Air pollution-induced missed abortion risk for pregnancies

Liqiang Zhang [1,6]*, Weiwei Liu [2,6]*, Kun Hou[1,6], Jintai Lin [3]*, Chenghu Zhou [4]*, Xiaohua Tong[5], Ziye Wang[1], Yuebin Wang [1], Yanxiao Jiang[1], Ziwei Wang [3], Yibo Zheng[1], Yonglian Lan[2], Suhong Liu[1], Ruijing Ni [3], Mengyao Liu[3] and Panpan Zhu[1]

[1]State Key Laboratory of Remote Sensing Science, Faculty of Geographical Science, Beijing Normal University, Beijing, China. [2]Beijing Obstetrics and Gynecology Hospital, Capital Medical University, Beijing, China. [3]Laboratory for Climate and Ocean-Atmosphere Studies, Department of Atmospheric and Oceanic Sciences, School of Physics, Peking University, Beijing, China. [4]State Key Laboratory of Resources and Environment Information System, Institute of Geographical Science and Natural Resources, Chinese Academy of Sciences, Beijing, China. [5]School of Surveying and Geo-informatics, Tongji University, Shanghai, China. [6]These authors contributed equally: Liqiang Zhang, Weiwei Liu, Kun Hou. *e-mail: zhanglq@bnu.edu.cn; lffhornet01@163.com; linjt@pku.edu.cn; zhouch@lreis.ac.cn

Supplementary Material for

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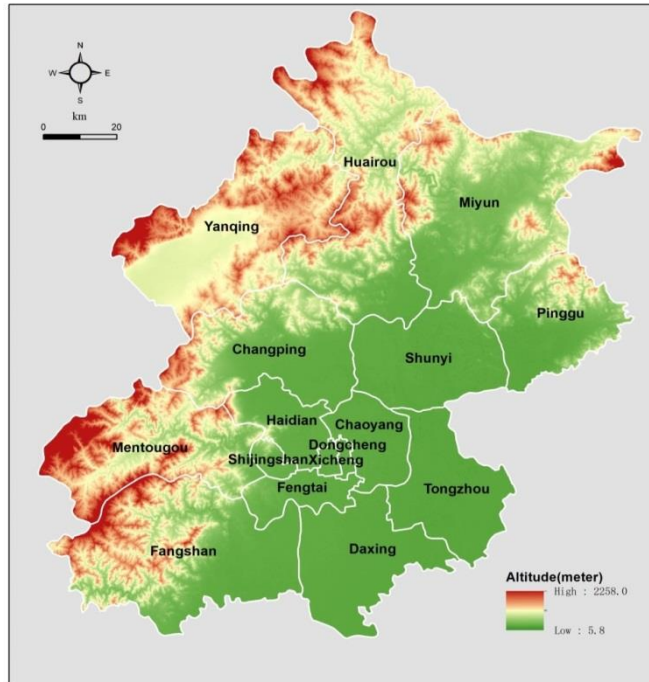
Fig. S1 | Terrain visualization of Beijing. The Beijing boundaries and zoning boundaries were provided by the National Geographic Information Resource Directory Service System, China.
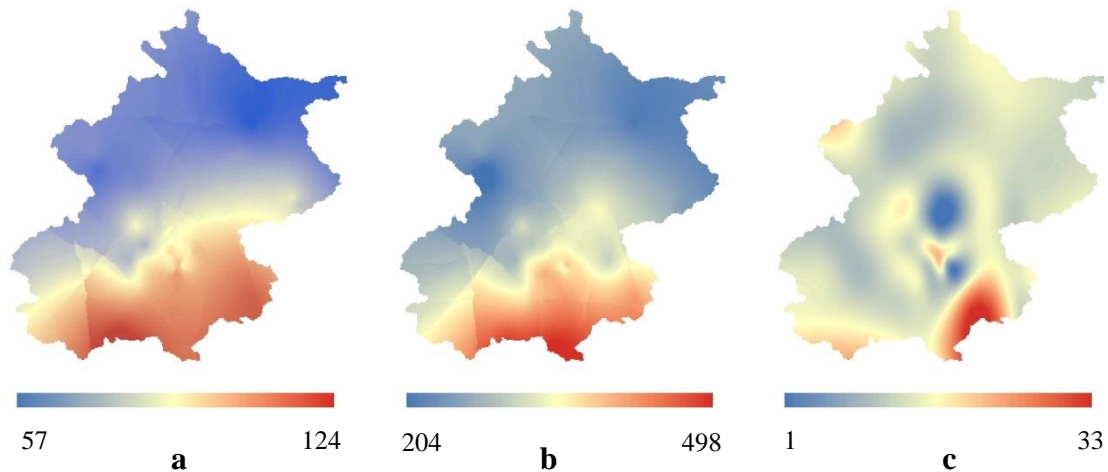

Fig. S2 | Spatial distribution of daily mean PM$_{2.5}$ concentrations (μg/m^3) over

2008-2017 in Beijing. a, Average daily PM$_{2.5}$ concentration. **b,** Maximum daily PM$_{2.5}$ concentration. **c,** Minimum daily PM$_{2.5}$ concentration.

Fig. S3 | Spatial distribution of daily SO$_2$ concentrations (μg/m^3) in Beijing from 2014–2017. a, Average daily SO$_2$ concentration. b, Maximum daily SO$_2$ concentration. c, Minimum daily SO$_2$ concentration. The Beijing boundaries and zoning boundaries were provided by the National Geographic Information Resource Directory Service System, China.
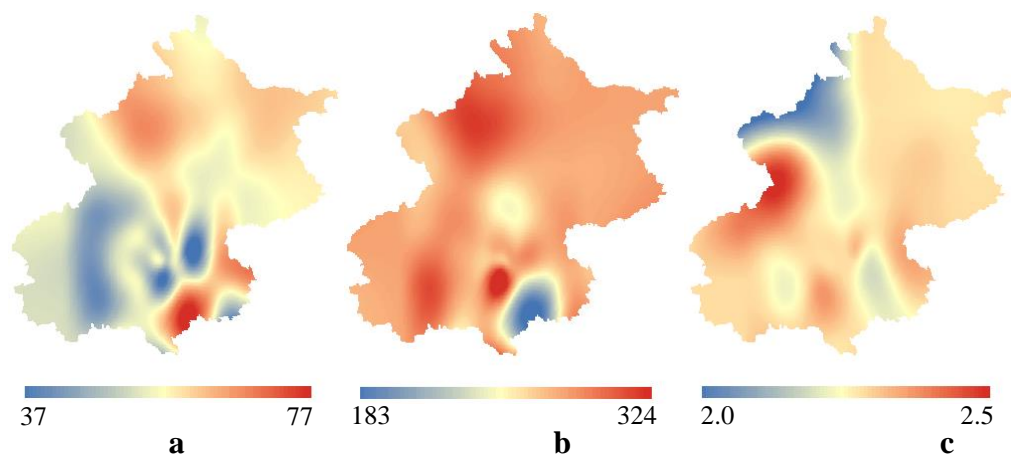
Fig. S4 | Spatial distribution of daily O$_3$ concentrations (μg/m^3) in Beijing from 2014–2017. a, Average daily O$_3$ concentration. **b,** Maximum daily O$_3$ concentration. **c,** Minimum daily O$_3$ concentration. The Beijing boundaries and zoning boundaries were provided by the National Geographic Information Resource Directory Service System, China.
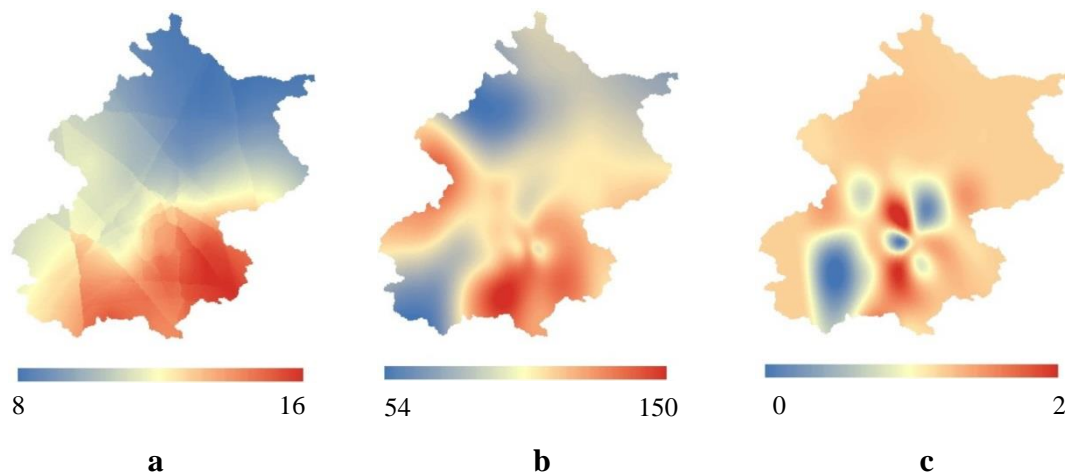
Fig. S5 | Spatial distribution of daily CO concentrations (mg/m³) in Beijing from 2014–2017. a, Average daily CO concentration. **b,** Maximum daily CO concentration. **c,** Minimum daily CO concentration. The Beijing boundaries and zoning boundaries were provided by the National Geographic Information Resource Directory Service System, China.
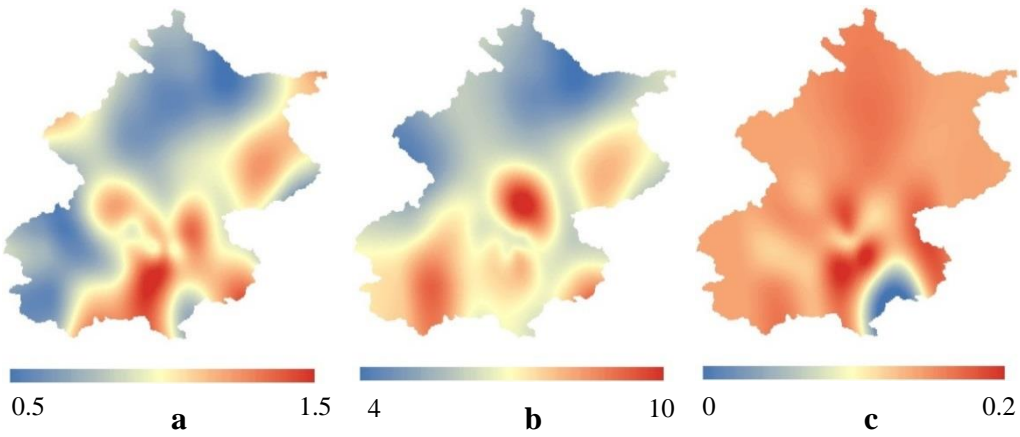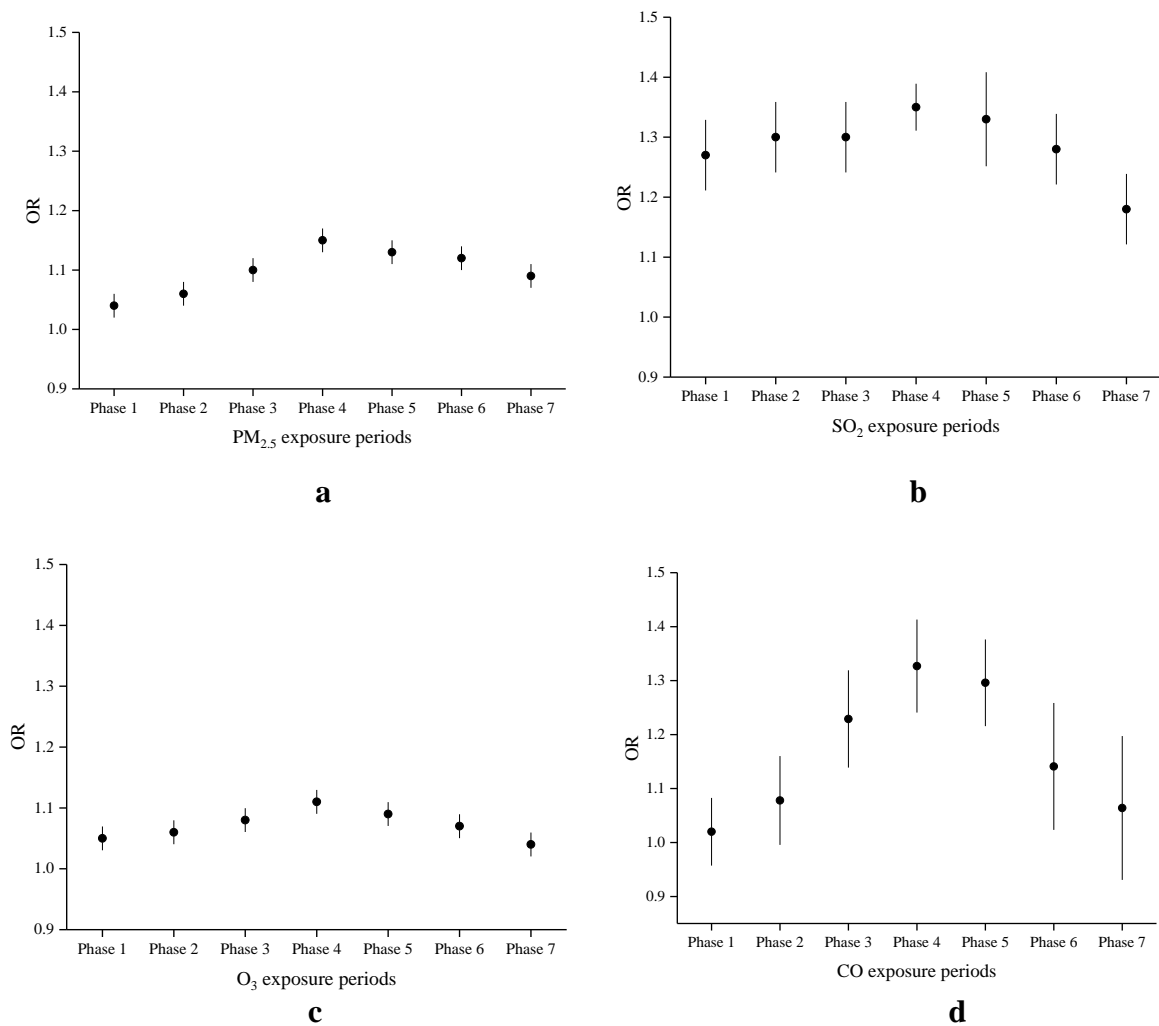

Fig. S6 | The ORs and 95% CIs for the association between MAFT and individual air pollutant concentrations in each period of exposure. a, the

association between MAFT and a 10.0 μg/m^3 increase in average PM$_{2.5}$ concentration. **b,** the association between MAFT and a 10.0 μg/m^3 increase in average SO$_2$ concentration. **c,** the association between MAFT and a 10.0 μg/m^3 increase in average O$_3$ concentration. **d,** the association between MAFT and a 1.0 mg/m^3 increase in average CO concentration.
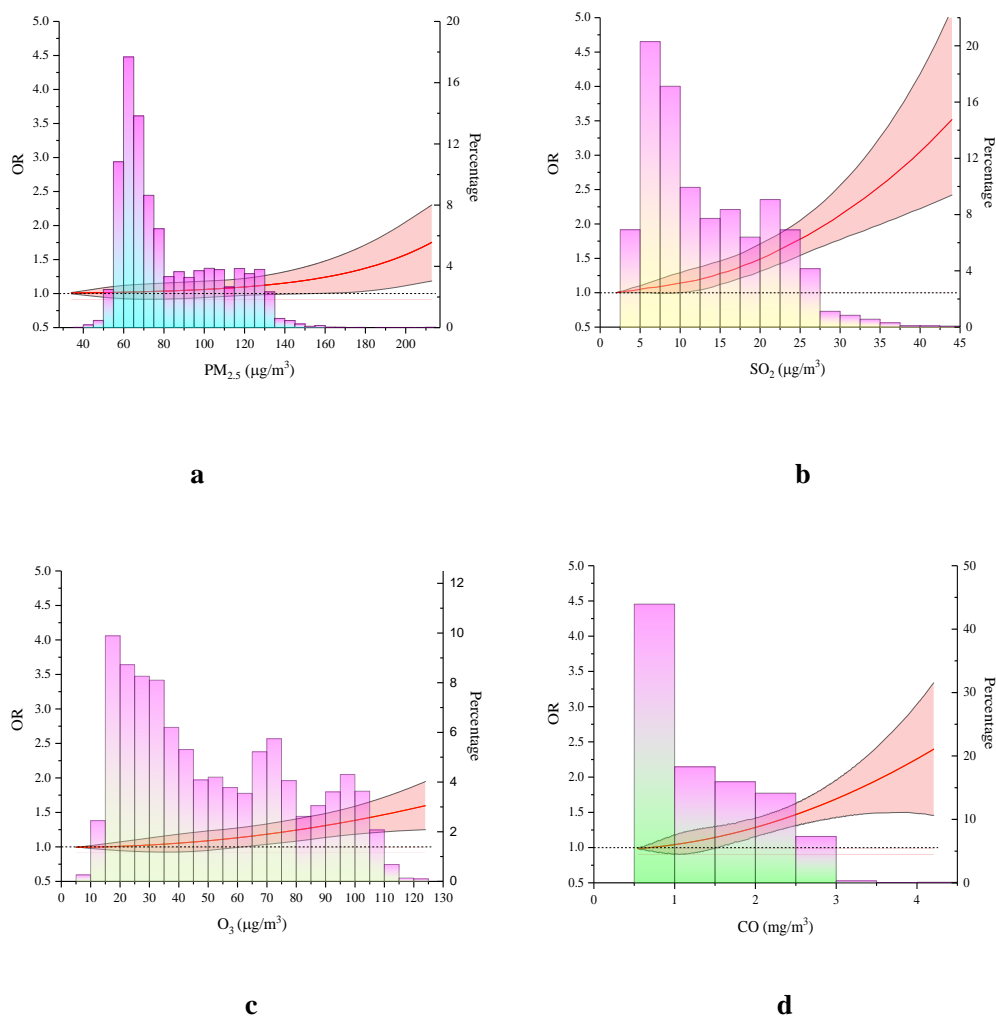

a

b

c

d

Fig. S7 | The exposure-response curve of the OR between air pollutant exposures and the MAFT risk. The red line denotes the OR. The black lines depict the 95% CIs. The histogram in the background shows the distribution of pollutant concentrations.
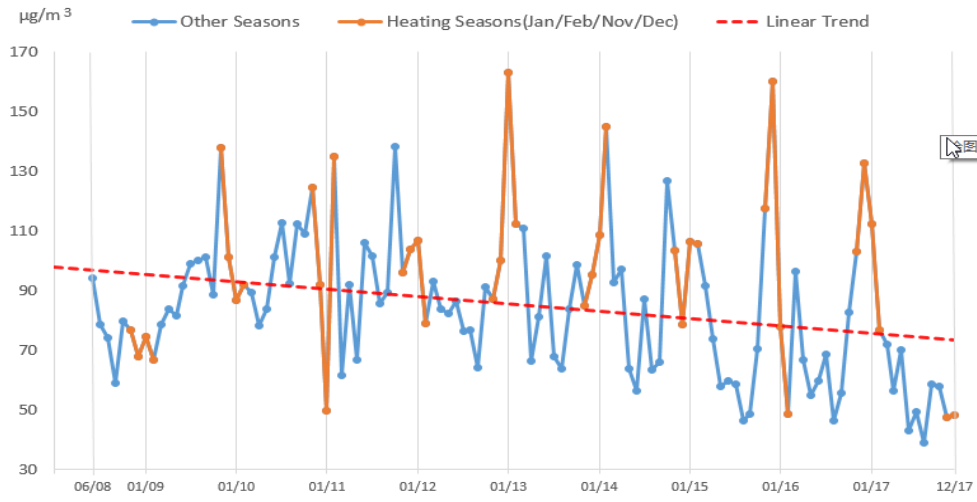
a
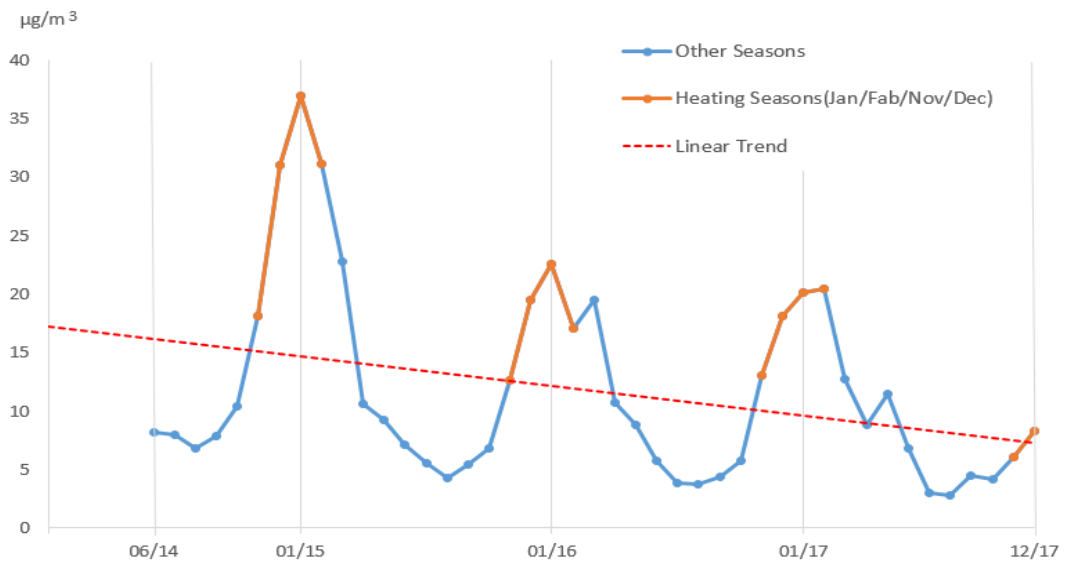
b
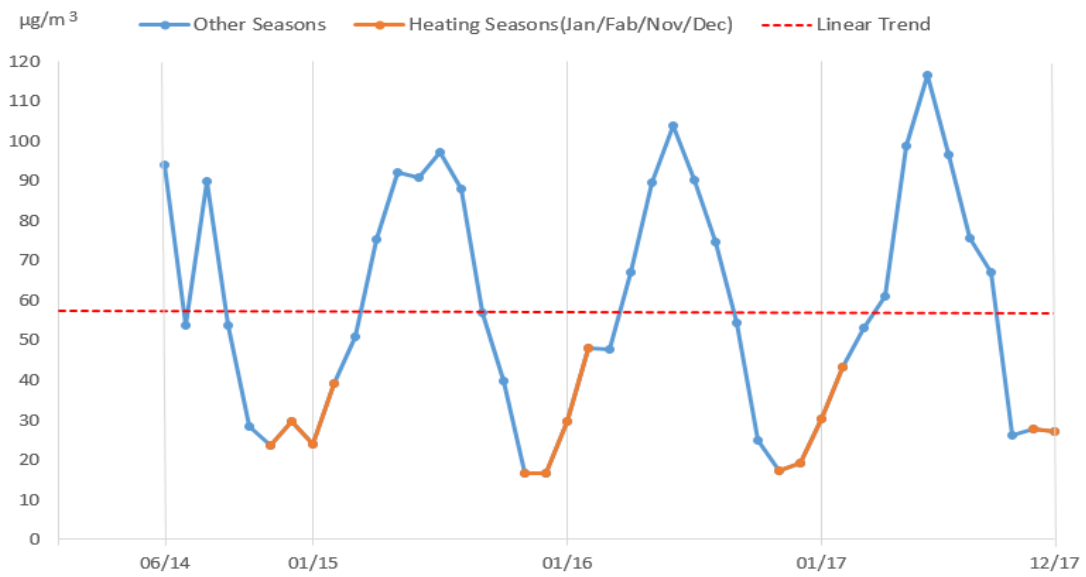
c
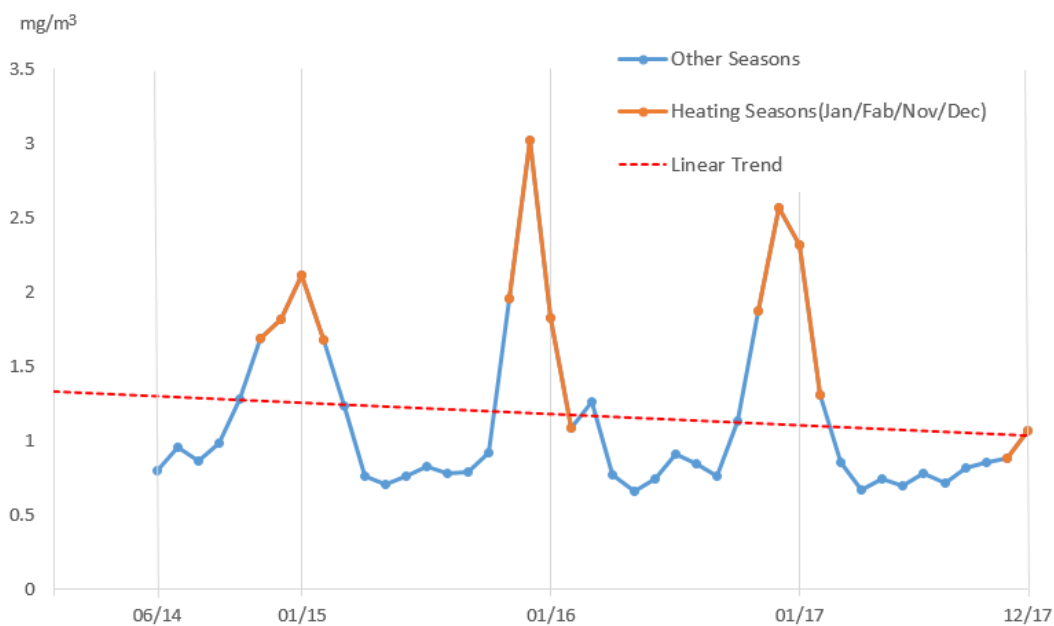
d

Fig. S8 | Average monthly air pollutant concentrations of the 34 air quality monitoring sites in Beijing. **a,** Average monthly $PM_{2.5}$ concentration from June 2008 through December 2017. **b,** Average monthly SO_2 concentration from June 2014 through December 2017. **c,** Average monthly O_3 concentration from June 2014 through December 2017. **d,** Average monthly CO concentration from June 2014 through December 2017. As opposed to other pollutants, ozone concentrations normally reach a minimum in winter. The low $PM_{2.5}$ concentrations in the 2017-2018 heating season were due to extremely strict short-term emission control in the residential, industrial and construction sectors.
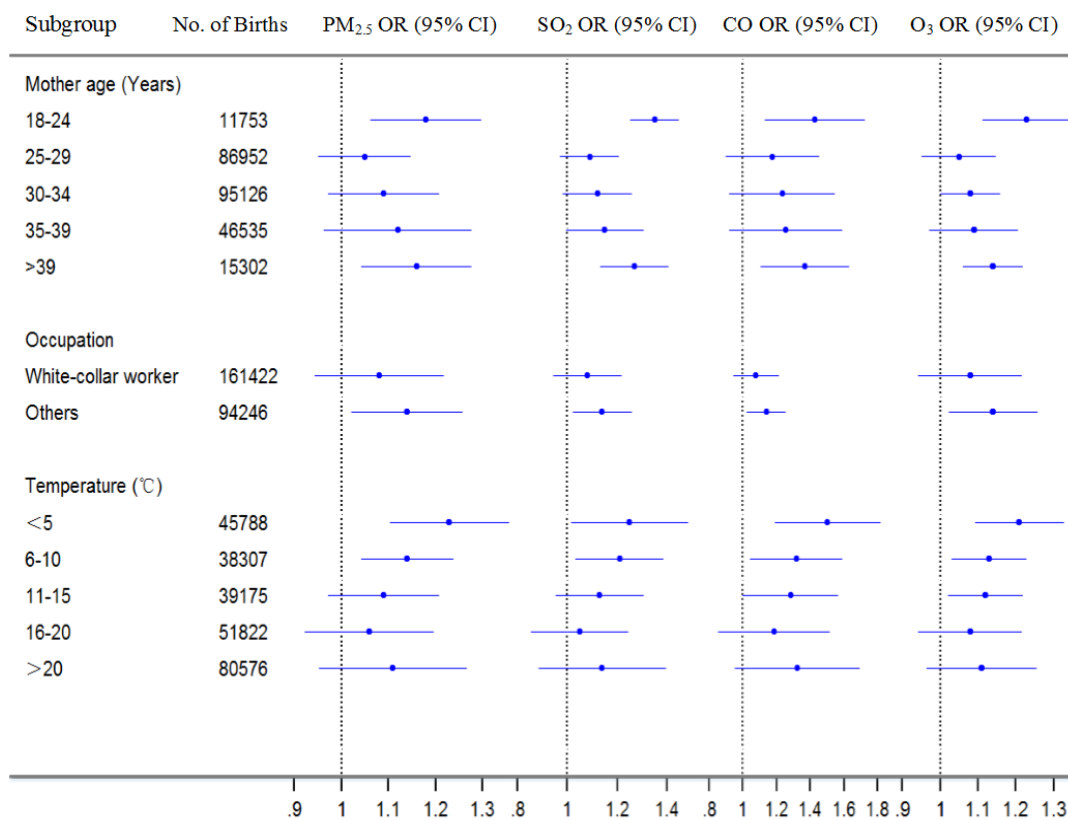
Fig. S9 | Adjusted ORs and 95% CIs for MAFT with respect to demographic and exposure variable categories. In each subgroup, the ORs are for a 10.0 μg/m^3 increase in PM$_{2.5}$, SO$_2$ or O$_3$ exposure, or a 1.0 mg/m^3 increase in CO exposure, in Phase 4.
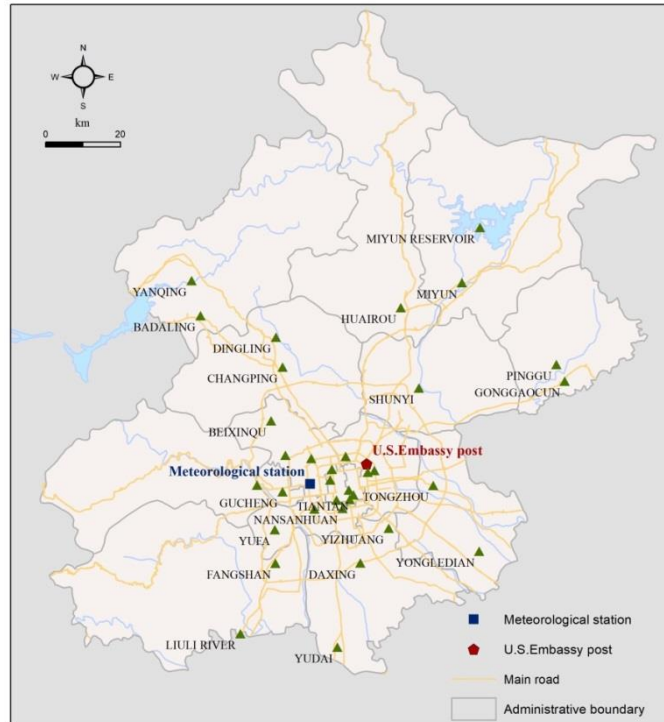
Fig. S10 | Air quality monitoring stations, meteorological measurement site, and main roads (i.e., primary urban roads and arterial roads) in Beijing. The Beijing boundaries and zoning boundaries were provided by the National Geographic Information Resource Directory Service System, China.
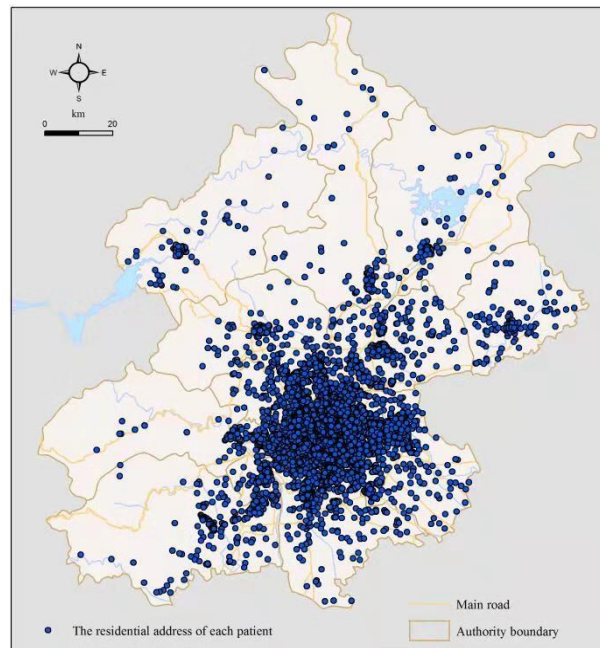
Fig. S11 | Spatial distribution of the participated pregnant women with MAFT from 2009 through 2017 in Beijing. The Beijing boundaries and zoning boundaries

were provided by the National Geographic Information Resource Directory Service System, China.

Fig. S12 | The partial residuals of *s(lan, long)* **through controlling the spatial distribution of pregnant women.**

Table S1 | Characteristics of 255,668 pregnant women in Beijing from 2009 to 2017 and the association between MAFT and environmental factors

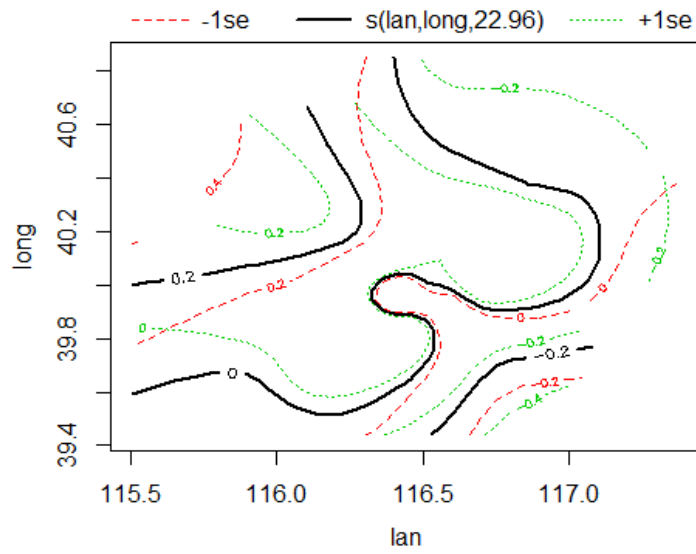| No. of pregnancies (%)			BF_{10}																	
			$PM_{2.5}$ (µg/m³)					SO_2 (µg/m³)				O_3 (µg/m³)				CO (mg/m³)			
Age (Y.)	Non-MAFT (%)	MAFT (%)	34.0-63.1	63.1-71.4	71.4-93.3	93.3-130.2	>130.2	2.6-7.1	7.1-11.4	11.4-19.5	>19.5	0-27.3	27.3-46.2	46.2-74.4	>74.4	0-0.9	0.9-1.1	1.1-1.9	>1.9
18-24	10,895 (92.7)	858 (7.3)	>100	>100	>100	>100	>100	98.69	>100	>100	>100	95.16	97.51	>100	>100	98.84	>100	>100	>100
25-29	81,561 (93.8)	5,391 (6.2)	96.67	97.38	99.04	>100	>100	97.32	98.68	>100	>100	91.02	94.36	>100	>100	95.27	97.03	>100	>100
30-34	88,562 (93.1)	6,564 (6.9)	98.94	>100	>100	>100	>100	96.14	98.92	>100	>100	>100	>100	>100	>100	97.65	>100	>100	>100
35-39	43,045 (92.5)	3,490 (7.5)	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
>39	14,108 (92.2)	1,194 (7.8)	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
Occupation																			
White-collar worker	86,766 (92.1)	7,480 (7.9)	95.26	>100	>100	>100	>100	92.48	>100	>100	>100	91.86	>100	>100	>100	94.32	98.26	>100	>100
Others*	151,405 (93.8)	100,17 (6.2)	91.37	96.29	98.38	>100	>100	91.39	93.52	98.94	>100	90.32	95.23	98.21	>100	91.10	97.33	>100	>100
Temperature (℃)																			
<5	424,20 (92.6)	3368 (7.4)	91.89	94.37	95.24	98.37	>100	98.12	>100	>100	>100	91.85	96.62	98.38	>100	93.86	96.68	>100	>100
5-10	357,03 (93.2)	2604 (6.8)	94.37	97.25	>100	>100	>100	>100	>100	>100	>100	97.68	>100	>100	>100	94.71	97.93	>100	>100
10-15	366,08 (93.4)	2567 (6.6)	95.84	98.84	>100	>100	>100	97.29	>100	>100	>100	94.96	>100	97.73	>100	92.46	97.10	>100	>100
15-20	48457 (93.5)	3365 (6.5)	98.63	>100	>100	>100	>100	>100	>100	>100	>100	98.14	>100	>100	>100	97.38	>100	>100	>100
>20	74983 (93.1)	5593 (6.9)	93.16	>100	>100	>100	>100	96.17	>100	>100	>100	93.28	>100	96.29	>100	94.66	96.91	>100	>100

*include farmers and blue-collar workers.

Table S2 | Correlations between concentrations of different air pollutants based on daily mean air pollution data over June 2014 through December 2017 obtained from 34 air pollution monitoring stations in Beijing

	SO_2	CO	O_3
$PM_{2.5}$	0.529	0.874	-0.262
SO_2		0.687	-0.281
CO			-0.266

Table S3 | The ORs and 95% CIs of MAFT associated with maternal exposure to $PM_{2.5}$ in Phase 4 with/without controlling for other air pollutants at different periods

$PM_{2.5}$ ($\mu g/m^3$)	ORs (Jun. 2014-Dec. 2017, controlling for SO_2 and O_3)	ORs (Apr. 2008-Dec. 2017, without controlling other pollutants)	ORs (Jun. 2014-Dec. 2017, without controlling other pollutants)
0-63.1	1.08 (0.98, 1.18)	1.07 (0.97, 1.17)	1.09 (0.99, 1.19)
63.1-71.4	1.13 (1.03, 1.23)	1.15 (1.05, 1.25)	1.16 (1.06, 1.26)
71.4-93.3	1.28 (1.14, 1.42)	1.29 (1.15, 1.43)	1.31 (1.17, 1.45)
93.3-130.2	1.39 (1.23, 1.55)	1.41 (1.25, 1.57)	1.43 (1.27, 1.59)
＞130.2	1.51 (1.33, 1.69)	1.53 (1.35, 1.71)	1.52 (1.34, 1.70)

Table S4 | Percentage agreement between 10 fields in the dataset and their counterparts extracted from case notes at four hospitals

Field	Percentage agreement (Kappa)			
	H-1 ($n = 235$)	H-2 ($n = 247$)	H-3 ($n = 203$)	H-4 ($n = 241$)
Delivery date	99.5	99.8	99.6	99.7
Delivery place	99.4 (0.91)	100 (1.00)	99.5 (0.92)	100(1.00)
First antenatal assessment	95.0	95.6	97.8	96.1
Gestation	96.8	97.7	96.9	97.8
Mode of delivery	99.4 (0.98)	99.3 (0.96)	100(0.99)	99.7 (0.99)
Sex of neonate	99.0 (0.99)	99.0 (0.99)	99.2 (1.00)	99.2 (1.00)
Fetus status (Alive/MAFT/stillborn)	100 (1.00)	99.5 (0.98)	99.1 (0.98)	0.99 (1.00)
Birthweight	99.5	98.9	99.6	99.4
State of perineum	97.4 (0.97)	97.2 (0.92)	95.8 (0.96)	98.8 (0.98)
Maternal infection	98.7	99.1	98.6	99.2

Table S5 | Descriptive statistics of the studied 255,668 pregnant women

No. of pregnancies (%)		
Age (Y.)	Non-MAFT (%)	MAFT (%)
18-24	10,895 (92.7)	858 (7.3)
25-29	81,561 (93.8)	5,391 (6.2)
30-34	88,562 (93.1)	6,564 (6.9)
35-39	43,045 (92.5)	3,490 (7.5)
>39	14,108 (92.2)	1,194 (7.8)
Occupation		
White-collar worker	86,766 (92.1)	7,480 (7.9)
Others*	151,405 (93.8)	100,17 (6.2)
Temperature (℃)		
<5	424,20 (92.6)	3368 (7.4)
5-10	357,03 (93.2)	2604 (6.8)
10-15	366,08 (93.4)	2567 (6.6)
15-20	48457 (93.5)	3365 (6.5)
>20	74983 (93.1)	5593 (6.9)

Table S6 | Relationships between PM$_{2.5}$ concentrations measured at the U.S. Embassy and PM$_{2.5}$ concentrations measured at each of the 34 MEE stations in Beijing from June 2014 through December 2017

No.	Station	Slope	Intercept	R^2
1	NONGZHANGUAN	0.97	3.14	0.93
2	DONGSIHUAN	0.99	5.99	0.90
3	AOTIZHONGXIN	0.83	10.08	0.80
4	QIANMEN	0.91	11.53	0.79
5	NANSANHUAN	0.94	15.36	0.80
6	WANLIU	0.84	9.36	0.81
7	DONGGAOCUN	0.67	16.70	0.63
8	FANGSHAN	0.92	16.02	0.71
9	BEIBUXINQU	0.70	20.82	0.63
10	CHANGPING	0.63	14.59	0.63
11	DAXING	0.93	17.72	0.69
12	DINGLING	0.64	11.15	0.60
13	FENGTAIHUAYUAN	0.93	11.33	0.80
14	GUCHENG	0.82	14.33	0.74
15	GUANYUAN	0.83	11.93	0.81
16	HUAIROU	0.64	13.68	0.64
17	LIULIHE	0.92	33.87	0.51
18	MENTOUGOU	0.67	13.50	0.64
19	MIYUN	0.66	11.42	0.66
20	MIYUNSHUIKU	0.52	9.86	0.56
21	PINGGU	0.70	17.78	0.62
22	ZHIWUYUAN	0.67	12.84	0.67
23	SHUNYI	0.79	11.68	0.73
24	TIANTAN	0.83	10.69	0.82
25	TONGZHOU	0.91	14.96	0.74
26	WANSHOUXIGONG	0.87	10.23	0.80
27	XIZHIMENBEI	0.88	11.07	0.80
28	YANQING	0.53	19.48	0.50
29	YIZHUANG	0.92	17.13	0.75
30	YONGDINGMENNEI	0.94	11.34	0.82
31	YONGLEDIAN	0.88	28.20	0.58
32	YUDAI	0.80	30.99	0.48
33	BADALING	0.53	11.51	0.47
34	YUNGANG	0.83	13.53	0.75

Table S7 | The ORs and 95% CIs of MAFT associated with maternal exposure to PM$_{2.5}$ in Phase 4. The ORs in the second column are computed based on daily mean PM$_{2.5}$ data over Jun. 2014 through Dec. 2017 obtained from 34 air pollution monitoring stations in Beijing. Those in the third column are computed based on daily mean PM$_{2.5}$ data over 2008 through 2017 in Beijing

PM$_{2.5}$ (μg/m^3)	ORs	ORs
0-63.1	1.07 (0.97, 1.17)	1.08 (0.98, 1.18)
63.1-71.4	1.15 (1.05, 1.25)	1.13 (1.03, 1.23)
71.4-93.3	1.29 (1.15, 1.43)	1.28 (1.14, 1.42)
93.3-130.2	1.41 (1.25, 1.57)	1.39 (1.23, 1.55)
＞130.2	1.53 (1.35, 1.71)	1.51 (1.33, 1.69)

Table S8 | Collinearity analysis between the four pollutants using the multivariate linear model

Pollutants	Tolerances	Variance inflation factors
PM$_{2.5}$	0.087	11.437
SO$_2$	0.429	2.334
CO	0.101	9.857
O$_3$	0.406	2.466