



Find out how to access preview-only contentLook inside Get Access
Air Quality, Atmosphere & Health

March 2014

Impacts of intercontinental transport of anthropogenic fine particulate matter on human mortality

Citations

Abstract

Fine particulate matter with diameter of 2.5 μm or less ($\text{PM}_{2.5}$) is associated with premature mortality and can travel long distances, impacting air quality and health on intercontinental scales. We estimate the mortality impacts of 20 % anthropogenic primary $\text{PM}_{2.5}$ and $\text{PM}_{2.5}$ precursor emission reductions in each of four major industrial regions (North America, Europe, East Asia, and South Asia) using an ensemble of global chemical transport model simulations coordinated by the Task Force on Hemispheric Transport of Air Pollution and epidemiologically-derived concentration-response functions. We estimate that while 93–97 % of avoided deaths from reducing emissions in all four regions occur within the source region, 3–7 % (11,500; 95 % confidence interval, 8,800–14,200) occur outside the source region from concentrations transported between continents. Approximately 17 and 13 % of global deaths avoided by reducing North America and Europe emissions occur extraregionally, owing to large downwind populations, compared with 4 and 2 % for South and East Asia. The coarse resolution global models used here may underestimate intraregional health benefits occurring on local scales, affecting these relative contributions of extraregional versus intraregional health benefits. Compared with a previous study of 20 % ozone precursor emission reductions, we find that despite greater transport efficiency for ozone, absolute mortality impacts of intercontinental $\text{PM}_{2.5}$ transport are comparable or greater for neighboring source-receptor pairs, due to the stronger effect of $\text{PM}_{2.5}$ on mortality. However, uncertainties in modeling and concentration-response relationships are large for both estimates.

Page %P

Page 1

Impacts of intercontinental transport of anthropogenic fine particulate matter on human mortality

Susan C. Anenberg · J. Jason West · Hongbin Yu · Mian Chin · Michael Schulz · Dan Bergmann · Isabelle Bey · Huisheng Bian · Thomas Diehl · Arlene Fiore · Peter Hess · Elina Marmer · Veronica Montanaro · Rokjin Park · Drew Shindell · Toshihiko Takemura · Frank Dentener

Received: 27 November 2013 / Accepted: 27 January 2014
© Springer Science+Business Media Dordrecht (outside the USA) 2014

Abstract Fine particulate matter with diameter of 2.5 μm or less ($\text{PM}_{2.5}$) is associated with premature mortality and can travel long distances, impacting air quality and health on intercontinental scales. We estimate the mortality impacts of 20 % anthropogenic primary $\text{PM}_{2.5}$ and $\text{PM}_{2.5}$ precursor emission reductions in each of four major industrial regions (North America, Europe, East Asia, and South Asia) using an

ensemble of global chemical transport model simulations coordinated by the Task Force on Hemispheric Transport of Air Pollution and epidemiologically-derived concentration response functions. We estimate that while 93–97 % of avoided deaths from reducing emissions in all four regions occur within the source region, 3–7 % (11,500; 95 % confidence interval, 8,800–14,200) occur outside the source region.

Electronic supplementary material The online version of this article (doi:10.1007/s11869-014-0248-9) contains supplementary material, which is available to authorized users.

S. C. Anenberg (✉)
US Environmental Protection Agency, 1200 Pennsylvania Ave NW
MC6301A, Washington, DC 20460, USA
e-mail: anenberg.susan@epa.gov

J. J. West
University of North Carolina, Chapel Hill, NC, USA

H. Yu
University of Maryland, College Park, MD, USA

M. Chin · H. Bian · T. Diehl
NASA Goddard Space Flight Center, Greenbelt, MD, USA

M. Schulz
Norwegian Meteorological Institute, Oslo, Norway

D. Bergmann
Lawrence Livermore National Laboratory, Livermore, CA, USA

I. Bey
Swiss Federal Institute of Technology, Zurich, Switzerland

T. Diehl
Universities Space Research Association, Columbia, MD, USA

A. Fiore
Lamont-Doherty Earth Observatory, Columbia University, Palisades,
NY, USA

P. Hess
Department of Biological and Environmental Engineering, Cornell
University, Ithaca, NY, USA

E. Marmer
Department of Education, University of Hamburg, Hamburg,
Germany

V. Montanaro
University of L'Aquila, L'Aquila, Italy

R. Park
Seoul National University, Seoul, Korea

D. Shindell
NASA Goddard Institute for Space Studies, New York, NY, USA

D. Shindell
Columbia Earth Institute, New York, NY, USA

T. Takemura
Research Institute for Applied Mechanics, Kyushu University,
Fukuoka, Japan

F. Dentener
European Commission, Joint Research Center, Institute for
Environment and Sustainability, Ispra, Italy

No Body Text -- translate me!
Page 2

from concentrations transported between continents. Approximately 17 and 13 % of global deaths avoided by reducing North America and Europe emissions occur extraregionally, owing to large downwind populations, compared with 4 and 2 % for South and East Asia. The coarse resolution global models used here may underestimate intraregional health benefits occurring on local scales, affecting these relative contributions of extraregional versus intraregional health benefits. Compared with a previous study of 20 % ozone precursor emission reductions, we find that despite greater transport efficiency for ozone, absolute mortality impacts of intercontinental PM_{2.5} transport are comparable or greater for neighboring source-receptor pairs, due to the stronger effect of PM_{2.5} on mortality. However, uncertainties in modeling and concentration-response relationships are large for both estimates.

Keywords Health impact assessment · Particulate matter · Long-range transport · Chemical transport modeling

Introduction

Fine particulate matter, particles with diameter of 2.5 μm or less (PM_{2.5}), is associated with deleterious health effects, including premature mortality due to cardiopulmonary disease and lung cancer (Krewski et al. 2009). Despite its relatively short atmosphere lifetime (days to weeks), both PM_{2.5} and its precursors can travel long distances, affecting air quality and health far from the emission source (e.g., Langner et al. 1992; Park et al. 2003; Park et al. 2004; Heald et al. 2006; Chin et al. 2007; Hadley et al. 2007; Liu et al. 2009a; Liu et al. 2009b; TF HTAP 2010; Yu et al. 2008; Ewing et al. 2013). Although PM_{2.5} is transported most efficiently at altitude in the free troposphere, PM_{2.5} originating from distant sources can influence surface PM_{2.5} concentrations where people are exposed (Park et al. 2004; Chin et al. 2007; Liu et al. 2009a). In addition to dust, which is the dominant contributor to aerosol transport globally (Chin et al. 2007; Liu et al. 2009a; Yu et al. 2012), anthropogenic emission sources can affect PM_{2.5} air quality on intercontinental scales through emissions of primary PM_{2.5} (black carbon (BC) and primary organic aerosol); precursors of secondary PM_{2.5} components including sulfate (SO₄), nitrate (NO₃), and secondary organic aerosol; and changes to oxidants that influence the formation of secondary PM_{2.5} (Pham et al. 1995; Leibensperger et al. 2011; Fry et al. 2012). Because secondary components may be formed downwind, they typically affect air quality on larger spatial scales than primary emissions (Heald et al. 2006; Liu et al. 2009a; Leibensperger et al. 2011).

Compared with aerosols, intercontinental transport of ozone has generally received more attention in both science and policy arenas, since ozone has a longer atmospheric

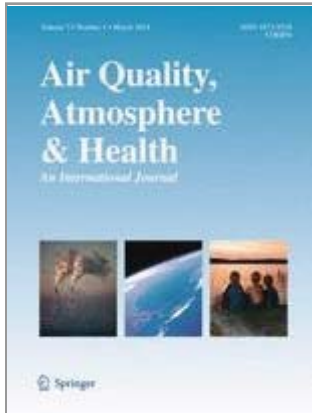
lifetime (about a month) and is transported in the atmosphere more efficiently (TF HTAP 2010). However, PM_{2.5} has a stronger effect on mortality (e.g., Bell et al. 2004; Jerrett et al. 2009; Krewski et al. 2009) and is the dominant contributor to premature mortality from outdoor air pollution (Anenberg et al. 2010; Lim et al. 2013). Previous studies that ozone precursor emissions affect health globally, with >50 % of regional ozone-related deaths caused by extraregional emissions (Anenberg et al. 2009; West et al. 2009). North American and European emissions are estimated to have greater health impacts outside the source region than within, mainly due to large exposed populations in East and South Asia (Duncan et al. 2008; Anenberg et al. 2009; Vignati et al. 2009). One previous study addressed the health impact of intercontinental PM_{2.5} transport, using a tagging approach to estimate that intercontinental transport of non-dust aerosols is associated with nearly 90,000 annual premature deaths globally, approximately 60 % of which occur in the densely populated East Asia, India, and Southeast Asia (Liu et al. 2009b).

Here, we calculate the impacts of intercontinental transport of anthropogenic PM_{2.5} on surface air quality and human mortality using an ensemble of global chemical transport models coordinated by the Task Force on Hemispheric Transport of Air Pollution (TF HTAP 2010). We use multimodel simulations of 20 % anthropogenic primary PM_{2.5} and PM_{2.5} precursor emission reductions in each of four major industrial regions to calculate their impact on premature mortality within the region and elsewhere in the world. Compared with estimates made using a single atmospheric model, using a multimodel ensemble allows a more robust estimate and characterization of uncertainty due to intermodel differences (e.g., Fiore et al. 2009). As ambient air quality standards continue to tighten and controlling local emissions becomes increasingly expensive in some countries, improved understanding of foreign emission contributions to PM_{2.5} concentrations and mortality may help inform future mitigation strategies (Keating et al. 2004).

Methods

We use TF HTAP multimodel ensemble estimates of the impact of 20 % regional emission reductions on PM_{2.5} concentrations around the world. The TF HTAP was established in 2004 by the Convention on Long-Range Transboundary Air Pollution (CLRTAP) to improve understanding of intercontinental transport of air pollutants across the Northern Hemisphere for consideration by the CLRTAP. Over the last decade, the TF HTAP has organized a series of multimodel experiments to advance the state of the science related to the transport of pollutants, including ozone and PM_{2.5}, among others. The first set of multimodel exper-

No Body Text -- translate me!



Within this Article

1. Introduction
2. Methods
3. Results
4. Discussion
5. References
6. References

Related Content



Supplementary Material (1)

- 11869_2014_248_MOESM1_ESM.docx (1299KB)
ESM 1:
(DOCX 1,298 kb)

References (49)

1. Anenberg SC, West JJ, Fiore AM, Jaffe DA, Prather MJ, Bregmann D, Cuvelier K, Dentener FJ, Duncan BN, Gauss M, Hess P, Jonson JE, Lupu A, MacKenzie IA, Marmer E, Park RJ, Sanderson MG, Schultz M, Shindell DT, Szopa S, Vivanco MG, Wild O, Zeng G (2009) Intercontinental impacts of ozone air pollution on human mortality. *Environ Sci Technol* 43:6482–6487 CrossRef
2. Anenberg SC, Horowitz LW, Tong DQ, West JJ (2010) An estimate of the global burden of anthropogenic ozone and fine particulate matter on premature human mortality using atmospheric modeling. *Environ Health Perspect* 118:1189–1195 CrossRef
3. Anenberg SC, Schwartz J, Shindell D, Amann M, Faluvegi G, Klimont Z, Janssens-Maenhout G, Pozzoli L, Van Dingenen R, Vignati E, Emberson L, Muller NZ, West JJ, Williams M, Demkine V, Hicks WK, Kuylensstierna J, Raes F, Ramanathan V (2012) Global air quality and health co-benefits of mitigating near-term climate change through methane and black carbon emission controls. *Environ Health Perspect* 120:831–839 CrossRef
4. Beelen R, Raaschou-Nielsen O, Stafoggia M, Andersen ZJ, Weinmayr G, Hoffmann B, Wolf K, Samoli E, Fischer P, Nieuwenhuijsen M, Vineis P, Xun WW, Katsouyanni K, Dimakopoulou K, Oudin A, Forsberg B, Modig L, Havulinna AS, Lanki T, Turunen A, Oftedal B, Nystad W, Nafstad P, De Faire U, Pedersen NL, Ostenson C-G, Fratiglioni L, Pennell J, Korek M, Pershagen G, Eriksen KT, Overvad K, Ellermann T, Eeftens M, Peeters PH, Meliefste K, Wang M, Bueno-de-Mesquita B, Sugiri D, Kramer U, Heinrich J, de Hoogh K, Key T, Peters A, Hampel R, Concin H, Nagel G, Ineichen A, Schaffner E, Probst-Hensch N, Kunzli N, Schindler C, Schikowski T, Adam M, Krogh HV, Tsai M-Y, Ricceri F, Sacerdote C, Galassi C, Migliore E, Ranzi A, Cesaroni G, Badaloni C, Forastiere F, Tamayo I, Amiano P, Dorronsoro M, Katsoulis M, Trichopoulou A,

- Brunekreef B, Hoek G (2013) Effects of long-term exposure to air pollution on natural-cause mortality: an analysis of 22 European cohorts within the multicentre ESCAPE project. *Lancet*. doi: 10.1016/S0140-6736(13)62158-3
5. Bell ML, McDermott A, Zeger SL, Samet JM, Dominici F (2004) Ozone and short-term mortality in 95 US urban communities. *JAMA* 292:2372–2378 CrossRef
 6. Brauer M, Amann M, Burnett RT, Cohen A, Dentener F, Ezzati M, Henderson SB, Krzyzanowski M, Martin RV, Van Dingenen R, Van Donkelaar A, Thurston GD (2012) Exposure assessment for estimation of the global burden of disease attributable to outdoor air pollution. *Environ Sci Technol* 46:652–660 CrossRef
 7. Chin M, Diehl T, Ginoux P, Malm W (2007) Intercontinental transport of pollution and dust aerosols: implications for regional air quality. *Atmos Chem Phys* 7:5501–5517 CrossRef
 8. Chin M, Diehl T, Tan Q, Prospero JM, Kahn RA, Remer LA, Yu H, Sayer AM, Bian H, Geogdzhayev IV, Holben BN, Howell SG, Huebert BJ, Hsu NC, Kim D, Kucsera TL, Levy RC, Mishchenko MI, Pan X, Quinn PK, Schuster GL, Streets DG, Strode SA, Torres O, Zhao X-P (2013) Multi-decadal variations of atmospheric aerosols from 1980 to 2009: sources and regional trends. *Atmos Chem Phys Discuss* 13:19751–19835 CrossRef
 9. Duncan BN, West JJ, Yoshida Y, Fiore AM, Ziemke JR (2008) The influence of European pollution on the air quality in the Near East and northern Africa. *Atmos Chem Phys* 8:2267–2283 CrossRef
 10. Ewing SA, Christensen JN, Brown ST, Vancuren RA, Cliff SS, Depaolo DJ (2013) Pb isotopes as an indicator of the Asian contribution to particulate air pollution in urban California. *Environ Sci Technol* 44:8911–8916 CrossRef
 11. Fiore AM, Dentener FJ, Wild O, Cuvelier C, Schultz MG, Hess P, Textor C, Schulz M, Doherty RM, Horowitz LW, MacKenzie IA, Sanderson MG, Shindell DT, Stevenson DS, Szopa S, Van Dingenen R, Zeng G, Atherton C, Bergmann D, Bey I, Carmichael G, Collins WJ, Duncan BN, Faluvegi G, Folberth G, Gauss M, Gong S, Hauglustaine D, Holloway T, Isaksen ISA, Jacob DJ, Jonson JE, Kaminski JW, Keating TJ, Lupu A, Marmer E, Montanaro V, Park RJ, Pitari G, Pringle KJ, Pyle JA, Schroeder S, Vivanco MG, Wind P, Wojcik G, Wu S, Zuber A (2009) Multimodel estimates of intercontinental source-receptor relationships for ozone pollution. *J Geophys Res* 114:D4. doi:10.1029/2008JD010816

12. Fry MM, Naik V, West JJ, Schwarzkopf MD, Fiore AM, Collins WJ, Dentener FJ, Shindell DT, Atherton C, Bergmann D, Duncan BN, Hess P, MacKenzie IA, Marmer E, Schultz MG, Szopa S, Wild O, Zeng G (2012) The influence of ozone precursor emissions from four world regions on tropospheric composition and radiative forcing. *J Geophys Res* 117, D07306. doi:10.1029/2011JD017134
13. Ginoux P, Horowitz LW, Ramaswamy V, Geogdzhayev IV, Holben BN, Stenchikov G, Tie X (2006) Evaluation of aerosol distribution and optical depth in the Geophysical Fluid Dynamics Laboratory coupled model CM2.1 for present climate. *J Geophys Res* 111:D22
14. Hadley OL, Ramanathan V, Carmichael GR, Tang Y, Corrigan CE, Roberts GC, Mauger GS (2007) Trans-Pacific transport of black carbon and fine aerosols ($D < 2.5 \mu\text{m}$) into North America. *J Geophys Res* 112:D05309. doi:10.1029/2006JD007632
15. Heald CL, Jacob DJ, Park RJ, Alexander B, Fairlie TD, Yantosca RM, Chu DA (2006) Transpacific transport of Asian anthropogenic aerosols and its impact on surface air quality in the United States. *J Geophys Res* 111, D14310. doi:10.1029/2005JD006847 CrossRef
16. Health Effects Institute Public Health and Air Pollution in Asia Program (HEI) Public Health and Air Pollution in Asia: coordinated studies of short-term exposure to air pollution and daily mortality in four cities. HEI Research Report 154. Health Effects Institute, Boston, MA, 2010
17. Jeong JI, Park RJ (2013) Effects of the meteorological variability on regional air quality in East Asia. *Atmos Environ* 69:46–55 CrossRef
18. Jerrett M, Burnett RT, Pope CA III, Ito K, Thurston G, Krewski D, Shi Y, Calle E, Thun M (2009) Long-term ozone exposure and mortality. *New Engl J Med* 360:1085–1095 CrossRef
19. Keating TJ, West JJ, Farrell AE (2004) Prospects for international management of intercontinental air pollution transport. In: Stohl A (ed) *Intercontinental transport of air pollution*. Springer, Berlin
20. Koch D, Schmidt GA, Field C (2005) Sulfur, sea salt and radionuclide aerosols in GISS. ModelE, *J Geophys Res* 111, D06206. doi:10.1029/2004JD005550
21. Koch D, Bond TC, Streets DG, Unger N, van der Werf GR (2007) Global impacts of aerosols from particular source regions and sectors. *J Geophys Res* 112, D02205.

doi:10.1029/2005JD007024

22. Koch D, Schulz M, Kinne S, Bond TC, Balkanski Y, Bauer S, Berntsen T, Boucher O, Chin M, Clarke A, De Luca N, Dentener F, Diehl T, Dubovik O, Easter R, Fahey DW, Feichter J, Fillmore D, Freitag S, Ghan S, Ginoux P, Gong S, Horowitz L, Iversen T, Kirkevåg A, Klimont Z, Kondo Y, Krol M, Liu X, McNaughton C, Miller R, Montanaro V, Moteki N, Myhre G, Penner JE, Perlwitz J, Pitari G, Reddy S, Sahu L, Sakamoto H, Schuster G, Schwarz JP, Seland O, Spackman JR, Stier P, Takegawa N, Takemura T, Textor C, Van Aardenne JA, Zhao Y (2009) Evaluation of black carbon estimations in global aerosol models. *Atmos Chem Phys* 9:9001–9026 CrossRef
23. Koffi B, Schulz M, Breon F-M, Griesfeller J, Balkanski Y, Bauer S, Berntsen T, Chin M, Collins WD, Dentener F, Diehl T, Easter R, Ghan S, Ginoux P, Gong S, Horowitz LW, Iversen T, Kirkevåg A, Koch D, Krol M, Myhre G, Stier P, Takemura T, Winker D (2012) Application of the CALIOP layer product to evaluate the vertical distribution of aerosols estimated by global models: AeroCom Phase I results. *J Geophys Res* 117:D10201. doi:10.1029/2011JD016858 CrossRef
24. Krewski D, Jerrett M, Burnett RT, Ma R, Hughes E, Shi Y, Turner MC, Pope CA III, Thurston G, Calle EE, Thun MJ, Beckerman B, DeLuca P, Finkelstein N, Ito K, Moore DK, Newbold KB, Ramsay T, Ross Z, Shin H, Tempalski B (2009) Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality. Health Effects Institute, Boston, MA
25. Lamarque J-F, Emmons LK, Hess PG, Kinnison DE, Tilmes S, Vitt F, Heald CL, Holland EA, Lauritzen PH, Neu J, Orlando JJ, Rasch PJ, Tyndall GK (2012) CAM-Chem: description and evaluation of interactive atmospheric chemistry in the Community Earth System Model. *Geosci Model Dev* 5:369–411 CrossRef
26. Langner J, Rodhe H, Crutzen PJ, Zimmerman P (1992) Anthropogenic influence on the distribution of tropospheric sulphate aerosol. *Nature* 359:712–716 CrossRef
27. Leibensperger EM, Mickley LJ, Jacob DJ, Barrett SRH (2011) Intercontinental influence of NO_x and CO emissions on particulate matter air quality. *Atmos Environ* 45:3310–3324 CrossRef
28. Lepeule J, Laden F, Dockery D, Schwartz J (2012) Chronic exposure to fine particles and mortality: an extended follow-up of the Harvard Six Cities Study from 1974–2009. *Environ Health Perspect* 12:965–970 CrossRef
29. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, Amann M,

Anderson HR, Andrews KG, Aryee M, Atkinson C, Bacchus LJ, Bahalim AN, Balakrishnan K, Balmes J, Barker-Collo S, Baxter A, Bell ML, Blore JD, Blyth F, Bonner C, Borges G, Bourne R, Boussinesq M, Brauer M, Brooks P, Bruce NG, Brunekreef B, Bryan-Hancock C, Bucello C, Buchbinder R, Bull F, Burnett RT, Byers TE, Calabria B, Carapetis J, Carnahan E, Chafe Z, Charlson F, Chen H, Chen JS, Cheng AT-A, Child JC, Cohen A, Colson KE, Cowie BC, Darby S, Darling S, Davis A, Degenhardt L, Dentener F, Des Jarlais DC, Devries K, Dherani M, Ding EL, Dorsey ER, Driscoll T, Edmond K, Ali SE, Engell RE, Erwin PJ, Fahimi S, Falder G, Farzadfar F, Ferrari A, Finucane MM, Flaxman S, Fowkes FGR, Freedman G, Freeman MK, Gakidou E, Ghosh S, Giovannucci E, Gmel G, Graham K, Grainger R, Grant B, Gunnell D, Gutierrez HR, Hall W, Hoek HW, Hogan A, Hosgood Iii HD, Hoy D, Hu H, Hubbell BJ, Hutchings SJ, Ibeanusi SE, Jacklyn GL, Jasrasaria R, Jonas JB, Kan H, Kanis JA, Kassebaum N, Kawakami N, Khang YH, Khatibzadeh S, Khoo J-P, Kok C, Laden F, Lalloo R, Lan Q, Lathlean T, Leasher JL, Leigh J, Li Y, Lin JK, Lipshultz SE, London S, Lozano R, Lu Y, Mak J, Malekzadeh R, Mallinger L, Marcenes W, March L, Marks R, Martin R, McGale P, McGrath J, Mehta S, Mensah GA, Merriman TR, Micha R, Michaud C, Mishra V, Hanafiah KM, Mokdad AA, Morawska L, Mozaffarian D, Murphy T, Naghavi M, Neal B, Nelson PK, Nolla JM, Norman R, Olives C, Omer SB, Orchard J, Osborne R, Ostro B, Page A, Pandey KD, Parry CDH, Passmore E, Patra J, Pearce N, Pelizzari PM, Petzold M, Phillips MR, Pope D, Pope Iii CA, Powles J, Rao M, Razavi H, Rehfuss EA, Rehm JT, Ritz B, Rivara FP, Roberts T, Robinson C, Rodriguez-Portales JA, Romieu I, Room R, Rosenfeld LC, Roy A, Rushton L, Salomon JA, Sampson U, Sanchez-Riera L, Sanman E, Sapkota A, Seedat S, Shi P, Shield K, Shivakoti R, Singh GM, Sleet DA, Smith E, Smith KR, Stapelberg NJC, Steenland K, Stöckl H, Stovner LJ, Straif K, Straney L, Thurston GD, Tran JH, Van Dingenen R, van Donkelaar A, Veerman JL, Vijayakumar L, Weintraub R, Weissman MM, White RA, Whiteford H, Wiersma ST, Wilkinson JD, Williams HC, Williams W, Wilson N, Woolf AD, Yip P, Zielinski JM, Lopez AD, Murray CJL, Ezzati M (2013) A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 380:2224–2260 CrossRef

30. Liu J, Mauzerall DL, Horowitz LW, Ginoux P, Fiore AM (2009a) Evaluation inter-continental transport of fine aerosols: (1) methodology, global aerosol distribution and optical depth. *Atmos Environ* 43:4327–4338 CrossRef
31. Liu J, Mauzerall DL, Horowitz LW (2009b) Evaluating inter-continental transport of fine

- aerosols: (2) global health impacts. *Atmos Environ* 43:4339–4347 CrossRef
32. Oak Ridge National Laboratory (2008) LandScan Global Population Database 2006. <http://www.ornl.gov/sci/landscan/index.html>. Accessed March 2008
 33. Park RJ, Jacob DJ, Chin M, Martin RV (2003) Sources of carbonaceous aerosols over the United States and implications for natural visibility. *J Geophys Res* 108:4355. doi:10.1029/2002JD003190 CrossRef
 34. Park RJ, Jacob DJ, Field BD, Yantosca RM, Chin M (2004) Natural and transboundary pollution influences on sulfate-nitrate-ammonium aerosols in the United States: implications for policy. *J Geophys Res* 109, D15204. doi:10.1029/2003JD004473 CrossRef
 35. Park RJ, Jacob DJ, Kumar N, Yantosca RM (2006) Regional visibility statistics in the United States: natural and transboundary pollution influences, and implications for the Regional Haze Rule. *Atmos Environ* 40:5405–5423 CrossRef
 36. Pham M, Muller J-F, Brasseur GP, Granier C, Megie G (1995) A three-dimensional study of the tropospheric sulfur cycle. *J Geophys Res*. doi:10.1029/95JD02095
 37. Pope CA III, Burnett RT, Krewski D, Jerrett M, Shi Y, Calle EE, Thun MJ (2009) Cardiovascular mortality and exposure to airborne fine particulate matter and cigarette smoke: shape of the exposure-response relationship. *Circulation* 120:941–948 CrossRef
 38. Pope CA III, Burnett RT, Turner MC, Cohen A, Krewski D, Jerrett M, Gapstur SM, Thun MJ (2011) Lung cancer and cardiovascular disease mortality associated with ambient air pollution and cigarette smoke: shape of the exposure-response relationship. *Environ Health Perspect* 119:1616–1621 CrossRef
 39. Roman HA, Walker KD, Walsh TL, Conner L, Richmond HM, Hubbell BJ, Kinney PL (2008) Expert judgment assessment of the mortality impact of changes in ambient fine particulate matter in the US. *Environ Sci Technol* 42:2268–2274 CrossRef
 40. Shindell DT, Chin M, Dentener F, Doherty RM, Faluvegi G, Fiore AM, Hess P, Koch DM, MacKenzie IA, Sanderson MG, Schultz MG, Schulz M, Stevenson DS, Teich H, Textor C, Wild O, Bergmann DJ, Bey I, Bian H, Cuvelier C, Duncan BN, Folberth G, Horowitz LW, Jonson J, Kaminski JW, Marmer E, Park R, Pringle KJ, Schroeder S, Szopa S, Takemura T, Zeng G, Keating TJ, Zuber A (2008) A multi-model assessment of pollution transport to the Arctic. *Atmos Chem Phys* 8:5353–5372 CrossRef
 41. Takemura T, Okamoto H, Maruyama Y, Numaguti A, Higurashi A, Nakajima T (2000)

- Global three-dimensional simulation of aerosol optical thickness distribution of various origins. *J Geophys Res* 105:17853–17873 CrossRef
42. Takemura T, Nakajima T, Dubovik O, Holben BN, Kinne S (2002) Single-scattering albedo and radiative forcing of various aerosol species with a global three-dimensional model. *J Climate* 15:333–352 CrossRef
 43. Task Force on Hemispheric Transport of Air Pollution (TF HTAP). Hemispheric Transport of Air Pollution 2010. United Nations Economic Commission for Europe: Geneva, 2010
 44. West JJ, Naik V, Horowitz LW, Fiore AM (2009) Effect of regional precursor emission controls on long-range ozone transport—Part 2: steady-state changes in ozone air quality and impacts on human mortality. *Atmos Chem Phys* 9:6095–6107 CrossRef
 45. World Health Organization (WHO) (2004) The World Health Report 2004: changing history. World Health Organization, Geneva
 46. World Health Organization (WHO) Mortality Database. <http://www.who.int/healthinfo/mortables/en/>. Accessed September 2008
 47. Yu H, Remer LA, Chin M, Bian H, Kleidman RG, Diehl T (2008) A satellite-based assessment of transpacific transport of pollution aerosol. *J Geophys Res* 113:D14S12. doi:10.1029/2007JD009349
 48. Yu H, Remer LA, Chin M, Bian H, Tan Q, Yuan T, Zhang Y (2012) Aerosols from overseas rival domestic emissions over North America. *Science* 337:566–569 CrossRef
 49. Yu H, Chin M, West JJ, Atherton CS, Bellouin N, Bergmann D, Bey I, Bian H, Diehl T, Forberth G, Hess P, Schulz M, Shindell D, Takemura T, Tan Q (2013) A multimodel assessment of the influence of regional anthropogenic emission reductions on aerosol direct radiative forcing and the role of intercontinental transport. *J Geophys Res* 118:700–720. doi:10.1029/2012JD0180148

About this Article

Title

Impacts of intercontinental transport of anthropogenic fine particulate matter on human mortality

Journal

Air Quality, Atmosphere & Health

DOI

10.1007/s11869-014-0248-9

Print ISSN

1873-9318

Online ISSN

1873-9326

Publisher

Springer Netherlands

Additional Links

- [Register for Journal Updates](#)
- [Editorial Board](#)
- [About This Journal](#)
- [Manuscript Submission](#)

Topics

- [Environmental Health](#)
- [Atmospheric Protection/Air Quality Control/Air Pollution](#)
- [Health Promotion and Disease Prevention](#)

Keywords

- [Health impact assessment](#)
- [Particulate matter](#)
- [Long-range transport](#)
- [Chemical transport modeling](#)

Authors

- [Susan C. Anenberg](#) ⁽¹⁾
- [J. Jason West](#) ⁽²⁾
- [Hongbin Yu](#) ⁽³⁾
- [Mian Chin](#) ⁽⁴⁾
- [Michael Schulz](#) ⁽⁵⁾

- Dan Bergmann ⁽⁶⁾
- Isabelle Bey ⁽⁷⁾
- Huisheng Bian ⁽⁴⁾
- Thomas Diehl ^{(4) (8)}
- Arlene Fiore ⁽⁹⁾
- Peter Hess ⁽¹⁰⁾
- Elina Marmer ⁽¹¹⁾
- Veronica Montanaro ⁽¹²⁾
- Rokjin Park ⁽¹³⁾
- Drew Shindell ^{(14) (15)}
- Toshihiko Takemura ⁽¹⁶⁾
- Frank Dentener ⁽¹⁷⁾

Author Affiliations

- 1. US Environmental Protection Agency, 1200 Pennsylvania Ave NW MC6301A, Washington, DC, 20460, USA
- 2. University of North Carolina, Chapel Hill, NC, USA
- 3. University of Maryland, College Park, MD, USA
- 4. NASA Goddard Space Flight Center, Greenbelt, MD, USA
- 5. Norwegian Meteorological Institute, Oslo, Norway
- 6. Lawrence Livermore National Laboratory, Livermore, CA, USA
- 7. Swiss Federal Institute of Technology, Zurich, Switzerland
- 8. Universities Space Research Association, Columbia, MD, USA
- 9. Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY, USA
- 10. Department of Biological and Environmental Engineering, Cornell University, Ithaca, NY, USA
- 11. Department of Education, University of Hamburg, Hamburg, Germany

- 12. University of L'Aquila, L'Aquila, Italy
- 13. Seoul National University, Seoul, Korea
- 14. NASA Goddard Institute for Space Studies, New York, NY, USA
- 15. Columbia Earth Institute, New York, NY, USA
- 16. Research Institute for Applied Mechanics, Kyushu University, Fukuoka, Japan
- 17. European Commission, Joint Research Center, Institute for Environment and Sustainability, Ispra, Italy

Continue reading...

To view the rest of this content please follow the download PDF link above.

Over 8.5 million scientific documents at your fingertips
© Springer, Part of Springer Science+Business Media

