

Online-only Supplements

Interactive effects of ambient fine particulate matter and ozone on daily mortality in 372 cities: two stage time series analysis

Table of contents

eTable 1. Summary statistics on annual number of death and region specification in 372 cities of 19 countries/regions.

eTable 2. Effect estimates of PM_{2.5} and O₃ classified by different WHO regions.

eTable 3. Synergy index and relative risk of PM_{2.5} and O₃ with total mortality stratified by region and season.

eTable 4. Percent changes (central estimates and 95% confidence interval) in total mortality associated with a 10 µg/m³ increase in PM_{2.5} and O₃ on different lag days in analyses stratified by level of co-pollutant.

eTable 5. Percent changes (central estimates and 95% confidence interval) in total mortality associated with a 10 µg/m³ increase in PM_{2.5} and O₃ in analyses stratified by level of co-pollutant, using different lag structures of temperature.

eFigure 1. Map of the 374 cities in 19 countries/regions included in the analysis, and the corresponding annual mean PM_{2.5} concentrations (µg/m³).

eFigure 2. Map of the 374 cities in 19 countries/regions included in the analysis, and the corresponding annual mean O₃ concentrations (µg/m³).

eFigure 3. Boxplots of PM_{2.5} and O₃ concentrations in 372 cities of 19 countries/regions.

eFigure 4. Spearman correlations between PM_{2.5}, O₃ and temperature in 372 cities of 19 countries/regions.

eFigure 5. Percentage changes in total mortality associated with a 10 µg/m³ increase in PM_{2.5} and O₃ concentrations at the city level.

eFigure 6. Number of deaths from all causes attributable to PM_{2.5}/O₃ exposure in each country.

eTable 1. Summary statistics on annual number of death and region specification in 372 cities of 19 countries/regions.

Num	Cityname	Country/Region	Time period	Annual deaths	Latitude ^a	WHO region ^b
1	Brisbane	Australia	2003–2009	8378.7	Low–latitude	WPRO
2	Melbourne	Australia	2000–2004	20319.6	High–latitude	WPRO
3	Sydney	Australia	2000–2009	22787.3	High–latitude	WPRO
4	Abbotsford	Canada	1997–2015	2075.9	High–latitude	AMRO
5	Calgary	Canada	1997–2015	5734.3	High–latitude	AMRO
6	Edmonton	Canada	1998–2015	6775.4	High–latitude	AMRO
7	Halifax	Canada	2006–2015	2779.6	High–latitude	AMRO
8	Hamilton	Canada	1998–2015	4318.1	High–latitude	AMRO
9	Kingston	Canada	2003–2014	1672.1	High–latitude	AMRO
10	Kitchener	Canada	1998–2015	3009.6	High–latitude	AMRO
11	London Ontario	Canada	2001–2015	3494.8	High–latitude	AMRO
12	Montreal	Canada	1997–2015	14502.7	High–latitude	AMRO
13	Oakville	Canada	2003–2015	2810.5	High–latitude	AMRO
14	Oshawa	Canada	1997–2015	3305.4	High–latitude	AMRO
15	Ottawa	Canada	1998–2015	6385.5	High–latitude	AMRO
16	Regina	Canada	2001–2013	1981.8	High–latitude	AMRO
17	Sarnia	Canada	2000–2015	1230.9	High–latitude	AMRO
18	Sudbury	Canada	2004–2015	1596.5	High–latitude	AMRO
19	Saint John Nb	Canada	1997–2015	1731.6	High–latitude	AMRO
20	St. John'S Nfl	Canada	1998–2015	2211.9	High–latitude	AMRO
21	Sault Ste. Marie	Canada	2000–2015	1244.1	High–latitude	AMRO
22	Saskatoon	Canada	2003–2015	2187.8	High–latitude	AMRO
23	Thunder Bay	Canada	2001–2015	1374.5	High–latitude	AMRO
24	Toronto	Canada	1997–2015	28837.4	High–latitude	AMRO
25	Victoria	Canada	1998–2015	3283.1	High–latitude	AMRO
26	Vancouver	Canada	1999–2015	13427.1	High–latitude	AMRO
27	Windsor	Canada	1999–2015	2932.2	High–latitude	AMRO
28	Winnipeg	Canada	1997–2015	6500.7	High–latitude	AMRO
29	Beijing	China	2013–2015	28725.3	Low–latitude	WPRO
30	Guangzhou	China	2013–2015	15917.3	Low–latitude	WPRO
31	Shanghai	China	2013–2015	38262.7	Low–latitude	WPRO
32	Santiago	Chile	2008–2014	36334.9	High–latitude	AMRO
33	Valparaiso	Chile	2008–2013	4732.2	Low–latitude	AMRO
34	Famagusta	Cyprus	2010–2019	253.7	Low–latitude	EURO
35	Nicosia	Cyprus	2010–2019	1850.2	Low–latitude	EURO
36	Quito	Ecuador	2014–2018	8906.6	Low–latitude	AMRO
37	Helsinki	Finland	1994–2014	7300.4	High–latitude	EURO
38	Bordeaux	France	2007–2015	4880.9	High–latitude	EURO
39	Clermont–Ferrand	France	2007–2015	2271.6	High–latitude	EURO
40	Dijon	France	2009–2015	1801.1	High–latitude	EURO

41	Grenoble	France	2007–2015	3111.0	High–latitude	EURO
42	Le Havre	France	2007–2015	2229.6	High–latitude	EURO
43	Lille	France	2008–2015	7187.9	High–latitude	EURO
44	Lens–Douai	France	2011–2015	3348.4	High–latitude	EURO
45	Lyon	France	2007–2015	6992.1	High–latitude	EURO
46	Montpellier	France	2008–2015	2600.9	High–latitude	EURO
47	Marseille	France	2008–2015	8498.1	High–latitude	EURO
48	Nice	France	2013–2015	3803.0	High–latitude	EURO
49	Nancy	France	2008–2015	2454.0	High–latitude	EURO
50	Nantes	France	2009–2015	4199.3	High–latitude	EURO
51	Paris	France	2007–2015	40232.1	High–latitude	EURO
52	Rennes	France	2013–2015	1604.0	High–latitude	EURO
53	Rouen	France	2007–2015	3873.3	High–latitude	EURO
54	Strasbourg	France	2007–2015	3288.3	High–latitude	EURO
55	Toulouse	France	2007–2015	4661.9	High–latitude	EURO
56	Berlin	Germany	2008–2015	33422.6	High–latitude	EURO
57	Bremen	Germany	2007–2015	6504.9	High–latitude	EURO
58	Dresden	Germany	2008–2015	5344.3	High–latitude	EURO
59	Dortmund	Germany	2008–2015	6851.1	High–latitude	EURO
60	Dusseldorf	Germany	2009–2015	6592.9	High–latitude	EURO
61	Frankfurt	Germany	2008–2015	7221.1	High–latitude	EURO
62	Hamburg	Germany	2004–2015	18242.8	High–latitude	EURO
63	Hannover	Germany	2007–2015	11111.4	High–latitude	EURO
64	Leipzig	Germany	2010–2015	7209.3	High–latitude	EURO
65	Muenchen	Germany	2008–2015	12854.1	High–latitude	EURO
66	Stuttgart	Germany	2006–2015	5940.1	High–latitude	EURO
67	Tehran	Iran	2013–2015	48653.3	Low–latitude	WPRO
68	Beer Sheva	Israel	2011–2020	1419.4	Low–latitude	WPRO
69	Haifa	Israel	2000–2020	4637.5	Low–latitude	WPRO
70	Jerusalem	Israel	2002–2019	3236.9	Low–latitude	WPRO
71	Tel Aviv	Israel	2000–2020	9733.7	Low–latitude	WPRO
72	Aikita	Japan	2012–2015	3249.3	Low–latitude	WPRO
73	Aomori	Japan	2013–2015	3149.0	High–latitude	WPRO
74	Chiba	Japan	2011–2015	7256.4	Low–latitude	WPRO
75	Fukushima	Japan	2014–2015	2667.5	Low–latitude	WPRO
76	Fukuoka	Japan	2011–2015	10266.6	Low–latitude	WPRO
77	Fukui	Japan	2011–2015	2695.8	Low–latitude	WPRO
78	Gifu	Japan	2011–2015	4170.4	Low–latitude	WPRO
79	Hiroshima	Japan	2011–2015	9130.0	Low–latitude	WPRO
80	Kagoshima	Japan	2011–2015	5430.0	Low–latitude	WPRO
81	Kumamoto	Japan	2014–2015	5709.5	Low–latitude	WPRO
82	Kanazawa	Japan	2013–2015	3894.7	Low–latitude	WPRO
83	Kobe	Japan	2011–2015	12780.2	Low–latitude	WPRO
84	Kochi	Japan	2012–2015	3329.0	Low–latitude	WPRO

85	Kofu	Japan	2011–2015	2142.0	Low–latitude	WPRO
86	Kyoto	Japan	2012–2015	12906.8	Low–latitude	WPRO
87	Matsue	Japan	2011–2015	2226.8	Low–latitude	WPRO
88	Maebashi	Japan	2011–2015	3299.4	Low–latitude	WPRO
89	Mito	Japan	2012–2015	2363.5	Low–latitude	WPRO
90	Morioka	Japan	2011–2015	2668.0	Low–latitude	WPRO
91	Matsuyama	Japan	2011–2015	4806.8	Low–latitude	WPRO
92	Miyazaki	Japan	2013–2015	3213.7	Low–latitude	WPRO
93	Nagano	Japan	2011–2015	3963.6	Low–latitude	WPRO
94	Nagoya	Japan	2011–2015	20162.0	Low–latitude	WPRO
95	Naha	Japan	2014–2015	2229.0	Low–latitude	WPRO
96	Nara	Japan	2012–2015	3154.5	Low–latitude	WPRO
97	Nagasaki	Japan	2014–2015	4237.5	Low–latitude	WPRO
98	Niigata	Japan	2011–2015	8076.4	Low–latitude	WPRO
99	Oita	Japan	2011–2015	3972.0	Low–latitude	WPRO
100	Okayama	Japan	2012–2015	6013.8	Low–latitude	WPRO
101	Osaka	Japan	2011–2015	27147.2	Low–latitude	WPRO
102	Otsu	Japan	2013–2015	2607.0	Low–latitude	WPRO
103	Saga	Japan	2012–2015	2338.5	Low–latitude	WPRO
104	Saitama	Japan	2011–2015	8222.0	Low–latitude	WPRO
105	Sendai	Japan	2011–2015	7608.4	Low–latitude	WPRO
106	Shizuoka	Japan	2011–2015	7058.2	Low–latitude	WPRO
107	Sapporo	Japan	2011–2015	16041.2	High–latitude	WPRO
108	Takamatsu	Japan	2012–2015	3887.3	Low–latitude	WPRO
109	Tokushima	Japan	2011–2015	2758.0	Low–latitude	WPRO
110	Tokyo	Japan	2011–2015	74837.4	Low–latitude	WPRO
111	Toyama	Japan	2012–2015	4167.5	Low–latitude	WPRO
112	Tsu	Japan	2011–2015	2983.8	Low–latitude	WPRO
113	Utsunomiya	Japan	2013–2015	4009.0	Low–latitude	WPRO
114	Wakayama	Japan	2011–2015	4289.8	Low–latitude	WPRO
115	Yokohama	Japan	2011–2015	27801.2	Low–latitude	WPRO
116	Yamaguchi	Japan	2011–2015	1923.2	Low–latitude	WPRO
117	Yamagata	Japan	2012–2015	2501.8	Low–latitude	WPRO
118	Oslo	Norway	2000–2018	4447.7	High–latitude	EURO
119	Beja	Portugal	2005–2018	2265.6	Low–latitude	EURO
120	Castelobranco	Portugal	2004–2018	2742.6	Low–latitude	EURO
121	Faro	Portugal	2004–2018	4618.3	Low–latitude	EURO
122	Lisboa	Portugal	2004–2018	21041.0	Low–latitude	EURO
123	Brasov	Romania	2009–2016	2703.0	High–latitude	EURO
124	Constanta	Romania	2009–2016	3227.4	High–latitude	EURO
125	Craiova	Romania	2009–2016	2609.8	High–latitude	EURO
126	Galati	Romania	2009–2016	2448.6	High–latitude	EURO
127	Timisoara	Romania	2009–2016	3009.9	High–latitude	EURO
128	Albacete	Spain	2009–2013	1110.2	Low–latitude	EURO

129	Bilbao	Spain	2011–2012	3093.0	High–latitude	EURO
130	Barcelona	Spain	2004–2014	15228.5	High–latitude	EURO
131	Burgos	Spain	2009–2013	1338.8	High–latitude	EURO
132	Huesca	Spain	2010–2011	464.5	High–latitude	EURO
133	Madrid	Spain	2009–2013	25888.6	High–latitude	EURO
134	Oviedo	Spain	2009–2012	1706.0	High–latitude	EURO
135	Palmas G. Canaria	Spain	2009–2013	2890.0	Low–latitude	EURO
136	Palma Mallorca	Spain	2010–2012	2745.3	Low–latitude	EURO
137	San Sebastian	Spain	2011–2012	1544.5	High–latitude	EURO
138	Tenerife	Spain	2010–2013	1588.0	Low–latitude	EURO
139	Toledo	Spain	2010–2013	482.5	Low–latitude	EURO
140	Vitoria	Spain	2011–2012	1534.5	High–latitude	EURO
141	Valladolid	Spain	2010–2013	2746.8	High–latitude	EURO
142	Valencia	Spain	2009–2013	6907.8	Low–latitude	EURO
143	Kaohsiung	Taiwan	2007–2014	17127.3	Low–latitude	WPRO
144	Taipei	Taiwan	2007–2014	32742.8	Low–latitude	WPRO
145	Taichung	Taiwan	2007–2014	13388.3	Low–latitude	WPRO
146	Blackpool	United Kingdom	2010–2016	2013.3	High–latitude	EURO
147	Birkenhead	United Kingdom	2010–2016	2549.3	High–latitude	EURO
148	Bristol	United Kingdom	2008–2016	3621.3	High–latitude	EURO
149	Cardiff	United Kingdom	2008–2016	2434.2	High–latitude	EURO
150	Coventry	United Kingdom	2008–2016	1965.1	High–latitude	EURO
151	Eastbourne	United Kingdom	2009–2016	731.5	High–latitude	EURO
152	Kingston Upon Hull	United Kingdom	2008–2016	2147.9	High–latitude	EURO
153	Leicester	United Kingdom	2008–2016	2713.3	High–latitude	EURO
154	London	United Kingdom	1998–2016	55312.0	High–latitude	EURO
155	Liverpool	United Kingdom	2008–2016	6446.8	High–latitude	EURO
156	Manchester	United Kingdom	2008–2016	14836.6	High–latitude	EURO
157	Norwich	United Kingdom	2009–2016	1111.5	High–latitude	EURO
158	Nottingham	United Kingdom	2008–2016	4077.8	High–latitude	EURO
159	Newport	United Kingdom	2008–2016	1272.7	High–latitude	EURO
160	Plymouth	United Kingdom	2010–2016	1714.9	High–latitude	EURO
161	Preston	United Kingdom	2010–2016	1514.6	High–latitude	EURO
162	Reading	United Kingdom	2008–2016	1397.8	High–latitude	EURO
163	Sheffield	United Kingdom	2008–2016	3657.9	High–latitude	EURO
164	Sunderland	United Kingdom	2008–2016	1927.0	High–latitude	EURO
165	South Hampshire	United Kingdom	2008–2016	4659.4	High–latitude	EURO
166	Southend–On–Sea	United Kingdom	2009–2016	2231.1	High–latitude	EURO
167	Stoke–On–Trent	United Kingdom	2008–2016	2129.0	High–latitude	EURO
168	Swansea	United Kingdom	2007–2016	1497.9	High–latitude	EURO
169	Teesside	United Kingdom	2008–2016	2490.0	High–latitude	EURO
170	Tyneside	United Kingdom	2008–2016	5300.2	High–latitude	EURO
171	Wigan	United Kingdom	2008–2016	807.0	High–latitude	EURO
172	West Midlands	United Kingdom	2008–2016	16894.6	High–latitude	EURO

173	West Yorkshire	United Kingdom	2008–2016	9419.4	High–latitude	EURO
174	Augusta	United States	1999–2006	1746.0	Low–latitude	AMRO
175	Akron	United States	1999–2006	5043.8	High–latitude	AMRO
176	Albany	United States	1999–2006	2456.1	High–latitude	AMRO
177	Albuquerque	United States	1999–2006	3802.3	Low–latitude	AMRO
178	Allentown	United States	1999–2006	2933.6	High–latitude	AMRO
179	Anchorage	United States	1999–2006	946.0	High–latitude	AMRO
180	Anaheim	United States	1999–2006	15799.3	Low–latitude	AMRO
181	Ann Arbor	United States	1999–2006	1594.1	High–latitude	AMRO
182	Annandale	United States	1999–2006	3706.6	Low–latitude	AMRO
183	Austin	United States	1999–2006	3523.1	Low–latitude	AMRO
184	Atlantic City	United States	2001–2006	2160.8	Low–latitude	AMRO
185	Atlanta	United States	1999–2006	15520.5	Low–latitude	AMRO
186	Aztec	United States	1999–2006	482.3	Low–latitude	AMRO
187	Buffalo	United States	1999–2006	8779.4	High–latitude	AMRO
188	Bakersfield	United States	1999–2006	4626.6	Low–latitude	AMRO
189	Boulder	United States	1999–2006	1245.8	Low–latitude	AMRO
190	Baltimore	United States	1999–2006	13489.8	Low–latitude	AMRO
191	Bangor	United States	1999–2006	1264.0	High–latitude	AMRO
192	Boise City	United States	1999–2006	404.8	High–latitude	AMRO
193	Paterson	United States	1999–2006	10230.4	High–latitude	AMRO
194	Burlington	United States	1999–2006	855.9	High–latitude	AMRO
195	Birmingham	United States	1999–2006	8348.6	Low–latitude	AMRO
196	Brownsville	United States	2000–2006	1856.3	Low–latitude	AMRO
197	Boston	United States	1999–2006	20088.9	High–latitude	AMRO
198	Baton Rouge	United States	1999–2006	3204.0	Low–latitude	AMRO
199	Cedar Rapids	United States	1999–2006	1364.5	High–latitude	AMRO
200	Chicago	United States	1999–2006	48974.5	High–latitude	AMRO
201	Charlotte	United States	1999–2006	4076.6	Low–latitude	AMRO
202	Charleston	United States	1999–2006	2503.3	Low–latitude	AMRO
203	Chattanooga	United States	2000–2006	2732.0	Low–latitude	AMRO
204	Charleston	United States	1999–2006	2265.8	Low–latitude	AMRO
205	Columbus	United States	1999–2006	7685.0	Low–latitude	AMRO
206	Colorado Springs	United States	1999–2006	2650.5	Low–latitude	AMRO
207	Cleveland	United States	1999–2006	18464.8	High–latitude	AMRO
208	Cincinnati	United States	1999–2006	7662.6	Low–latitude	AMRO
209	Canton	United States	1999–2006	3635.0	High–latitude	AMRO
210	Columbia	United States	1999–2006	3940.0	Low–latitude	AMRO
211	Corpus Christi	United States	2000–2006	2278.0	Low–latitude	AMRO
212	Layton	United States	1999–2006	1050.4	High–latitude	AMRO
213	Dallas	United States	1999–2006	12578.6	Low–latitude	AMRO
214	Denver	United States	1999–2006	8869.6	Low–latitude	AMRO
215	Beaver Dam	United States	1999–2006	607.5	High–latitude	AMRO
216	Dover	United States	1999–2006	1013.0	Low–latitude	AMRO

217	Durham	United States	1999–2006	1490.6	Low–latitude	AMRO
218	Des Moines	United States	1999–2006	2561.5	High–latitude	AMRO
219	Detroit	United States	1999–2006	33252.5	High–latitude	AMRO
220	Davenport	United States	1999–2006	2487.6	High–latitude	AMRO
221	Daytona Beach	United States	1999–2006	5482.6	Low–latitude	AMRO
222	Dayton	United States	1999–2006	4991.9	Low–latitude	AMRO
223	El Centro	United States	1999–2006	778.4	Low–latitude	AMRO
224	Elkhart	United States	1999–2006	1241.5	High–latitude	AMRO
225	El Paso	United States	1999–2006	3802.3	Low–latitude	AMRO
226	Elizabeth	United States	1999–2006	4101.4	High–latitude	AMRO
227	Erie	United States	1999–2006	2485.9	High–latitude	AMRO
228	Essex	United States	2000–2006	6024.9	High–latitude	AMRO
229	Eugene	United States	1999–2006	2678.4	High–latitude	AMRO
230	Evansville	United States	1999–2006	1643.3	Low–latitude	AMRO
231	Everett	United States	1999–2006	3679.3	High–latitude	AMRO
232	Fargo	United States	1999–2006	692.0	High–latitude	AMRO
233	Flint	United States	1999–2006	3641.6	High–latitude	AMRO
234	Fresno	United States	1999–2006	5235.9	Low–latitude	AMRO
235	Fort Lauderdale	United States	1999–2006	14467.1	Low–latitude	AMRO
236	Fort Myers	United States	1999–2006	4748.0	Low–latitude	AMRO
237	Fort Pierce	United States	1999–2006	3600.3	Low–latitude	AMRO
238	Fort Worth	United States	1999–2006	8875.6	Low–latitude	AMRO
239	Fort Wayne	United States	1999–2006	2376.0	High–latitude	AMRO
240	Fayetteville	United States	1999–2006	1759.5	Low–latitude	AMRO
241	Gary	United States	1999–2006	4193.3	High–latitude	AMRO
242	Green Bay	United States	1999–2006	1461.3	High–latitude	AMRO
243	Greensburg	United States	1999–2006	4029.4	Low–latitude	AMRO
244	Grand Haven	United States	1999–2006	1367.4	High–latitude	AMRO
245	Grand Junction	United States	1999–2006	832.3	Low–latitude	AMRO
246	Grand Rapids	United States	1999–2006	3766.4	High–latitude	AMRO
247	Greensboro	United States	1999–2006	3000.0	Low–latitude	AMRO
248	Greenville	United States	1999–2006	2831.4	Low–latitude	AMRO
249	Gainesville	United States	1999–2006	1410.4	Low–latitude	AMRO
250	Gettysburg	United States	1999–2006	605.9	Low–latitude	AMRO
251	Holland	United States	1999–2006	574.3	High–latitude	AMRO
252	Harrisburg	United States	1999–2006	2290.8	Low–latitude	AMRO
253	Hartford	United States	1999–2006	7290.4	High–latitude	AMRO
254	Houston	United States	1999–2006	17704.6	Low–latitude	AMRO
255	Indianapolis	United States	1999–2006	6893.0	Low–latitude	AMRO
256	Iowa City	United States	1999–2006	361.5	High–latitude	AMRO
257	Jacksonville	United States	1999–2006	5789.9	Low–latitude	AMRO
258	Jersey City	United States	1999–2006	4010.8	High–latitude	AMRO
259	Kalamazoo	United States	1999–2006	1739.0	High–latitude	AMRO
260	Kenosha	United States	1999–2006	1106.1	High–latitude	AMRO

261	Kansas City	United States	1999–2006	10294.4	Low–latitude	AMRO
262	Knoxville	United States	1999–2006	3786.1	Low–latitude	AMRO
263	Lafayette	United States	1999–2006	884.6	High–latitude	AMRO
264	Lafayette	United States	1999–2006	1309.8	Low–latitude	AMRO
265	Lake Charles	United States	1999–2006	1567.3	Low–latitude	AMRO
266	Lakeland	United States	1999–2006	4903.4	Low–latitude	AMRO
267	Lancaster	United States	1999–2006	4043.3	Low–latitude	AMRO
268	Logan	United States	2000–2006	316.3	High–latitude	AMRO
269	Louisville	United States	1999–2006	6401.4	Low–latitude	AMRO
270	La Porte	United States	1999–2006	834.5	High–latitude	AMRO
271	Los Angeles	United States	1999–2006	55471.5	Low–latitude	AMRO
272	Las Vegas	United States	1999–2006	11586.6	Low–latitude	AMRO
273	Little Rock	United States	1999–2006	2815.1	Low–latitude	AMRO
274	Macon	United States	1999–2006	1513.5	Low–latitude	AMRO
275	Mcallen	United States	2000–2006	2807.0	Low–latitude	AMRO
276	Middlesex	United States	1999–2006	5042.6	High–latitude	AMRO
277	Middletown	United States	1999–2006	2521.6	High–latitude	AMRO
278	Medford	United States	1999–2006	1768.5	High–latitude	AMRO
279	Madison	United States	1999–2006	2210.0	High–latitude	AMRO
280	Modesto	United States	1999–2006	3266.3	Low–latitude	AMRO
281	Madison	United States	1999–2006	2410.4	High–latitude	AMRO
282	Miami	United States	1999–2002	17043.0	Low–latitude	AMRO
283	Melbourne	United States	2000–2006	4793.3	Low–latitude	AMRO
284	Milwaukee	United States	1999–2006	10567.6	High–latitude	AMRO
285	Memphis	United States	1999–2006	7025.0	Low–latitude	AMRO
286	Toms River	United States	1999–2006	11116.0	Low–latitude	AMRO
287	Minneapolis	United States	1999–2006	10423.0	High–latitude	AMRO
288	Montgomery	United States	1999–2006	1888.4	Low–latitude	AMRO
289	Mobile	United States	1999–2006	3532.4	Low–latitude	AMRO
290	Monroe	United States	1999–2006	1260.0	Low–latitude	AMRO
291	Mercer	United States	2000–2006	1239.0	High–latitude	AMRO
292	Upper Marlboro	United States	1999–2006	3657.0	Low–latitude	AMRO
293	Muskegon	United States	1999–2006	1482.6	High–latitude	AMRO
294	Muncie	United States	1999–2006	982.9	Low–latitude	AMRO
295	Nampa	United States	1999–2006	1.0	High–latitude	AMRO
296	Nashua	United States	2001–2006	2471.0	High–latitude	AMRO
297	Melville	United States	1999–2006	19619.0	High–latitude	AMRO
298	Niles	United States	1999–2006	1394.9	High–latitude	AMRO
299	Norfolk	United States	1999–2006	9016.8	Low–latitude	AMRO
300	Nashville	United States	1999–2006	4568.4	Low–latitude	AMRO
301	Newburgh	United States	2000–2006	2253.7	High–latitude	AMRO
302	New Haven	United States	1999–2006	7188.6	High–latitude	AMRO
303	New London	United States	1999–2006	1953.5	High–latitude	AMRO
304	New Orleans	United States	1999–2006	7857.3	Low–latitude	AMRO

305	Newark	United States	1999–2006	9282.3	High–latitude	AMRO
306	New York	United States	1999–2006	50784.8	High–latitude	AMRO
307	Ocala	United States	1999–2006	3338.0	Low–latitude	AMRO
308	Oklahoma City	United States	2004–2006	4320.7	Low–latitude	AMRO
309	Oakland	United States	1999–2006	15111.8	Low–latitude	AMRO
310	Omaha	United States	1999–2006	3271.0	High–latitude	AMRO
311	Orlando	United States	1999–2006	8296.0	Low–latitude	AMRO
312	Ottawa	United States	2000–2006	1185.6	High–latitude	AMRO
313	Philadelphia	United States	1999–2006	40975.0	Low–latitude	AMRO
314	Phoenix	United States	1999–2006	21071.3	Low–latitude	AMRO
315	Palm Beach	United States	1999–2006	12048.3	Low–latitude	AMRO
316	Plymouth	United States	2000–2006	3663.6	High–latitude	AMRO
317	Pensacola	United States	1999–2006	2597.4	Low–latitude	AMRO
318	Portland	United States	1999–2006	10123.1	High–latitude	AMRO
319	Provo	United States	1999–2006	1480.5	Low–latitude	AMRO
320	Port Arthur	United States	2000–2006	2301.1	Low–latitude	AMRO
321	Portage	United States	1999–2006	1028.3	High–latitude	AMRO
322	Portland	United States	1999–2006	2181.9	High–latitude	AMRO
323	Providence	United States	1999–2006	11231.9	High–latitude	AMRO
324	Pittsburgh	United States	1999–2006	13948.6	High–latitude	AMRO
325	Richmond	United States	1999–2006	5595.3	Low–latitude	AMRO
326	Rochester	United States	1999–2006	5412.8	High–latitude	AMRO
327	Rockville	United States	1999–2006	4191.9	Low–latitude	AMRO
328	Reading	United States	1999–2006	3306.6	Low–latitude	AMRO
329	Reno	United States	1999–2006	2492.8	Low–latitude	AMRO
330	Raleigh	United States	1999–2006	3033.9	Low–latitude	AMRO
331	Riverside	United States	1999–2006	22919.1	Low–latitude	AMRO
332	Sacramento	United States	1999–2006	8813.8	Low–latitude	AMRO
333	Scranton	United States	1999–2006	6791.6	High–latitude	AMRO
334	San Diego	United States	1999–2006	18226.9	Low–latitude	AMRO
335	San Francisco	United States	1999–2006	10066.6	Low–latitude	AMRO
336	Salt Lake City	United States	1999–2006	4605.4	High–latitude	AMRO
337	San Jose	United States	1999–2006	8150.9	Low–latitude	AMRO
338	San Antonio	United States	1999–2003	7475.8	Low–latitude	AMRO
339	Spokane	United States	1999–2006	3329.9	High–latitude	AMRO
340	Springfield	United States	2000–2006	4276.9	High–latitude	AMRO
341	Springfield	United States	1999–2006	2179.9	Low–latitude	AMRO
342	Spartanburg	United States	1999–2006	2297.6	Low–latitude	AMRO
343	Sarasota	United States	1999–2006	7360.4	Low–latitude	AMRO
344	Steubenville	United States	1999–2006	1010.9	Low–latitude	AMRO
345	St. Charles	United States	1999–2006	1653.5	Low–latitude	AMRO
346	Stockton	United States	1999–2006	4141.4	Low–latitude	AMRO
347	South Bend	United States	1999–2006	2158.1	High–latitude	AMRO
348	St. Louis	United States	1999–2006	13965.8	Low–latitude	AMRO

349	Stamford	United States	1999–2006	6319.9	High–latitude	AMRO
350	St. Petersburg	United States	1999–2006	7968.8	Low–latitude	AMRO
351	State College	United States	2000–2006	798.1	High–latitude	AMRO
352	Seattle	United States	1999–2006	10569.5	High–latitude	AMRO
353	Tacoma	United States	1999–2006	4900.1	High–latitude	AMRO
354	Tampa	United States	1999–2006	7968.8	Low–latitude	AMRO
355	Tucson	United States	1999–2006	6852.9	Low–latitude	AMRO
356	Tallahassee	United States	1999–2006	1386.9	Low–latitude	AMRO
357	Toledo	United States	1999–2006	4067.9	High–latitude	AMRO
358	Trenton	United States	1999–2006	2502.3	Low–latitude	AMRO
359	Terre Haute	United States	1999–2006	1058.9	Low–latitude	AMRO
360	Tulsa	United States	2004–2006	3665.7	Low–latitude	AMRO
361	Visalia	United States	1999–2006	2424.6	Low–latitude	AMRO
362	Vancouver	United States	1999–2005	2060.9	High–latitude	AMRO
363	Ventura	United States	1999–2006	4447.8	Low–latitude	AMRO
364	Wichita	United States	1999–2006	3400.3	Low–latitude	AMRO
365	Ogden	United States	1999–2006	1253.1	High–latitude	AMRO
366	Wilmington	United States	1999–2006	3625.5	Low–latitude	AMRO
367	Winston–Salem	United States	1999–2006	2567.5	Low–latitude	AMRO
368	Worcester	United States	2000–2006	6315.6	High–latitude	AMRO
369	Washington	United States	1999–2006	5283.8	Low–latitude	AMRO
370	Washington	United States	1999–2006	2260.9	Low–latitude	AMRO
371	Youngstown	United States	1999–2006	3961.4	High–latitude	AMRO
372	York	United States	1999–2006	3037.0	Low–latitude	AMRO

Notes: ^a High–Latitude (n=186), latitude above median (absolute value of 40.3°) across all cities; Low–Latitude (n=186), latitude below median across all cities.

^b Regions were classified by the World Health Organization, including the Western-Pacific Regional Office (WPRO): Australia, China, Iran, Israel, Japan, Taiwan; the Regional Office for Europe (EURO): Cyprus, Finland, France, Germany, Norway, Portugal, Romania, Spain, United Kingdom; and the Regional Office for the Americas (AMRO): Canada, Chile, Ecuador, United States.

eTable 2. Effect estimates of PM_{2.5} and O₃ classified by different WHO regions.

Regions ^a	Pollutant	Strata of Co-pollutant ^b	Estimates	<i>P</i> -values ^c
WPRO	PM _{2.5}	≤25% O ₃	0.10 (-0.08, 0.28)	<0.001
		25%–75% O ₃	0.61 (0.25, 0.97)	
		>75% O ₃	1.34 (0.69, 2.00)	
	O ₃	≤25% PM _{2.5}	0.13 (-0.17, 0.43)	
		25%–75% PM _{2.5}	0.17 (-0.03, 0.36)	
		>75% PM _{2.5}	0.21 (-0.04, 0.47)	
EURO	PM _{2.5}	≤25% O ₃	0.16 (-0.24, 0.55)	<0.001
		25%–75% O ₃	0.37 (0.06, 0.67)	
		>75% O ₃	1.46 (1.05, 1.87)	
	O ₃	≤25% PM _{2.5}	0.06 (-0.19, 0.31)	
		25%–75% PM _{2.5}	0.17 (0.04, 0.30)	
		>75% PM _{2.5}	0.20 (0.06, 0.35)	
AMRO	PM _{2.5}	≤25% O ₃	0.48 (0.18, 0.78)	<0.001
		25%–75% O ₃	1.02 (0.72, 1.32)	
		>75% O ₃	1.35 (1.00, 1.71)	
	O ₃	≤25% PM _{2.5}	0.01 (-0.17, 0.18)	
		25%–75% PM _{2.5}	0.18 (0.07, 0.30)	
		>75% PM _{2.5}	0.34 (0.21, 0.47)	

Abbreviations: WHO, World Health Organization.

Notes: ^a Regions were classified by the World Health Organization, including the Western-Pacific Regional Office (WPRO): Australia, China, Iran, Israel, Japan, Taiwan; the Regional Office for Europe (EURO): Cyprus, Finland, France, Germany, Norway, Portugal, Romania, Spain, United Kingdom; and the Regional Office for the Americas (AMRO): Canada, Chile, Ecuador, United States.

^b Strata were built based on the 25% and 75% quartiles of PM_{2.5} and O₃ concentrations.

^c *P*-values for interactions were obtained from likelihood ratio tests. *P*-values <0.05 indicate significant between-group differences.

eTable 3. Synergy index and relative risk of PM_{2.5} and O₃ with total mortality stratified by region and season.

Category	Region (relative risk and 95%CI)		Season (relative risk and 95%CI)	
	High-Latitude	Low-Latitude	Warm	Cold
Low-low	Reference	Reference	Reference	Reference
Low-high	1.000 (0.997, 1.004)	1.001 (0.997, 1.005)	0.999 (0.996, 1.002)	0.999 (0.996, 1.002)
High-low	1.008 (1.004, 1.011)	1.006 (1.004, 1.009)	1.011 (1.008, 1.013)	1.005 (1.002, 1.008)
High-high	1.020 (1.016, 1.025)	1.011 (1.007, 1.015)	1.017 (1.013, 1.020)	1.007 (1.004, 1.010)
Synergy index	2.59 (1.59, 6.87)	1.49 (1.01, 5.46)	1.68 (1.28, 3.01)	1.86 (1.09, 4.22)

Notes: Relative risk compares risk for certain strata of low/high levels of air pollutants to days with low levels for both pollutants. Low and high designations were based on whether levels were above or below the median values of air pollutants across cities. High-Latitude, latitude above median (absolute value 40.3°) across all cities; Low-Latitude, latitude below median across all cities. Warm season, March to August for northern hemisphere; Cold season, September to February for northern hemisphere. Low-low, low PM_{2.5} and low O₃ exposure (Reference); Low-high PM_{2.5} and high O₃ exposure (RR₀₁); High-low, high PM_{2.5} and low O₃ exposure (RR₁₀); High-high, high PM_{2.5} and high O₃ exposure (RR₁₁). Synergy index (SI) was calculated as $SI = [RR_{11} - 1] / [(RR_{10} - 1) + (RR_{01} - 1)]$.

eTable 4. Percent changes (central estimates and 95% confidence interval) in total mortality associated with a 10 µg/m³ increase in PM_{2.5} and O₃ on different lag days in analyses stratified by level of co-pollutant.

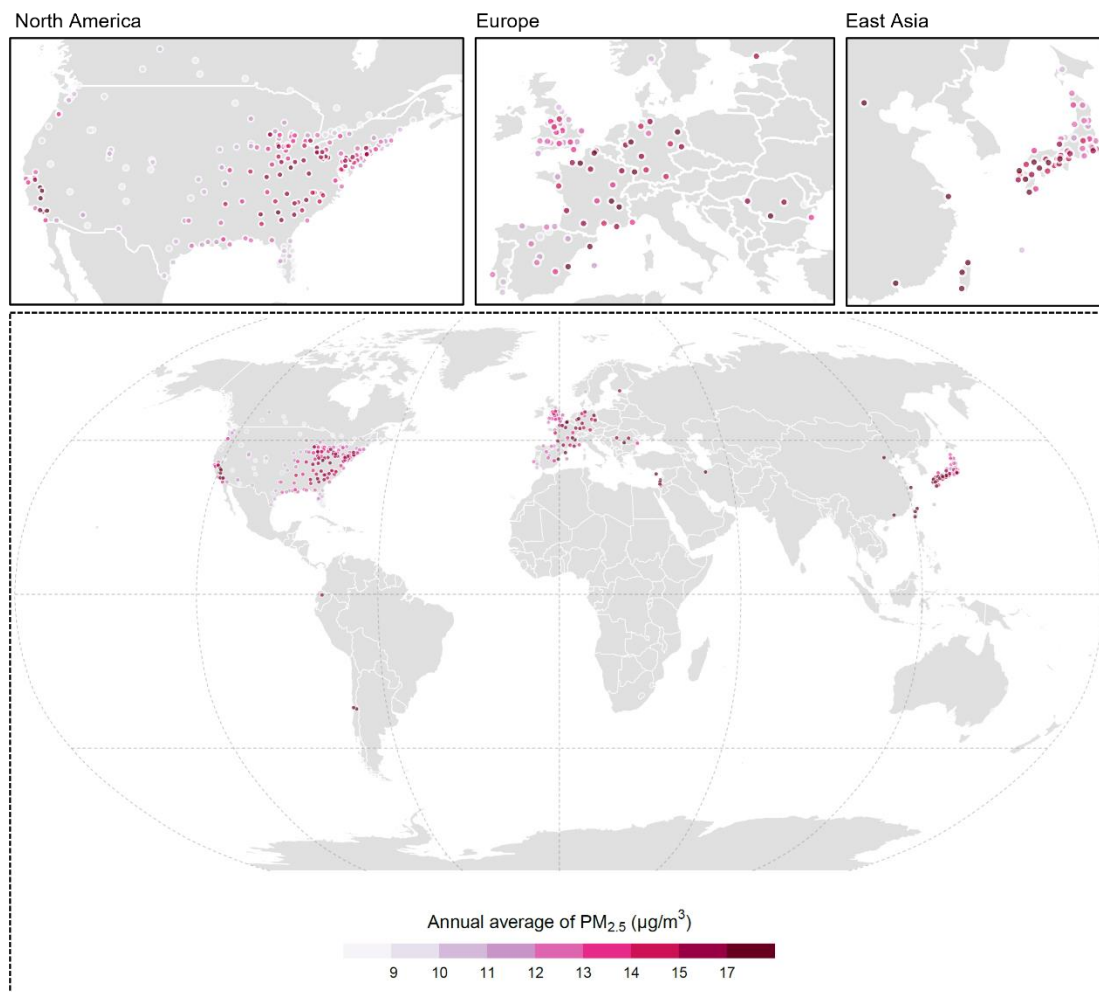
Pollutants	Strata	Estimates (% change, 95%CI)			
		Lag0	Lag0-1	Lag0-2	Lag0-3
PM _{2.5}	≤25% O ₃	0.13 (-0.02, 0.29)	0.47 (0.26, 0.67)	0.51 (0.30, 0.72)	0.44 (0.23, 0.66)
	25%–75% O ₃	0.60 (0.44, 0.75)	0.70 (0.53, 0.87)	0.55 (0.37, 0.73)	0.40 (0.21, 0.58)
	>75% O ₃	1.15 (0.94, 1.36)	1.25 (1.02, 1.48)	0.98 (0.74, 1.22)	0.66 (0.41, 0.91)
O ₃	≤25% PM _{2.5}	-0.01 (-0.11, 0.09)	0.04 (-0.09, 0.16)	0.09 (-0.04, 0.22)	0.13 (-0.01, 0.28)
	25%–75% PM _{2.5}	0.19 (0.11, 0.26)	0.19 (0.10, 0.28)	0.21 (0.11, 0.30)	0.20 (0.09, 0.31)
	>75% PM _{2.5}	0.26 (0.16, 0.35)	0.29 (0.18, 0.39)	0.32 (0.20, 0.44)	0.35 (0.22, 0.49)

Notes: PM_{2.5} and O₃ concentrations on lag0-1 day were used in the main analysis. Lag0, the present day; Lag0-1, the moving average of the present and the previous day; Lag0-2, the moving average of the present and the previous two days; Lag0-3, the moving average of the present and the previous three days.

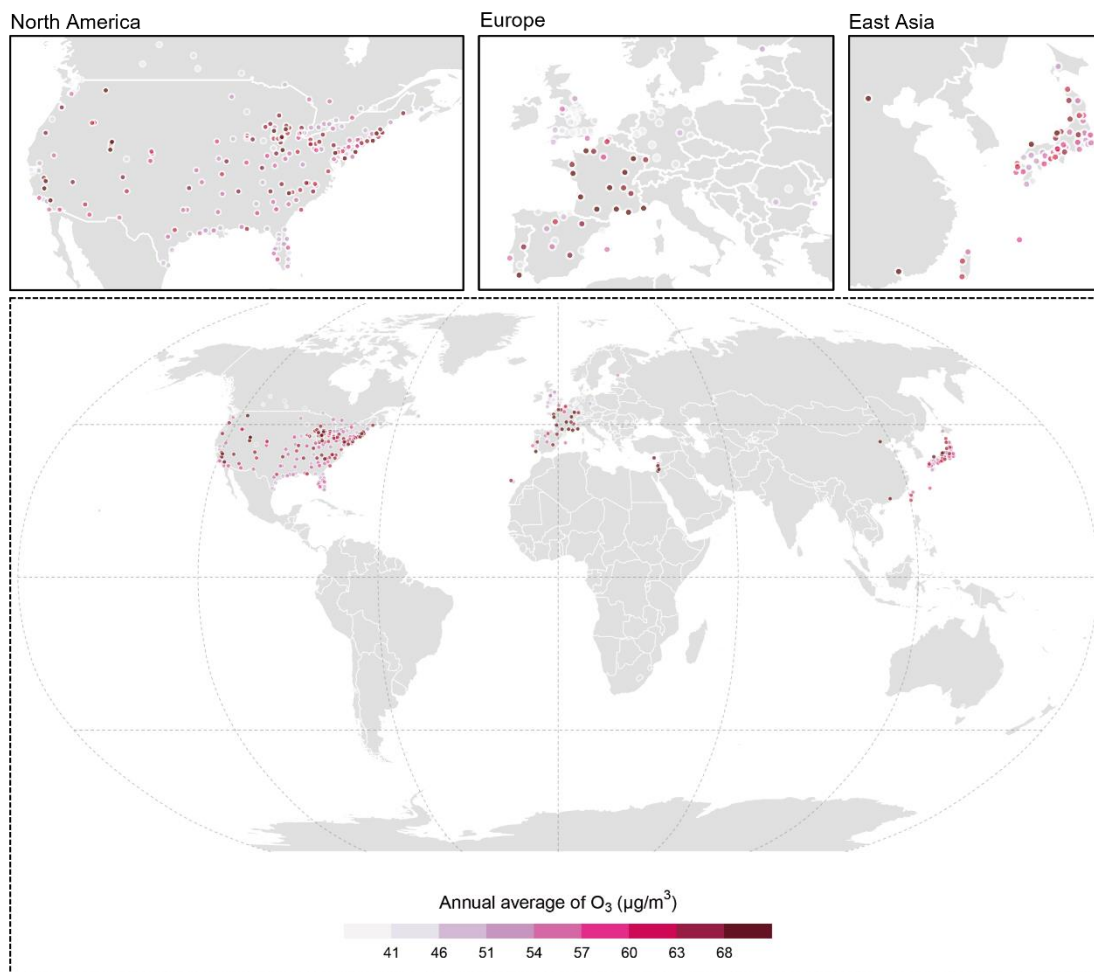
eTable 5. Percent changes (central estimates and 95% confidence interval) in total mortality associated with a 10 µg/m³ increase in PM_{2.5} and O₃ in analyses stratified by level of co-pollutant, using different lag structures of temperature.

Pollutants	Strata	Estimates (% change, 95%CI)				
		Lag0	Lag0-3	Lag0-7	Lag0-14	Lag0-21
PM _{2.5}	≤25% O ₃	0.38 (0.19, 0.57)	0.47 (0.26, 0.67)	0.39 (0.18, 0.59)	0.33 (0.12, 0.53)	0.49 (0.29, 0.68)
	25%–75% O ₃	0.30 (0.17, 0.44)	0.70 (0.53, 0.87)	0.75 (0.57, 0.93)	0.75 (0.57, 0.93)	0.85 (0.67, 1.03)
	>75% O ₃	0.73 (0.52, 0.95)	1.25 (1.02, 1.48)	1.69 (1.43, 1.94)	1.83 (1.56, 2.09)	1.88 (1.60, 2.16)
O ₃	≤25% PM _{2.5}	-0.06 (-0.19, 0.07)	0.04 (-0.09, 0.16)	0.07 (-0.06, 0.20)	0.10 (-0.03, 0.23)	0.01 (-0.12, 0.14)
	25%–75% PM _{2.5}	0.10 (0.02, 0.18)	0.19 (0.10, 0.28)	0.28 (0.18, 0.38)	0.32 (0.22, 0.42)	0.29 (0.19, 0.39)
	>75% PM _{2.5}	0.20 (0.10, 0.31)	0.29 (0.18, 0.39)	0.36 (0.25, 0.47)	0.39 (0.28, 0.50)	0.38 (0.27, 0.49)

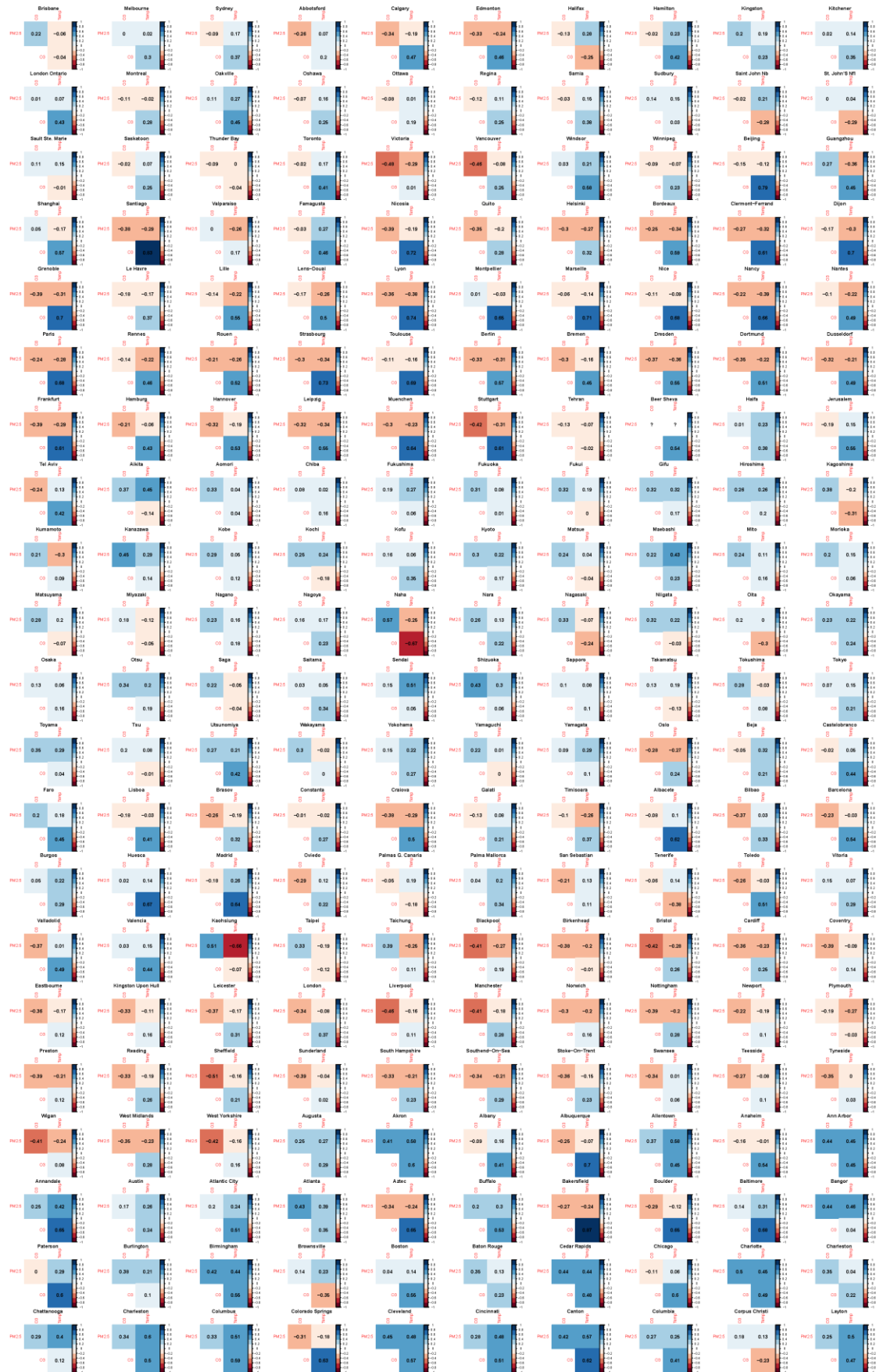
Notes: Temperature on lag0–3 day was used in the main analysis. Lag0–3, the moving average of the present and the previous day; Lag0–7, the moving average of the present and the previous seven days; Lag0–14, the moving average of the present and the previous 14 days; Lag0–21, the moving average of the present and the previous 21 days.

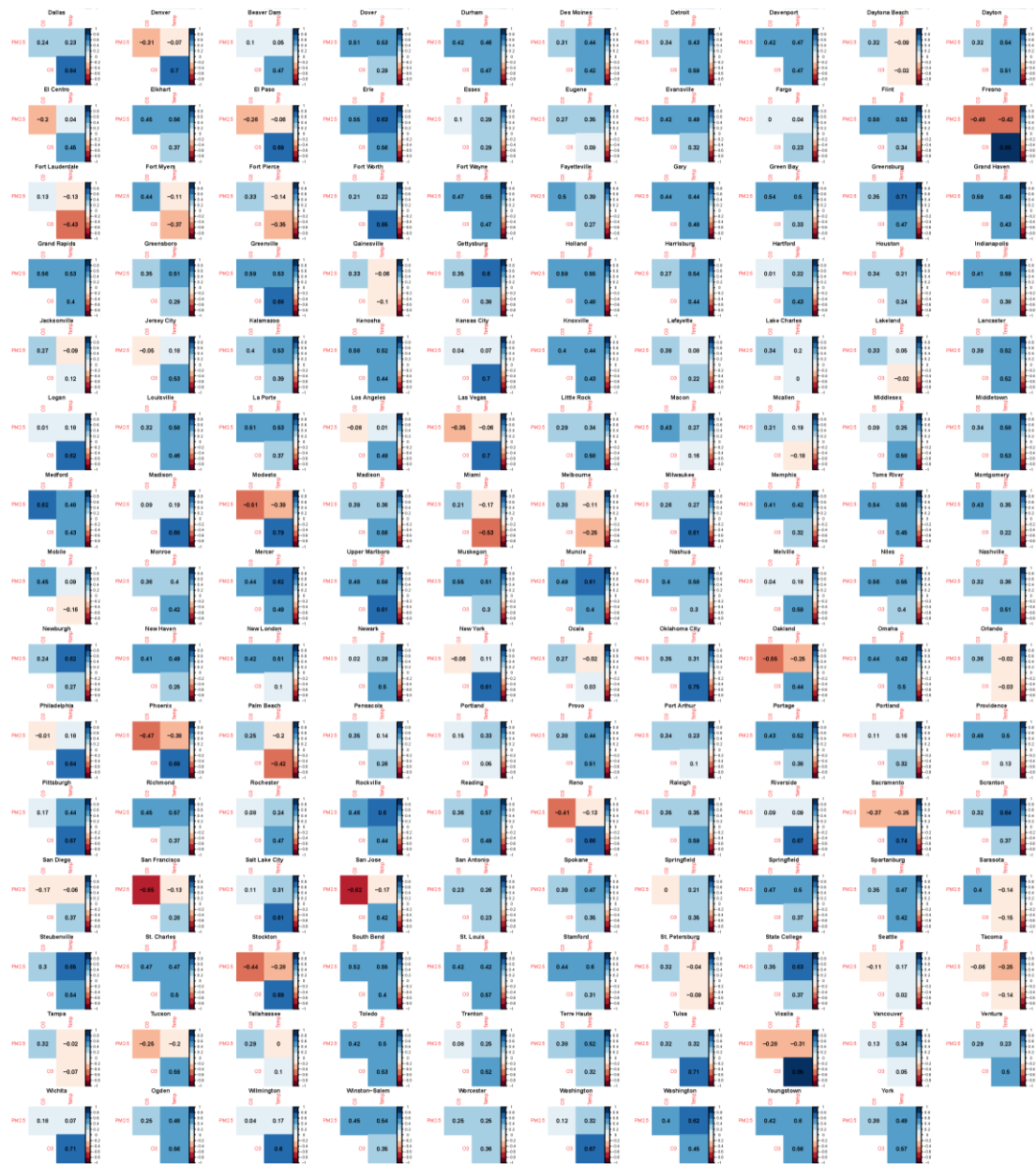


eFigure 1. Map of the 374 cities in 19 countries/regions included in the analysis, and the corresponding annual mean PM_{2.5} concentrations (µg/m³).

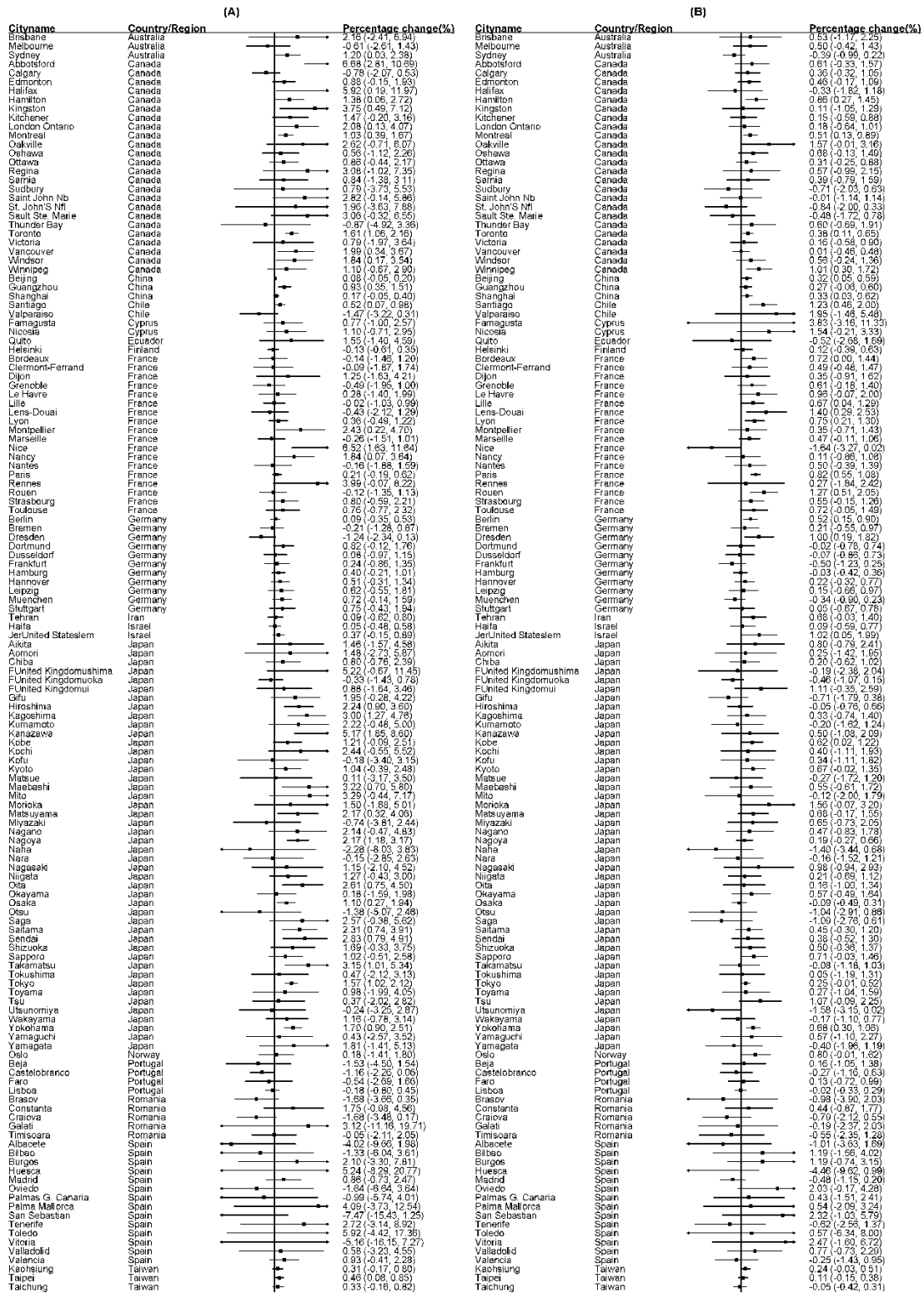


eFigure 2. Map of the 374 cities in 19 countries/regions included in the analysis, and the corresponding annual mean O₃ concentrations (µg/m³).





eFigure 4. Spearman correlations between PM_{2.5}, O₃ and temperature in 372 cities of 19 countries/regions.



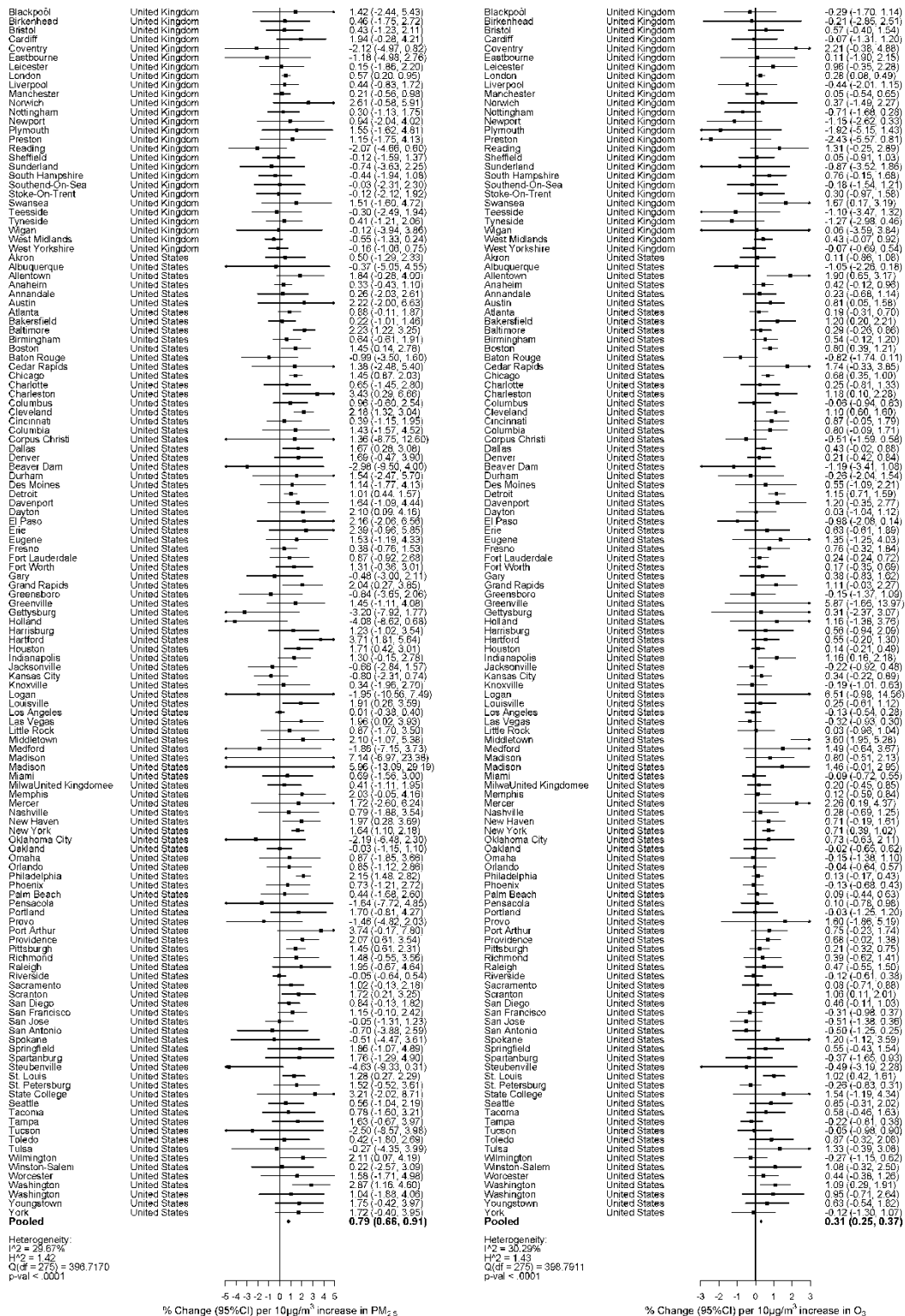
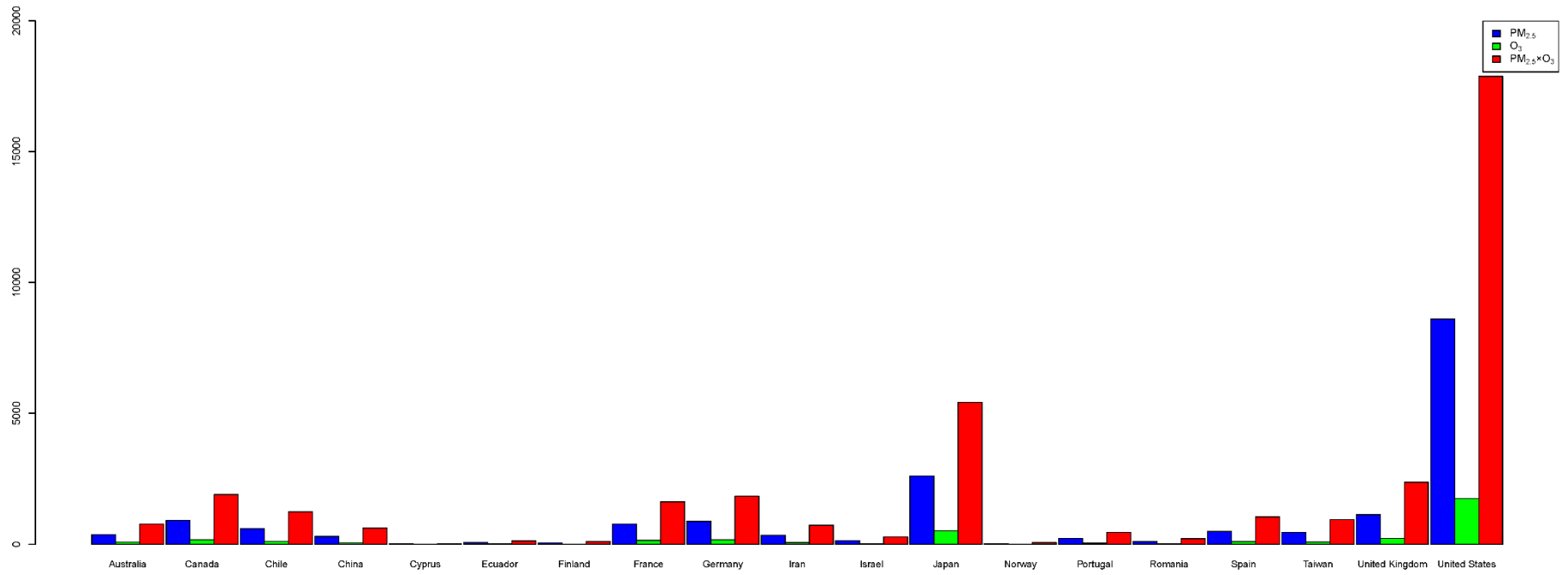


Figure 5. Percentage changes in total mortality associated with a 10 µg/m³ increase in PM_{2.5} and O₃ concentrations at the city level.



eFigure 6. Number of deaths from all causes attributable to PM_{2.5}/O₃ exposure in each country. Annual death numbers are summed from the country-specific time-series data. Population attributable risk (PAR%) was calculated based on (RR-1)/RR, where RR is the country-specific relative risk of mortality associated with exposure to PM_{2.5}, O₃ and their interaction PM_{2.5} × O₃.