The contribution of outdoor air pollution sources to premature mortality

A. Pozzer[1], J. Lelieveld [1,2], J.S. Evans [3], D.Giannadaki [2]

[1]Max Planck Institute for Chemistry, Atmospheric Chemistry Department, Mainz, Germany

[2]EEWRC, The Cyprus Institute, Nicosia, Cyprus [3]Harvard School of Public Health, Boston, USA.

Work published on Nature, 525, 367-371, doi:10.1038/nature15371, 2015

MAX-PLANCK-GESELLSCHAFT

MAX-PLANCK-INSTITUT FÜR CHEMIE

1. Introduction

Air pollution by fine particulate matter $PM2.5$ and ozone O_3 has increased strongly with industrialization and urbanization. We estimated the premature mortality rates caused by anthropogenic $PM2.5$ and O_3 on a global scale for recent past and for future years, based on numerical simulation of a "Business as Usual" (BaU) scenario. We applied a health impact function to estimate premature mortality for people of 30 years and older, using parameters derived from epidemiological cohort studies. In this work only the effects of anthropogenic emissions are investigated, thus ignoring possible effects of climate change on the atmospheric composition and not having any changes in the natural source of pollutants.

2. Methods

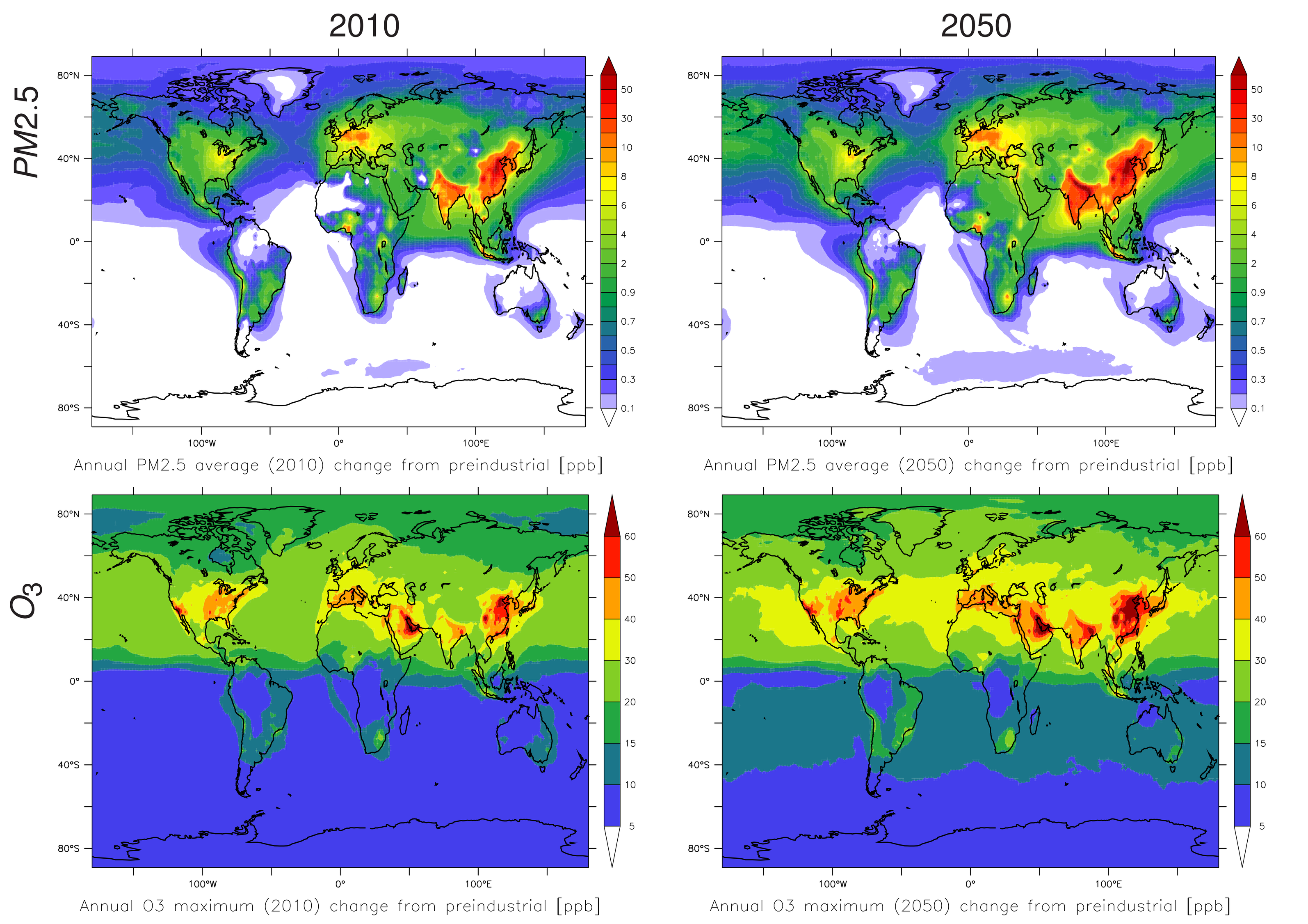
The annual premature mortality due to anthropogenic $PM2.5$ and O_3 concentrations has been estimated by employing the human health impact function adopted by the Global Burden of Deseases report [Burnett et al., 2014, GBD,, 2013]:

$$\Delta\text{Mort} = y_0\,[1 - 1/R(\beta, \Delta x)]\,\text{Pop}$$

- ΔMort is the excess mortalities attributable to air pollution.
- y_0 is the baseline mortality rate for a given population.
- $R(\beta\Delta x)$ is the concentration response function.
- Δx is the change in concentration of a given pollutants since preindustrial time.
- Pop is the total population with an age above 30 years.

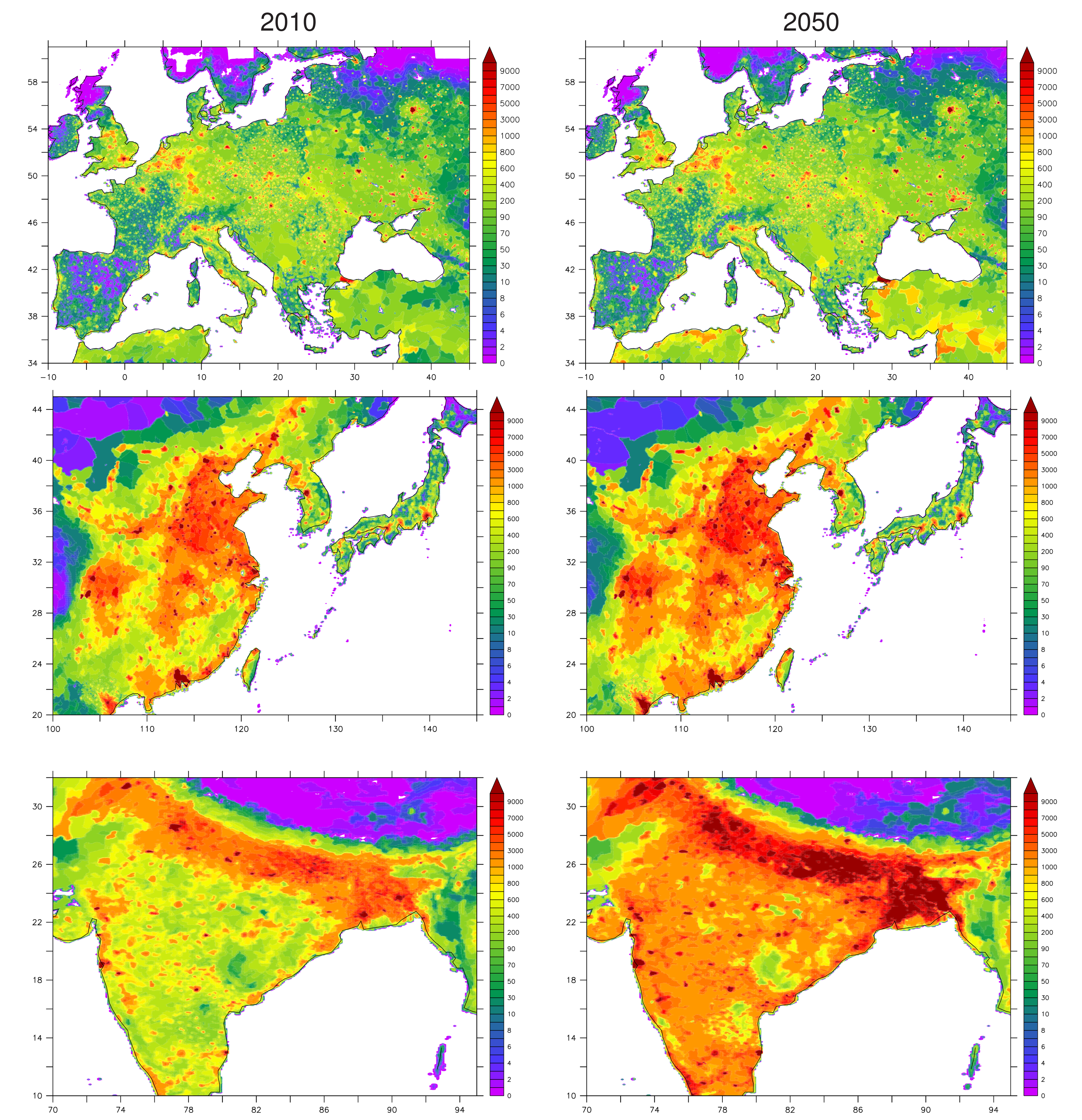
3. Model simulations

In this work we used the results obtained by Pozzer et al. [2012], where the global chemistry general circulation model EMAC [Jöckel et al., 2006, ECHAM5/MESSy for Atmospheric Chemistry] was used to estimate the potential impact of anthropogenic emission changes on air quality in recent and future years (2005, 2010, 2025 and 2050), based on a "business as usual" scenario. Natural emissions of aerosol are kept constant during all the simulations. The model was run at T106L31 resolution, corresponding to a horizontal resolution of $\approx 1.1 \times 1.1^\circ$ for the quadratic Gaussian grid, and with 31 vertical levels, up to 10 hPa in the lower stratosphere.



Simulated changes in $PM_{2.5}$ (top, in $\mu g\ m^{-3}$) and O_3 (bottom, in $pmol\ mnol^{-1}$) annual mean (maximum for $O3$) for the year 2010 (left) and the year 2050 (right) with respect to pre-industrial conditions.

4. Regional results

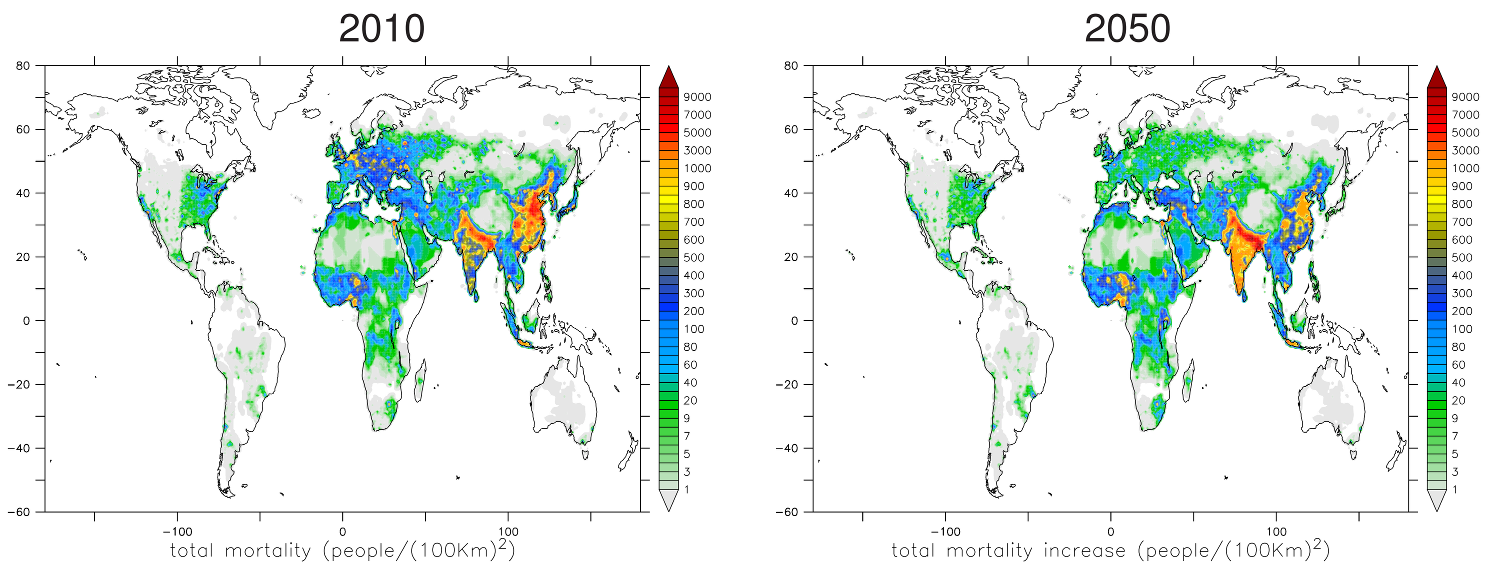


Estimated total mortality due to anthropogenic air pollution (individuals per $(100km)^2$)

Megacity	population $[1 \times 10^6]$		total mortality		ratio (mortality/population) [%]	
	2010	2050	2010	2050	2010	2050
London	8.08	10.20	2778	4229	0.0344	0.0415
Paris	8.38	10.22	3132	4597	0.0374	0.0450
Moscow	14.87	13.11	8558	11671	0.0575	0.0890
Po Valley	3.38	3.19	1299	1355	0.0384	0.0425
Istanbul	11.07	14.50	5553	13163	0.0501	0.0908
Teheran	9.74	11.35	2850	6863	0.0293	0.0605
Cairo	12.51	19.84	6023	11395	0.0482	0.0574
Lagos	8.32	21.96	3711	11157	0.0446	0.0508
Johannesburg	6.91	8.55	1523	3761	0.0220	0.0440
Karachi	11.85	19.36	7337	17886	0.0619	0.0924
Mumbai	18.02	26.77	10196	33097	0.0566	0.1236
Delhi	22.51	33.34	19656	51999	0.0873	0.1560
Kolkata	20.29	38.84	13463	54834	0.0663	0.1412
Dhaka	22.81	38.17	13081	49858	0.0574	0.1306
Szechuan	6.15	5.87	7414	9669	0.1205	0.1647
Bejing	10.78	10.41	13686	17712	0.1270	0.1701
Tianjin	3.73	3.60	4893	6335	0.1314	0.1761
Shanghai	14.11	13.19	14874	19401	0.1054	0.1470
Seoul	20.82	20.30	6640	8652	0.0319	0.0426
Tokyo	29.18	24.18	6032	5387	0.0207	0.0223
Osaka	13.48	10.85	2821	2639	0.0209	0.0243
Hong Kong	6.85	8.80	2619	4351	0.0383	0.0495
Pearl River	53.08	52.88	49239	67422	0.0928	0.1275
Manila	19.80	37.33	639	4531	0.0032	0.0121
Bankog	8.75	9.20	3125	5698	0.0357	0.0619
Jakarta	22.47	28.97	10392	22086	0.0463	0.0762
Sydney	1.82	2.99	107	243	0.0059	0.0082
Chicago	3.95	6.47	1089	2069	0.0276	0.0320
New York	12.53	17.45	3217	5173	0.0257	0.0296
Los Angeles	12.17	17.69	4090	6985	0.0336	0.0395
Atlanta	0.20	0.77	49	205	0.0250	0.0266
Mexico City	19.38	25.84	1626	5265	0.0084	0.0204
Lima	7.23	9.71	118	407	0.0016	0.0042
Rio de Janeiro	8.98	11.10	0	369	0.0000	0.0033
Sao Paulo	18.28	21.48	148	1275	0.0008	0.0059

Calculation based on urban population, i.e. with population density above 2000 $people/km^2$

5. Global results



Total global mortality for the year 2010 (left) and absolute increase between 2050 and 2010 (i.e. mortality 2050-2010, right) (Individuals per $(100km)^2$).

Region	population $[1 \times 10^6]$			ratio (mortality/population) $[1 \times 10^6]$		
	2010	2025	2050	2010	2025	2050
East-Asia	1812	1918	1861	806	1010	1111
South-Asia	1762	2059	2332	489	694	1054
West-Europe	867	890	886	438	504	598
World	6783	7838	9098	486	601	722

6.Conclusion

Based on "Business as Usual projection", it has been estimated that:

- The ratio between mortality and population will increase by $\sim$ 50% by 2050 worldwide.
- South Asia will suffer the highest increse of pro capita mortality by 2050.
- Eastern Asia has the highest actual pro capita mortality.
- Strong actions and further legislations are needed worldwide, especially in Asia.

Bibliography

Jöckel, P., Tost, H., Pozzer, A., Brühl, C., Buchholz, J., Ganzeveld, L., Hoor, P., Kerkweg, A., Lawrence, M. G., Sander, R., Steil, B., Stiller, G., Tanarhte, M., Taraborrelli, D., van Aardenne, J., and Lelieveld, J.: The atmospheric chemistry general circulation model ECHAM5/MESSy1: consistent simulation of ozone from the surface to the mesosphere, Atmos. Chem. Phys., 6, 5067–5104, doi:10.5194/acp-6-5067-2006, 2006.

Pozzer, A., de Meij, A., Pringle, K. J., Tost, H., Doering, U. M., van Aardenne, J., and Lelieveld, J.: Distributions and regional budgets of aerosols and their precursors simulated with the EMAC chemistry-climate model, Atmos. Chem. Phys., 12, 961–987, doi:10.5194/acp-12-961-2012, 2012.

Global Burden of Disease Study 2010. Global Burden of Disease Study 2010 (GBD 2010) - Ambient Air Pollution Risk Model 1990 - 2010. Seattle, i United States: Institute for Health Metrics and Evaluation (IHME), 2013.

R. T. Burnett, et al. : An Integrated Risk Function for Estimating the Global Burden of Disease Attributable to Ambient Fine Particulate Matter Exposure Environ Health Perspect, 122:397403; 2014 doi:10.1289/ehp.1307049,

J. Lelieveld, J. S. Evans, M. Fnais, D. Giannadaki and A. Pozzer The contribution of outdoor air pollution sources to premature mortality on a global scale Nature 525, 367-371, doi:10.1038/nature15371, 2015