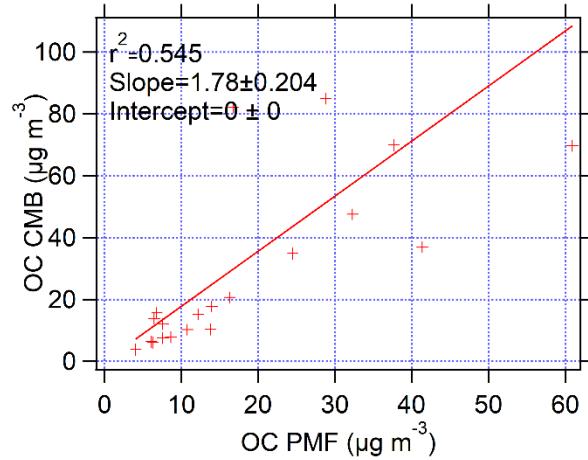
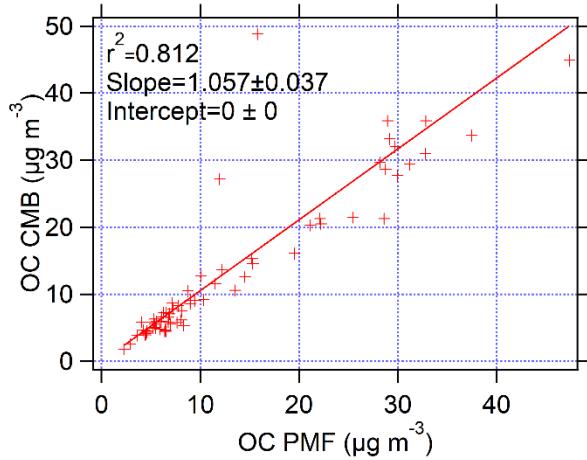
89 **Figure S10.** Comparison of Si and Al concentrations at both sites, IAP and PG, respectively.



91 **Figure S11.** OC mass closure observed at IAP during the winter period: OC modelled by online AMS
92 PMF vs OC modelled by filter based PMF, OC measured vs OC modelled by filter based PMF, OC
93 measured vs OC modelled by online AMS PMF, OC modelled by offline AMS PMF vs OC modelled by
94 filter based PMF, OC measured vs OC modelled by offline AMS PMF, OC measured vs WSOA.
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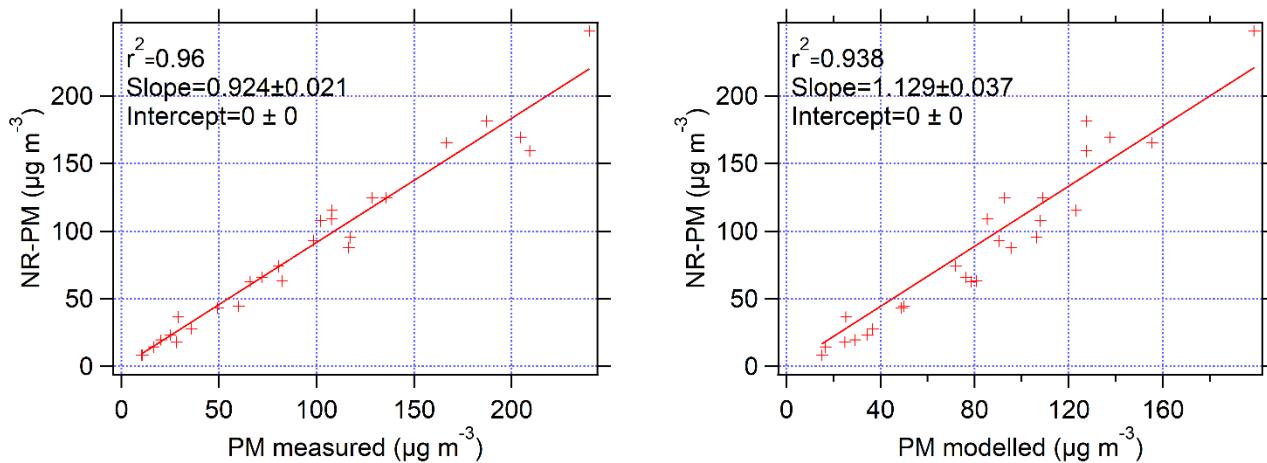
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100 **Figure S12.** OC mass closure: CMB vs filter-based PMF (right=PG, left =IAP, summer+winter).
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105 **Figure S13.** PM mass closure at IAP during the wintertime: NR-PM measured vs PM measured, NR-
106 PM measured vs PM modelled by filter based PMF

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