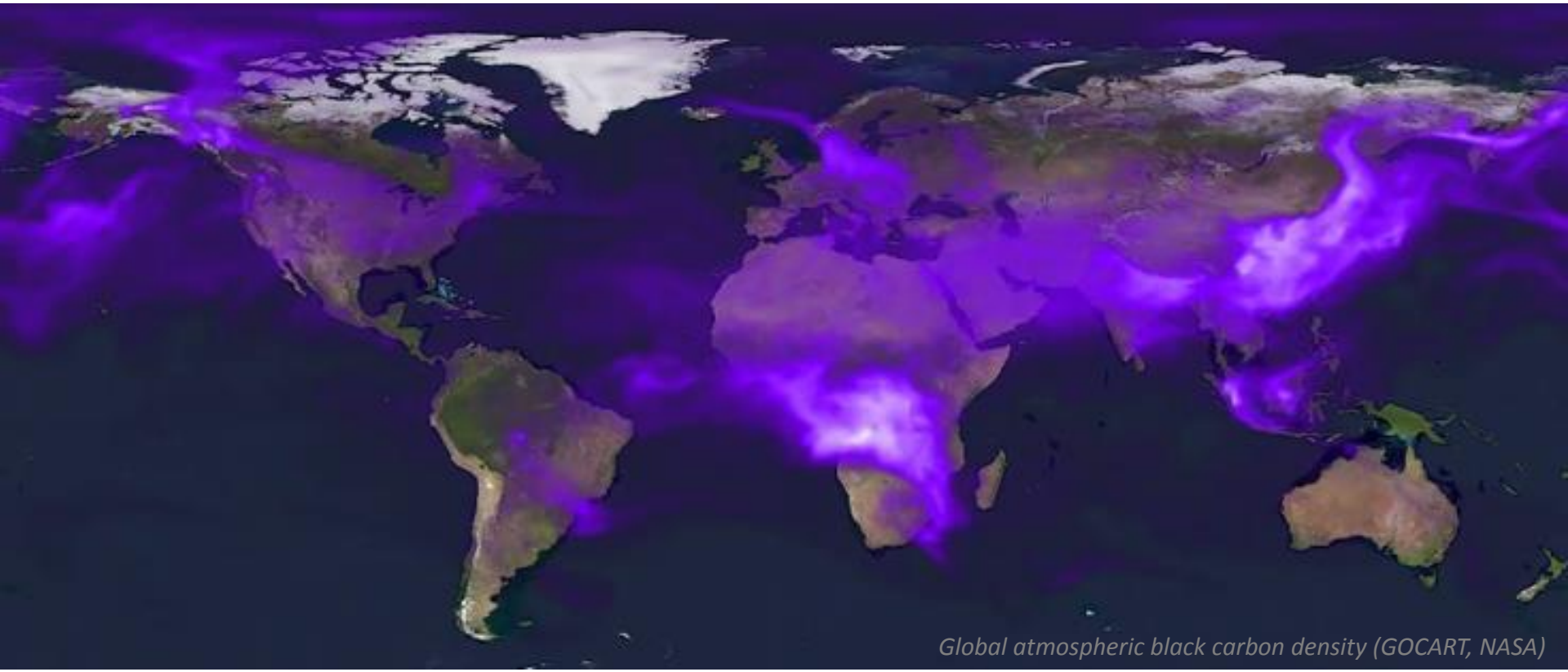
Health Impacts of Black Carbon



Global atmospheric black carbon density (GOCART, NASA)

Michael Brauer

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

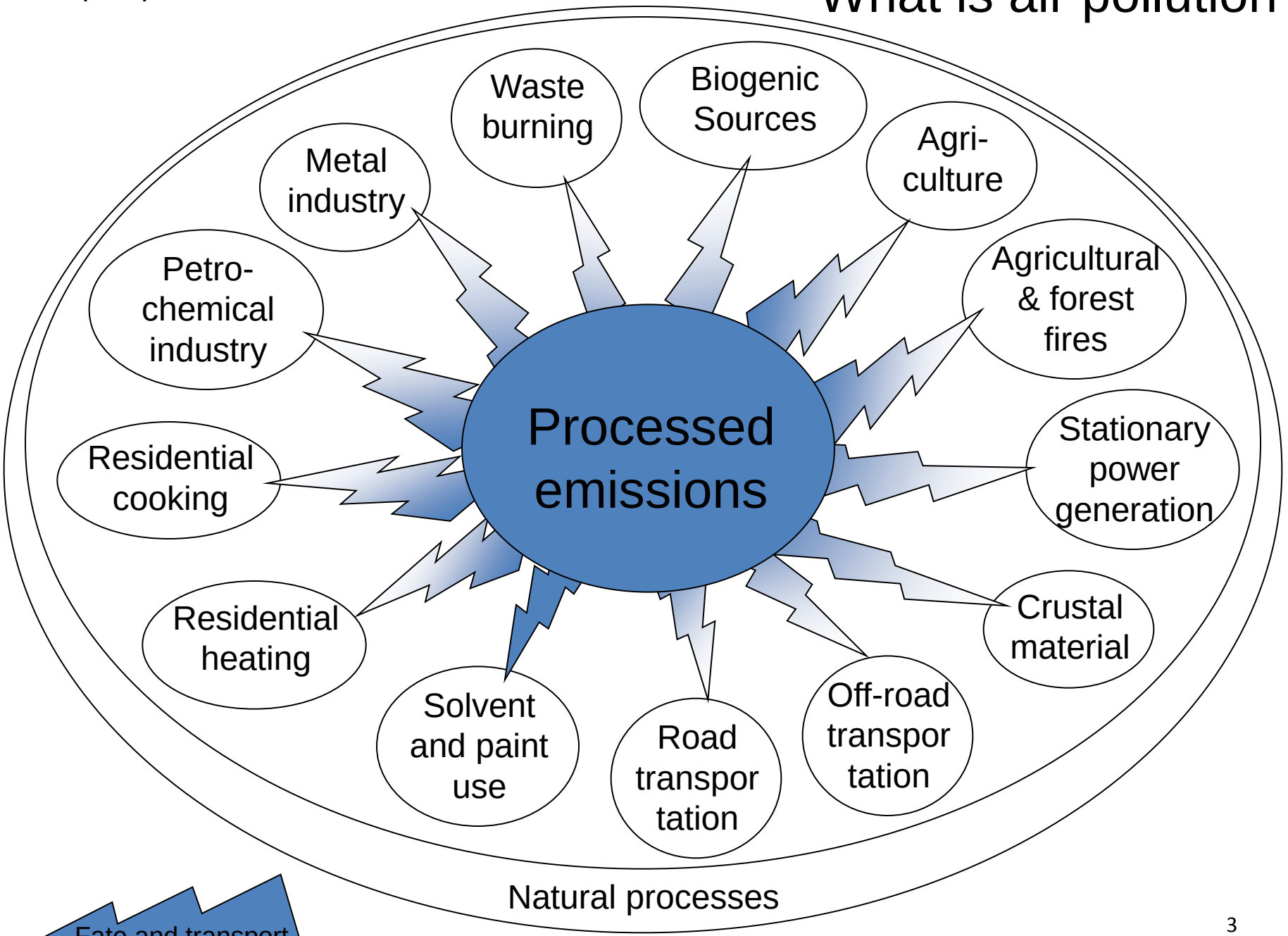
Anil Agarwal Dialogue 2015. *Poor in climate change: How the co-benefit agenda of short-lived climate pollutants can work for or against people and the planet.*
India Habitat Centre, New Delhi, March 11, 2015

Air pollution and health

- Ambient air pollution (individual) **risk** is typically small…but large **exposed population = large population risk**
- Major impacts are on chronic disease progression
- Diseases impacted by air pollution are multifactorial…
- …Air pollution as a contributing risk factor

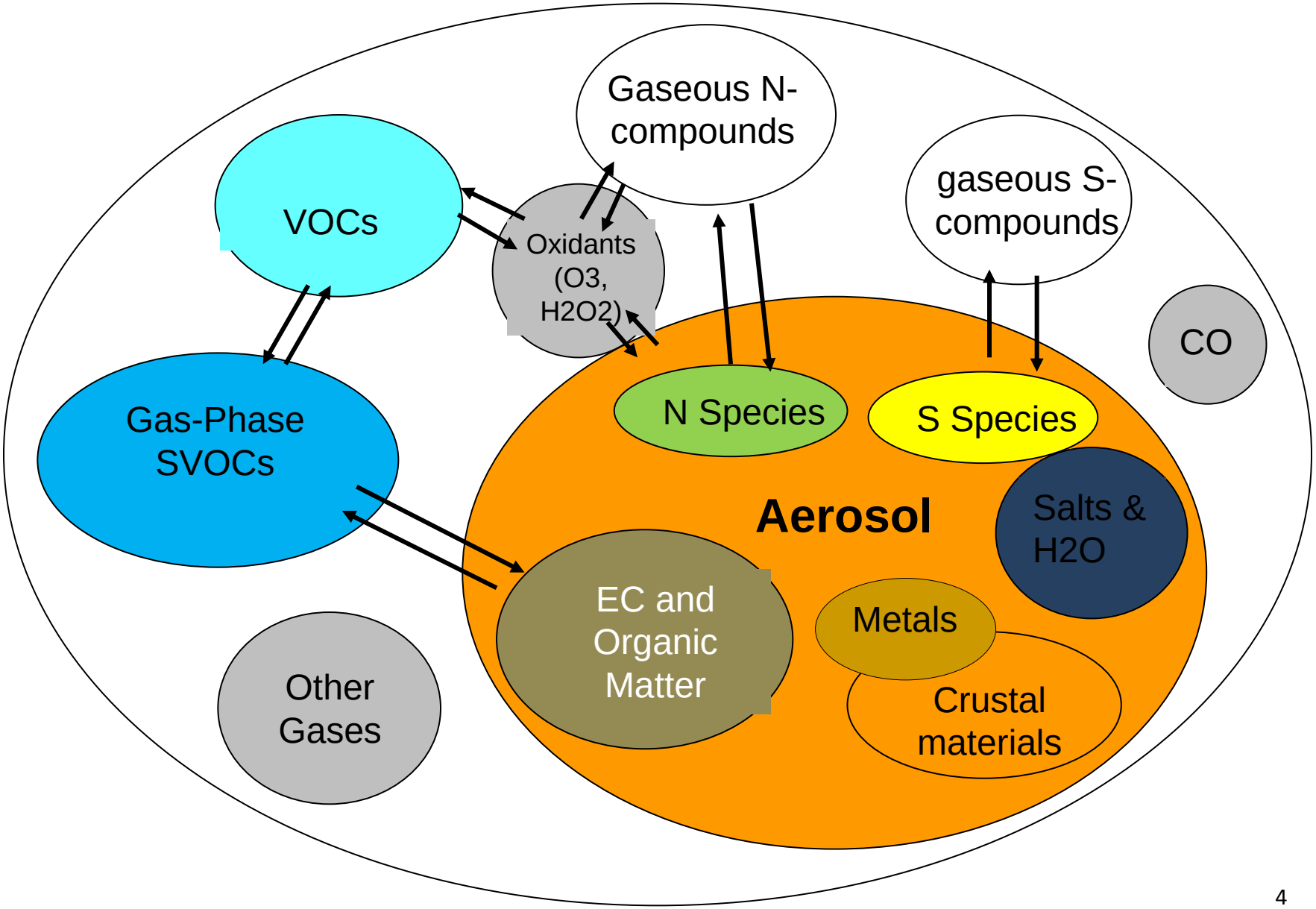
Source perspective

What is air pollution?



Component perspective

What is air pollution?

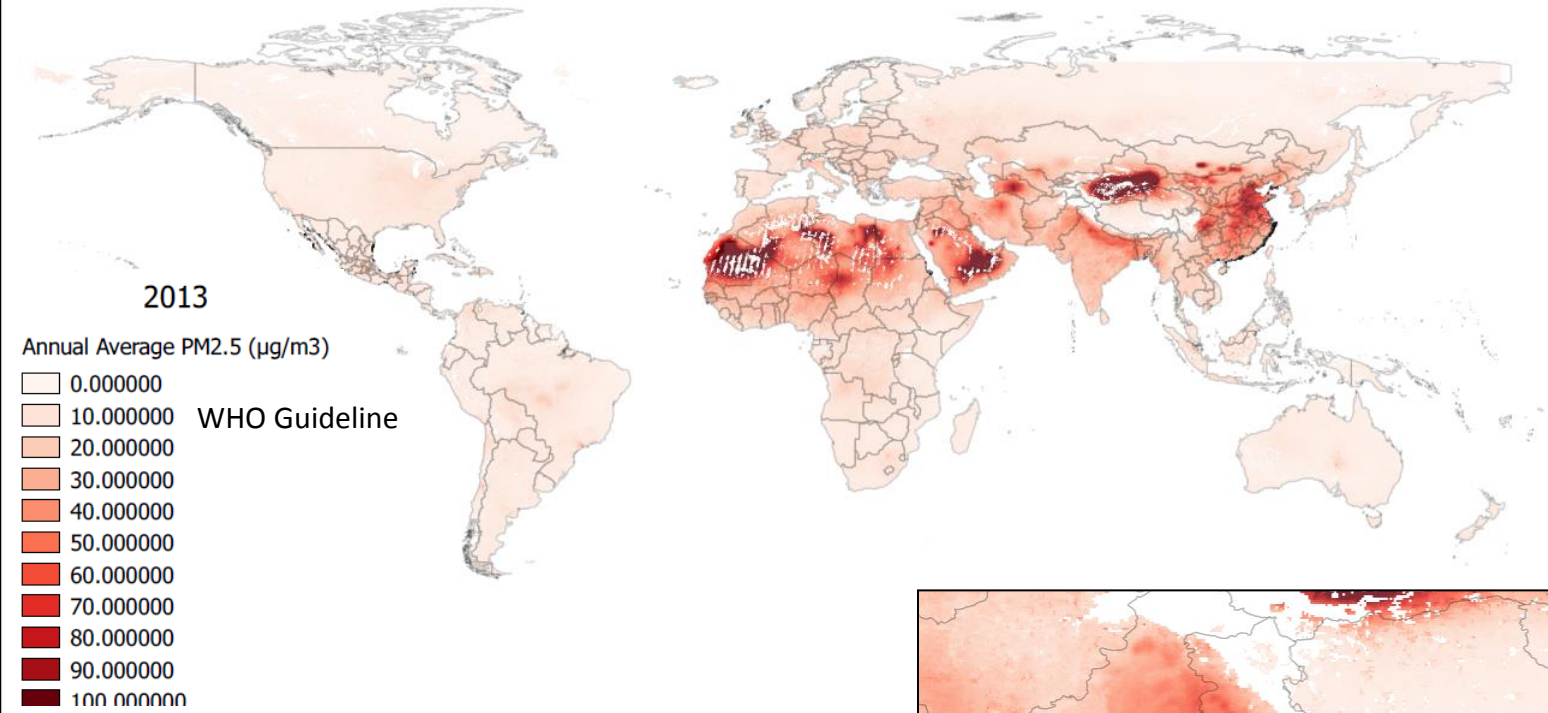


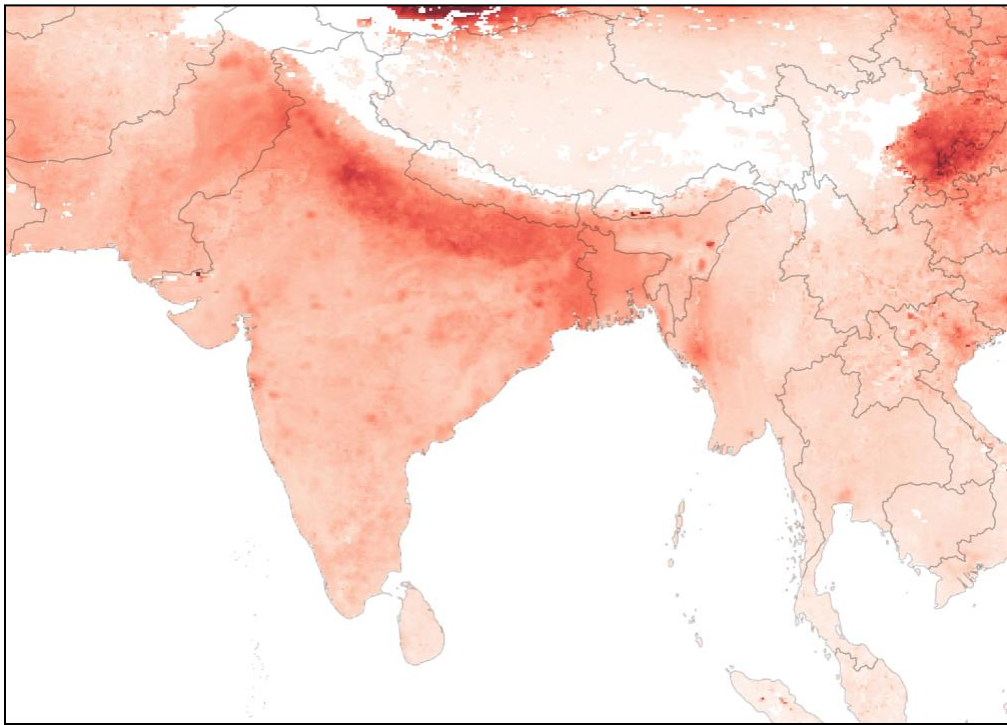
Examples of Particle Types and Mixtures Present in Combustion Plumes

Particle	Type	Radiative Properties
	Black carbon[a]	Absorbing (all solar wavelengths)
	Brown (or yellow) carbon[b]	Absorbing (UV and some visible)
	Non-absorbing carbon[b]	Scattering
	Nitrate[c]	Scattering
	Sulfate[c]	Scattering
	Black carbon coated with brown or non-absorbing carbon[d]	Absorbing (enhanced by partial internal reflection of solar radiation); fractionally scattering
	Black carbon associated with sulfate or nitrate[e]	Absorbing plus some scattering
	Cloud and fog droplets[f]	Scattering
	Complex of several particles[e]	Absorbing and scattering
	Mixed particle (cloud processed)[g]	Absorbing (enhanced by partial internal reflection of solar radiation); fractionally scattering

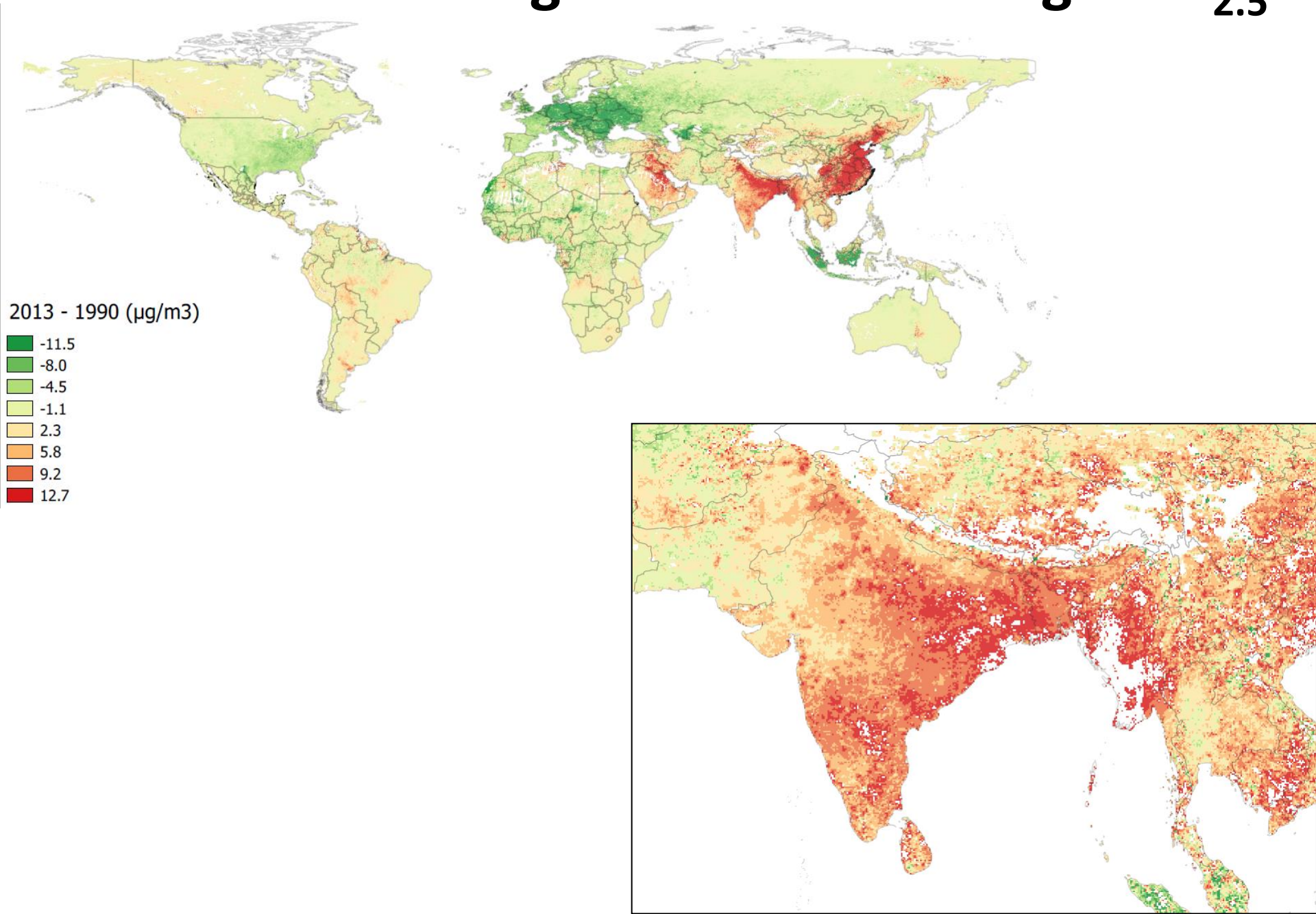
USEPA, 2012

2013 Annual Average $PM_{2.5}$

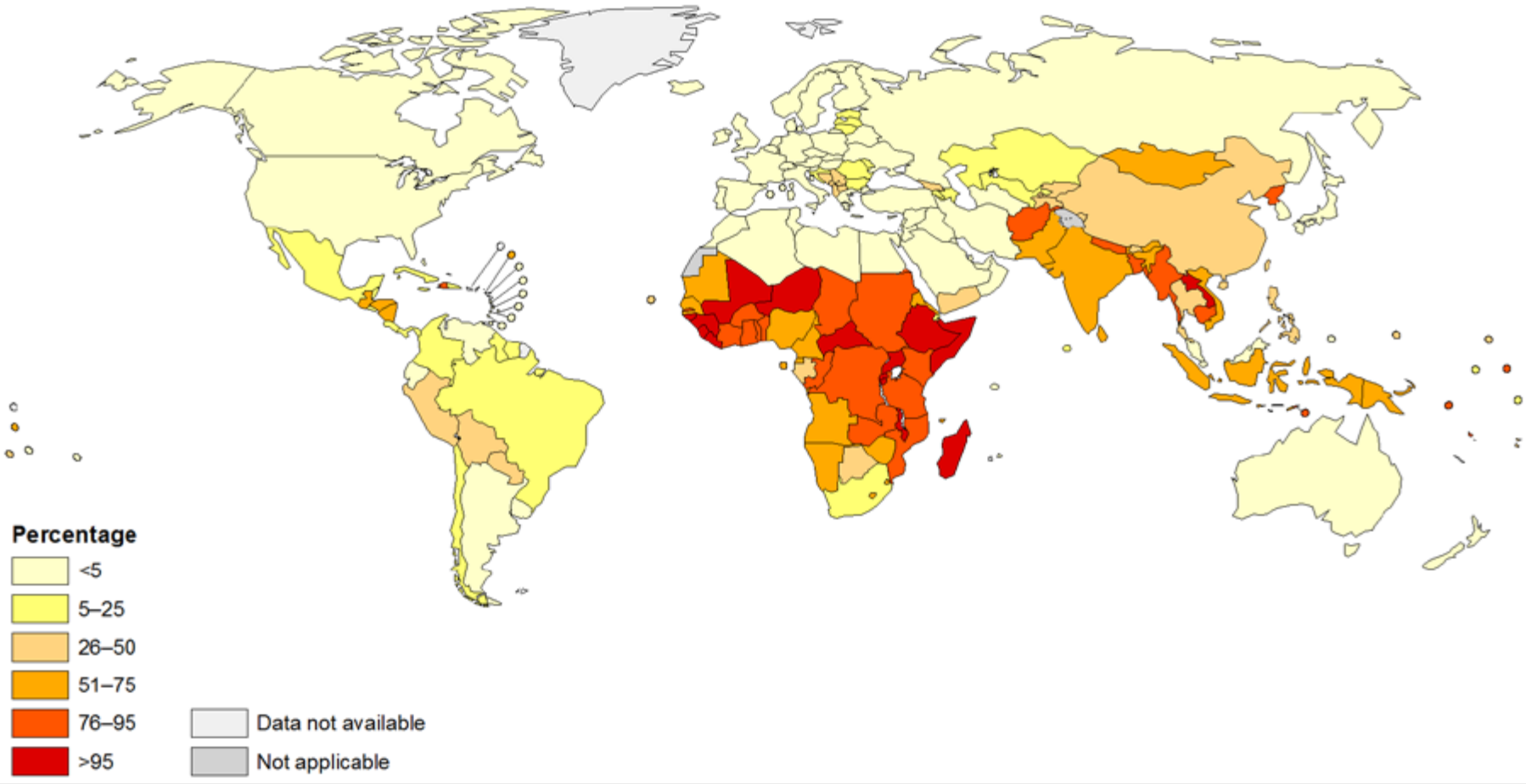




1990 – 2013 Change in Annual Average $PM_{2.5}$



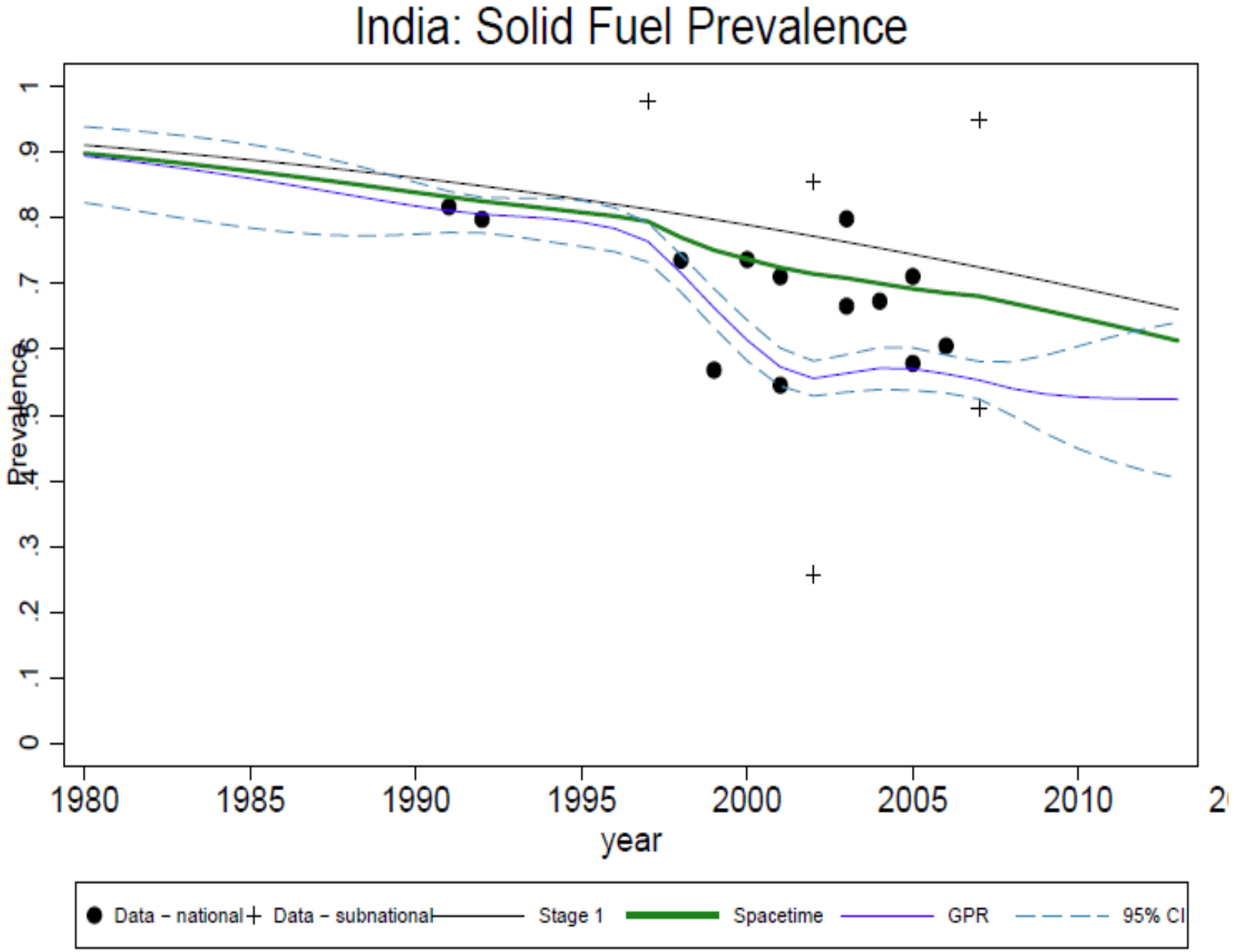
Total Population using solid fuels (%), 2010



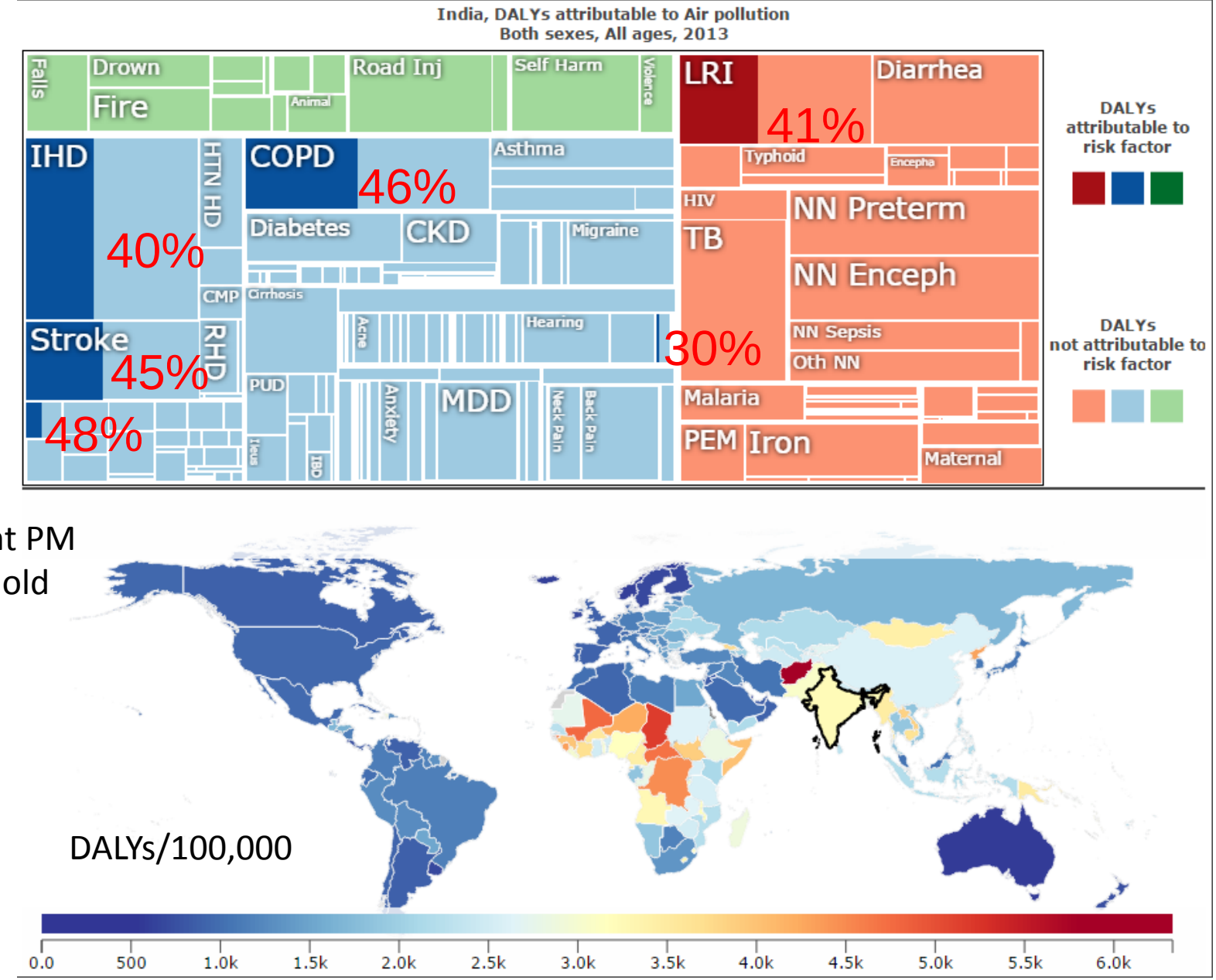
The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted and dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

Data Source: World Health Organization
Map Production: Public Health Information and Geographic Information Systems (GIS)
World Health Organization

World Health Organization



PRELIMINARY ESTIMATES – SUBJECT TO CHANGE



Ambient PM
Household
Ozone

PRELIMINARY ESTIMATES – SUBJECT TO CHANGE

What is BC?

- Operationally defined
- Incomplete combustion
  - diesel, household solid fuel, industrial, landscape fires
- Light absorbing PM component
  - US urban: 4 – 11% of $PM_{2.5}$ mass
  - Delhi: 10% (auto-rickshaw: 23%)
  - Cookstove emissions: 15 – 100%

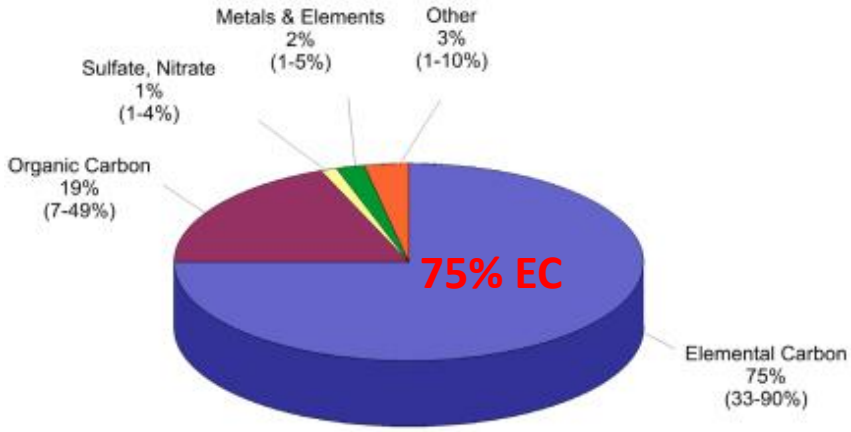
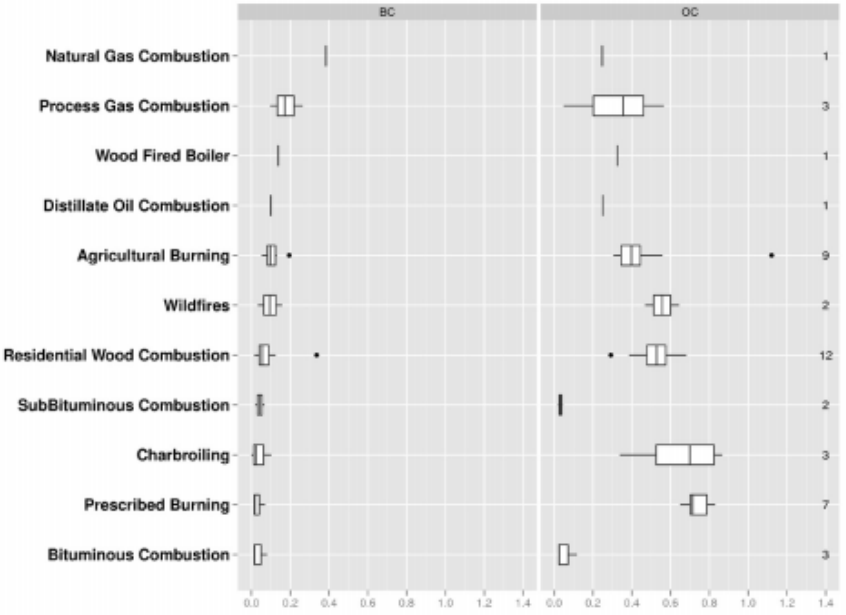


Figure 4-2. Heavy-Duty Diesel $PM_{2.5}$ Emissions Profile.
(Source: U.S. EPA, 2002b)



BC/OC fractions of $PM_{2.5}$ Emissions for the Highest BC Emitting Non-Mobile Source Categories (USA)

USEPA, 2012; Apte et al., 2011; Saraswat et al., 2013; Grieshop et al., 2011

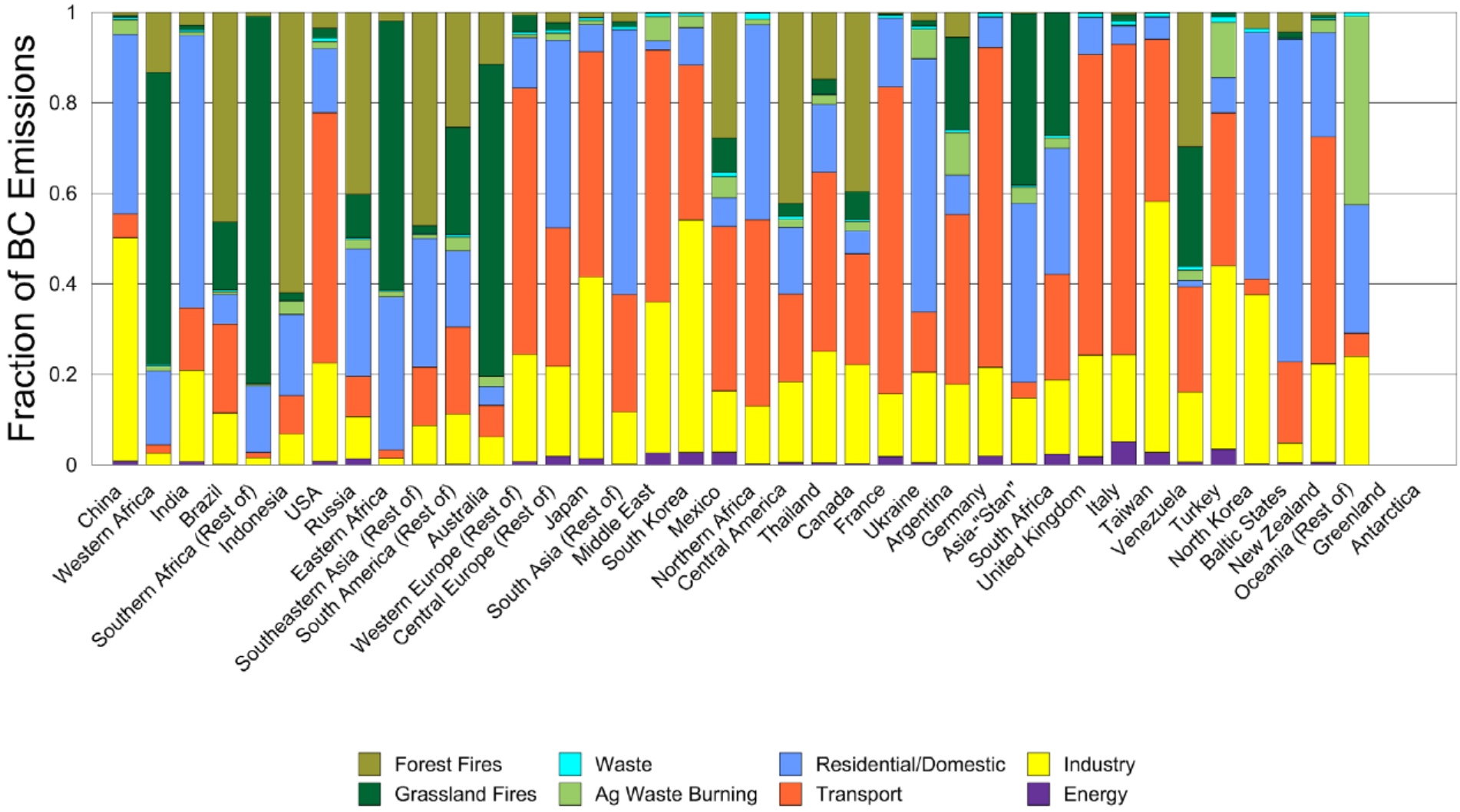
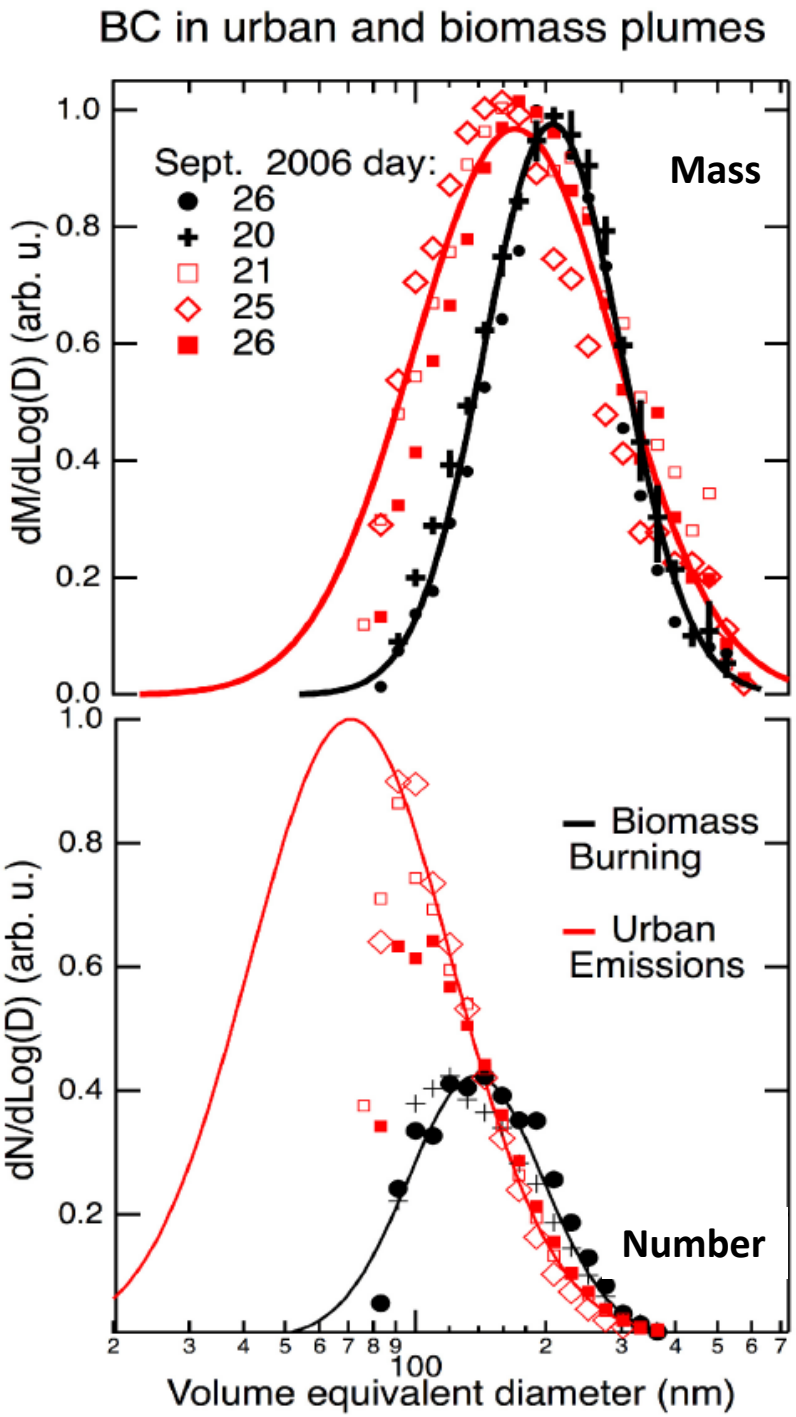
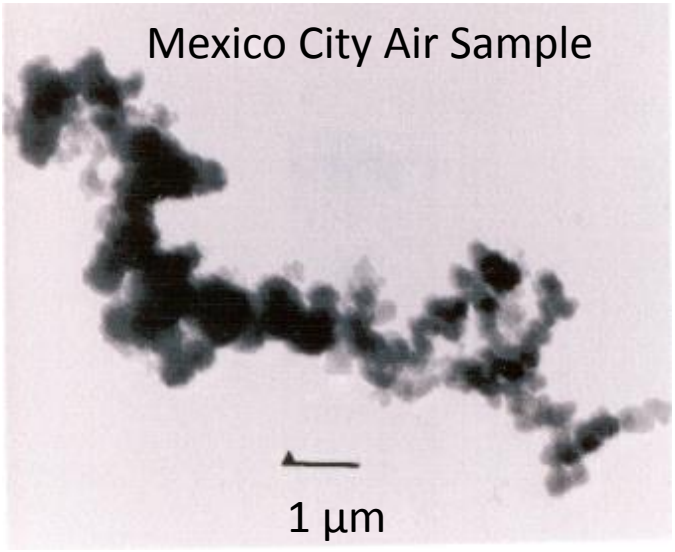
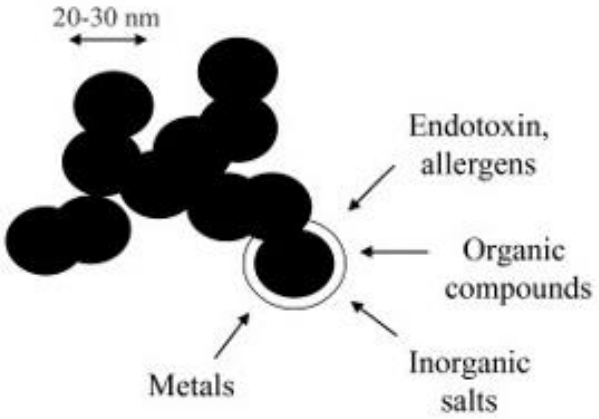


Figure 4-12. Global BC Emissions by Source Categories and Region. (Source: Lamarque et al., 2010)


BC in urban and biomass plumes
Sept. 2006 day:
26
20
21
25
26
Mass
dM/dLog(D) (arb. u.)
1.0
0.8
0.6
0.4
0.2
0.0
Biomass Burning
Urban Emissions
Number
dN/dLog(D) (arb. u.)
2 3 4 5 6 7 8 9 100 2 3 4 5 6 7
Volume equivalent diameter (nm)

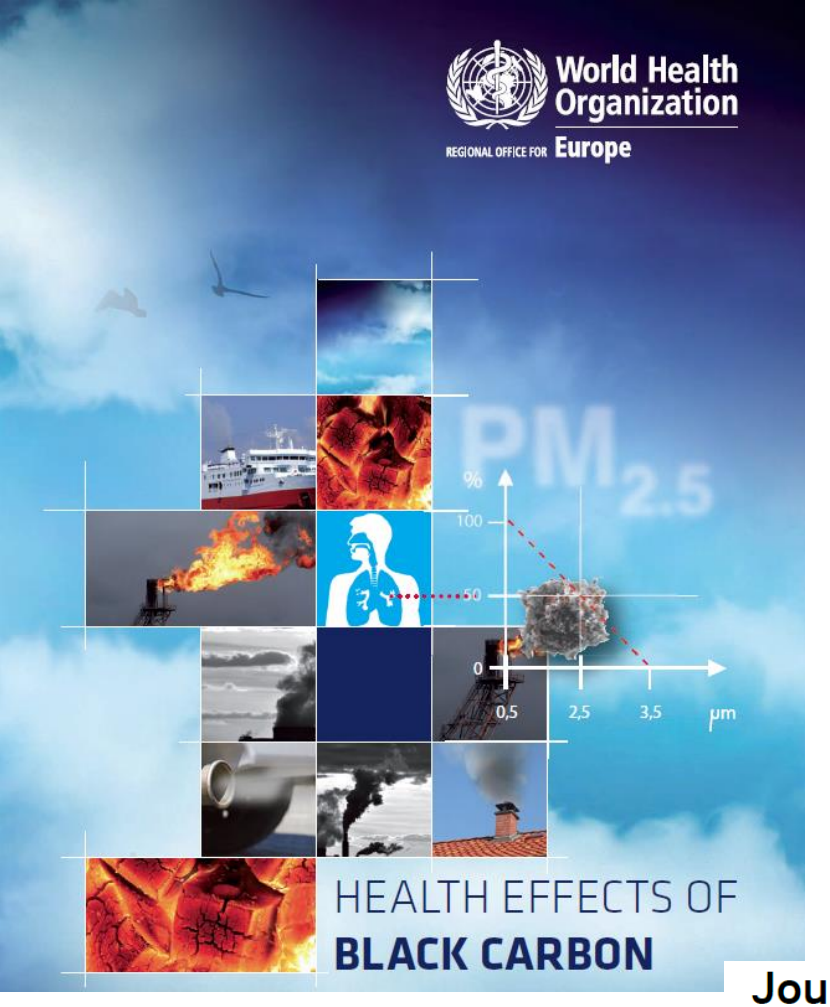

Mexico City Air Sample
1 µm

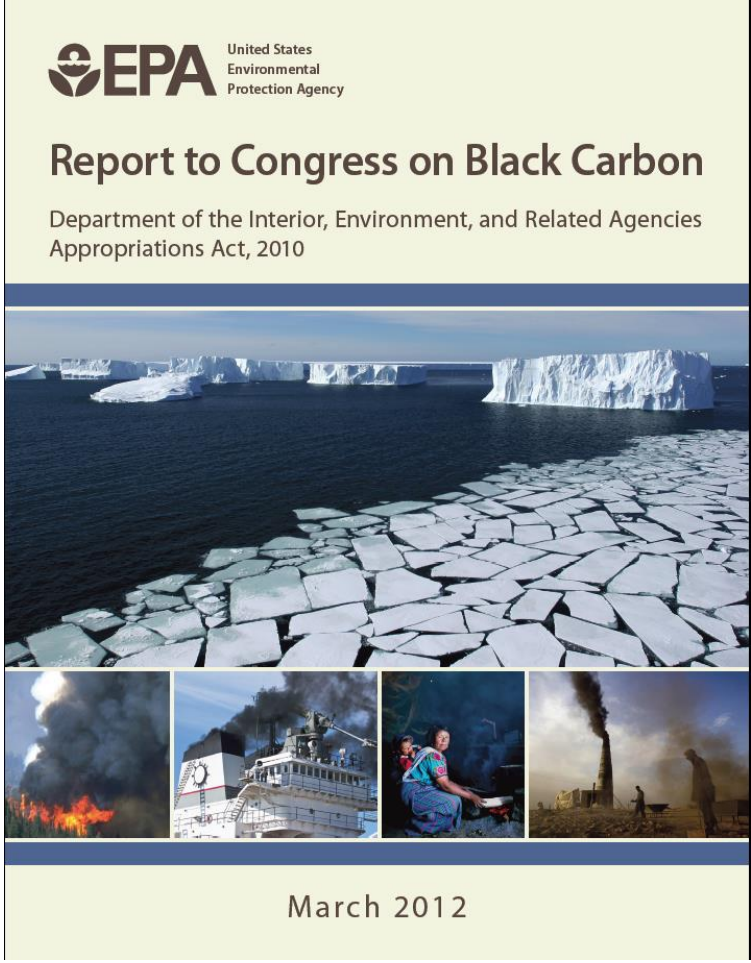

20-30 nm
Endotoxin, allergens
Organic compounds
Inorganic salts
Metals

Health impacts of PM constituents

Insufficient information to differentiate the health impacts of different PM constituents

- WHO, IARC, GBD, USEPA





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Public health and components of particulate matter: The changing assessment of black carbon

Thomas J. Grahame[a], Rebecca Klemm[b] & Richard B. Schlesinger[c]
[a] U.S. Department of Energy, Washington, DC, USA
[b] Klemm Analysis Group, Washington, DC, USA
[c] Department of Biology and Health Sciences, Pace University, New York, NY, USA
Accepted author version posted online: 29 Apr 2014.Published online: 20 May 2014.

BC and Health

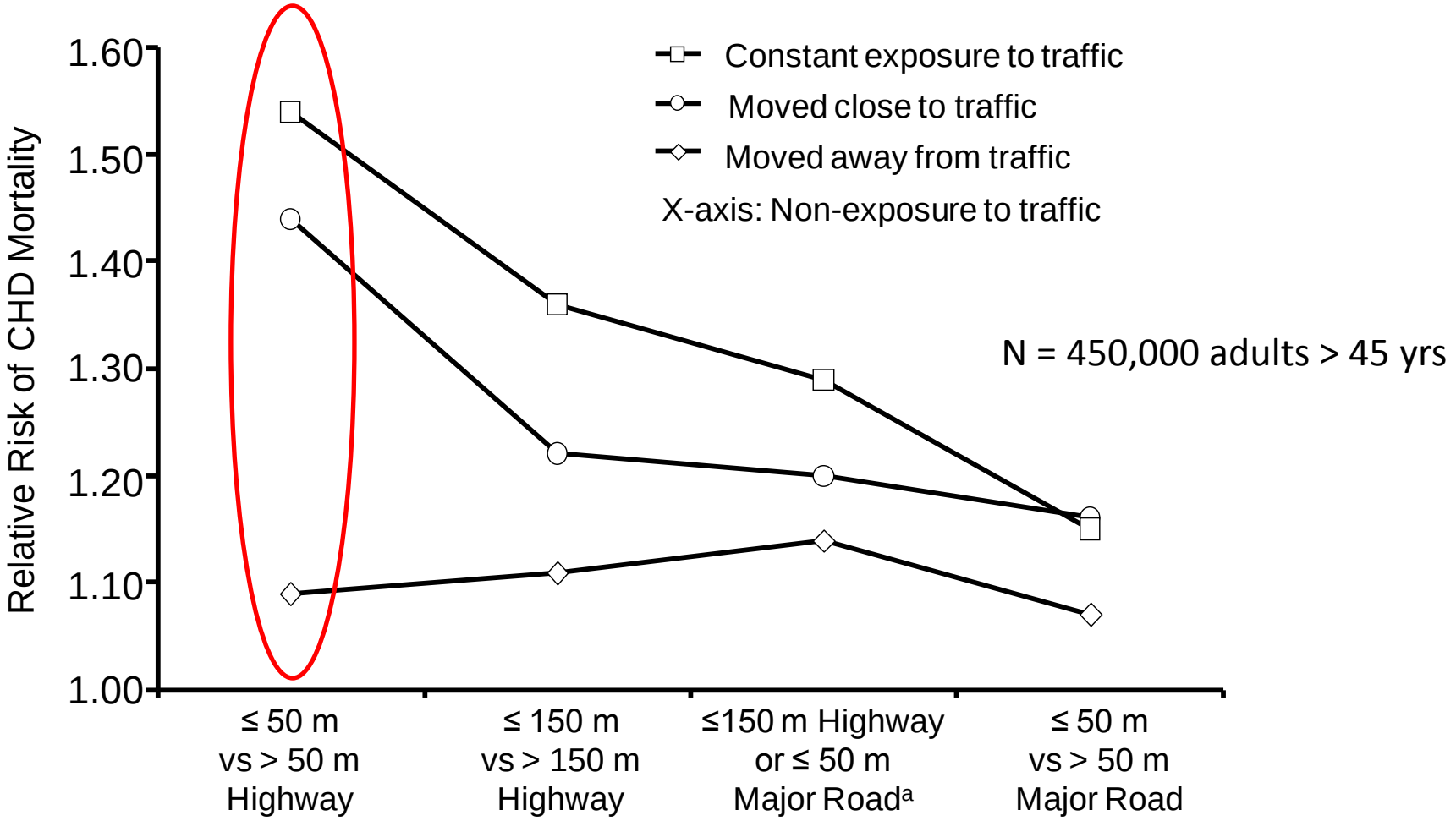
- BC represents one of the more health-relevant components of PM, especially for cardiovascular effects
  - Effects of BC and $PM_{2.5}$ mass similar per inter-quartile range in pollutant levels; BC 7-8 x higher per $\mu g/m^3$

BC and Health

- BC represents one of the more health-relevant components of PM, especially for cardiovascular effects

  - BC effects robust to adjustment for $PM_{2.5}$ mass; $PM_{2.5}$ mass effects decrease after adjustment for BC

Road proximity & cardiovascular death



Coronary heart disease (CHD) mortality: **Black Carbon**

Gan WQ, Tamburic L, Davies HW, Demers PA, Koehoorn M, **Brauer** M. Changes in residential proximity to road traffic and the risk of death from coronary heart disease. Epidemiology. 2010 Sep;21(5):642-9.

Long-Term Exposure to Traffic-Related Air Pollution and the Risk of Coronary Heart Disease Hospitalization and Mortality

Wen Qi Gan,[1] Mieke Koehoorn,[1,2] Hugh W. Davies,[1] Paul A. Demers,[1,2] Lillian Tamburic,[3] and Michael Brauer[1]

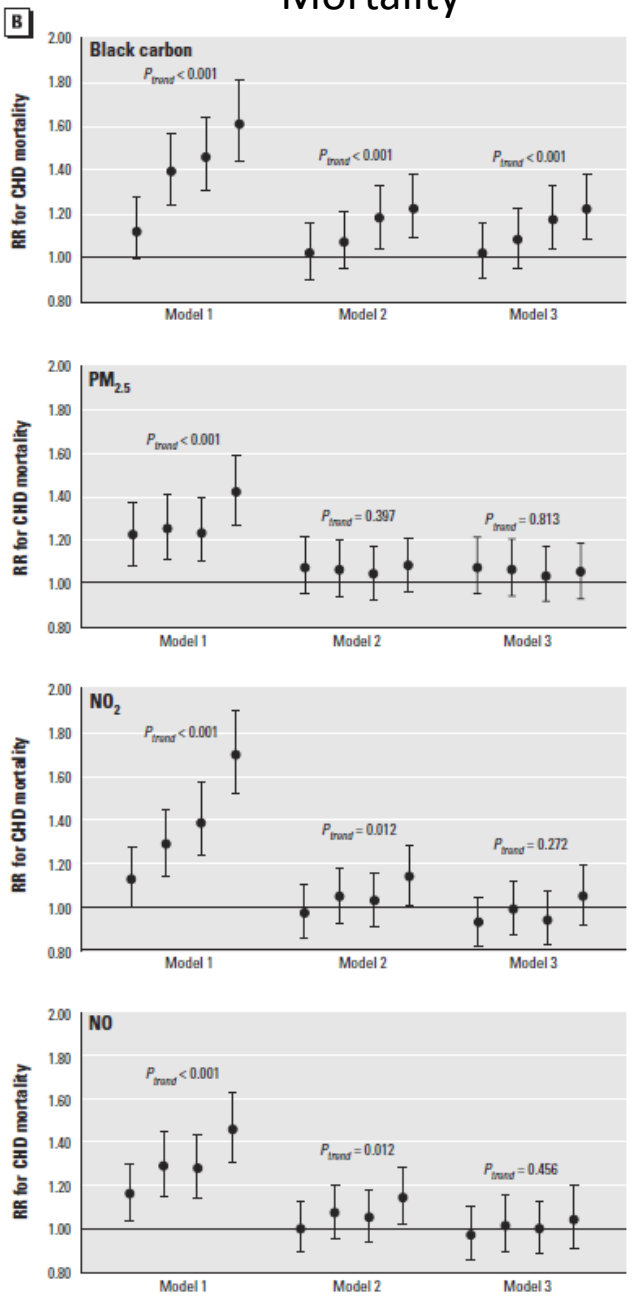
Environmental Health Perspectives • VOLUME 119 | NUMBER 4 | April 2011

Table 3. RRs (95% CIs) of CHD hospitalization and mortality for an IQR elevation in average concentrations of traffic-related air pollutants.

Model	BC (0.94×10^{-5}/m)[a]	$PM_{2.5}$ (1.58 μg/m^3)[a]	NO_2 (8.4 μg/m^3)[a]	NO (13.2 μg/m^3)[a]
Hospitalization				
Model 1: unadjusted single pollutant	1.04 (1.03–1.06)	1.03 (1.01–1.05)	1.02 (1.00–1.04)	0.99 (0.97–1.02)
Model 2: + sex, age, comorbidity, SES	1.01 (1.00–1.03)	1.00 (0.98–1.02)	0.97 (0.95–0.99)	0.96 (0.94–0.98)
Model 3: + two other pollutants[b]	1.03 (1.01–1.05)	1.02 (1.00–1.05)	0.96 (0.94–0.98)	0.95 (0.92–0.97)
Mortality				
Model 1: unadjusted single pollutant	1.14 (1.11–1.17)	1.13 (1.09–1.16)	1.19 (1.15–1.23)	1.13 (1.09–1.17)
Model 2: + sex, age, comorbidity, SES	1.06 (1.03–1.09)	1.01 (0.98–1.05)	1.04 (1.01–1.08)	1.06 (1.02–1.10)
Model 3: + two other pollutants[b]	1.06 (1.03–1.09)	1.00 (0.96–1.03)	1.03 (0.99–1.07)	1.03 (0.99–1.08)

+, additionally adjusted for covariates.
[a]IQR. [b]Additionally adjusted for $PM_{2.5}$ and NO_2 for black carbon, black carbon and NO_2 for $PM_{2.5}$, black carbon and $PM_{2.5}$ for NO_2 and NO.

Mortality



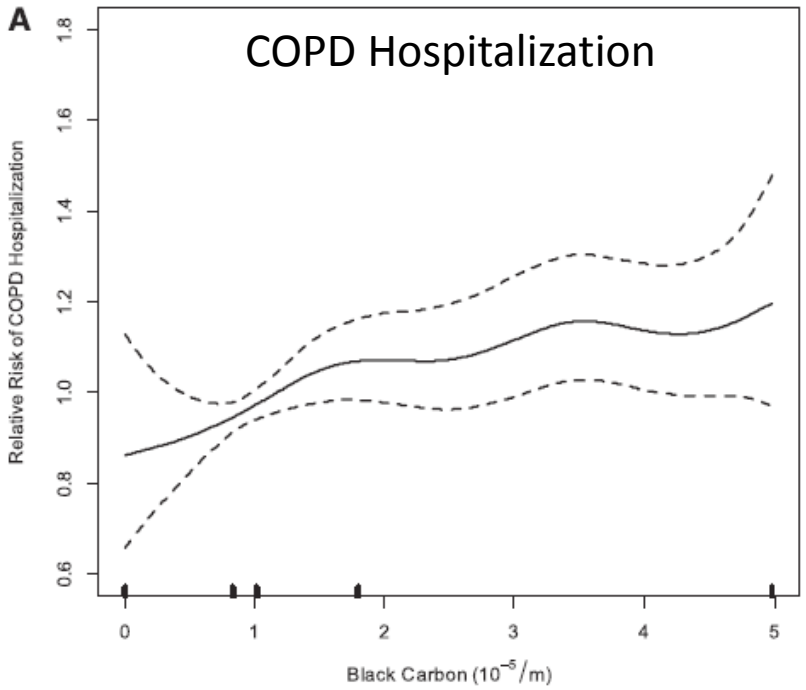
Associations of Ambient Air Pollution with Chronic Obstructive Pulmonary Disease Hospitalization and Mortality

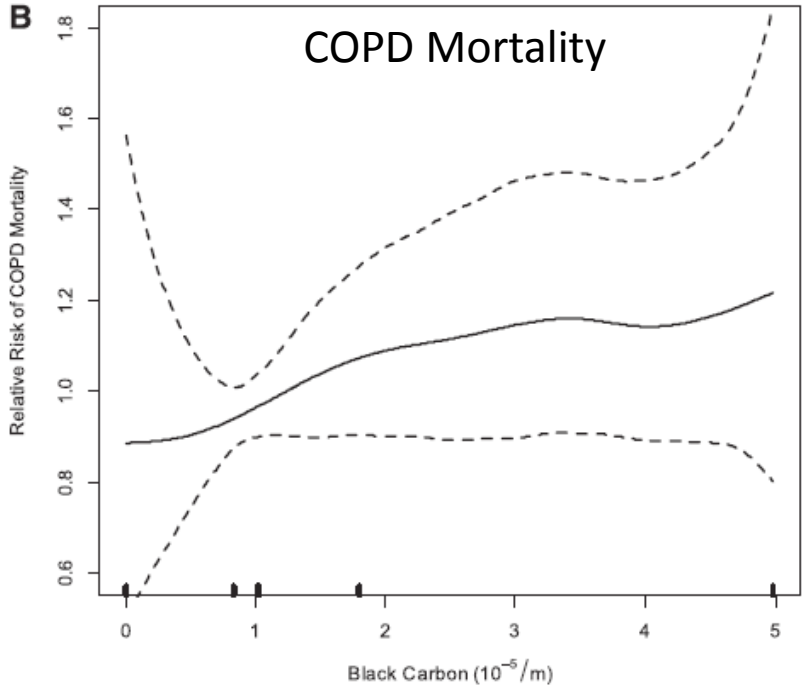
Am J Respir Crit Care Med Vol 187, Iss. 7, pp 721–727, Apr 1, 2013

Wen Qi Gan[1,2], J. Mark FitzGerald[3,4], Chris Carlsten[3,4,5], Mohsen Sadatsafavi[3,4], and Michael Brauer[3,4,5]

TABLE 3. RELATIVE RISKS (95% CONFIDENCE INTERVALS) FOR COPD HOSPITALIZATION AND MORTALITY ASSOCIATED WITH AN IQR ELEVATION IN TRAFFIC-RELATED AIR POLLUTANTS

	Black Carbon ($0.97 \times 10^{-5}/m$)*	$PM_{2.5}$ ($1.58\ \mu g/m^3$)*	NO_2 ($8.40\ \mu g/m^3$)*	NO ($13.2\ \mu g/m^3$)*
Hospitalization				
Model 1: unadjusted single pollutant model	1.14 (1.10–1.17)	1.15 (1.11–1.19)	1.17 (1.12–1.21)	1.11 (1.07–1.16)
Model 2: + age, sex, SES	1.06 (1.02–1.09)	1.02 (0.98–1.06)	1.00 (0.96–1.05)	1.03 (0.98–1.07)
Model 3: + asthma, diabetes, CHD, HHD	1.06 (1.02–1.09)	1.02 (0.98–1.06)	1.00 (0.96–1.05)	1.03 (0.98–1.08)
Model 4: + two other pollutants†	1.06 (1.02–1.10)	1.02 (0.98–1.07)	0.98 (0.93–1.03)	0.98 (0.93–1.04)
Mortality				
Model 1: unadjusted single pollutant model	1.17 (1.09–1.24)	1.17 (1.08–1.26)	1.24 (1.15–1.33)	1.15 (1.06–1.25)
Model 2: + age, sex, SES	1.07 (1.00–1.14)	1.02 (0.94–1.10)	1.04 (0.95–1.12)	1.06 (0.97–1.16)
Model 3: + asthma, diabetes, CHD, HHD	1.07 (1.00–1.14)	1.02 (0.94–1.10)	1.04 (0.96–1.13)	1.06 (0.97–1.16)
Model 4: + two other pollutants†	1.07 (1.00–1.14)	1.00 (0.92–1.09)	1.03 (0.93–1.13)	1.02 (0.91–1.13)





Highway proximity and black carbon from cookstoves as a risk factor for higher blood pressure in rural China

Jill Baumgartner[a,b,1], Yuanxun Zhang[c], James J. Schauer[d], Wei Huang[c], Yuqin Wang[c], and Majid Ezzati[e]

The effect of BC on SBP was almost three times greater in women living near the highway [6.2 mmHg; 95% confidence interval (CI), 3.6 to 8.9 vs. 2.6 mmHg; 95% CI, 0.1 to 5.2].

www.pnas.org/cgi/doi/10.1073/pnas.1317176111

BC and Health

- BC represents one of the more health-relevant components of PM, especially for cardiovascular effects

  - Toxicological studies: BC (measured as EC) may not be a major directly toxic component of $PM_{2.5}$, but may be a carrier of a wide variety of combustion-derived chemical constituents.

Implications

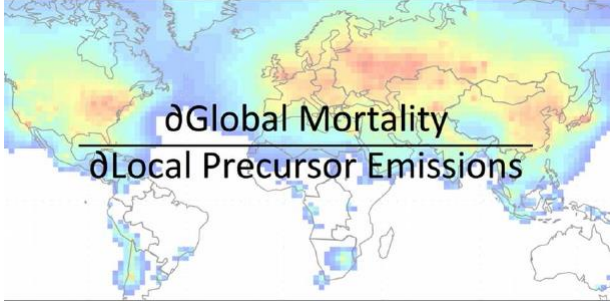
- BC is an indicator of combustion-derived $PM_{2.5}$ health impacts
- Reducing $PM_{2.5}$ (and BC) leads to health benefits
- Magnitude of benefits depends also on size of exposed population and their disease burden
  - Controls on direct emissions may be especially beneficial (exposure proximity)
- Reducing only BC will leave substantial health impacts from $PM_{2.5}$
  - BC mitigation strategies must also lead to net reduction in $PM_{2.5}$

EXTRA SLIDES

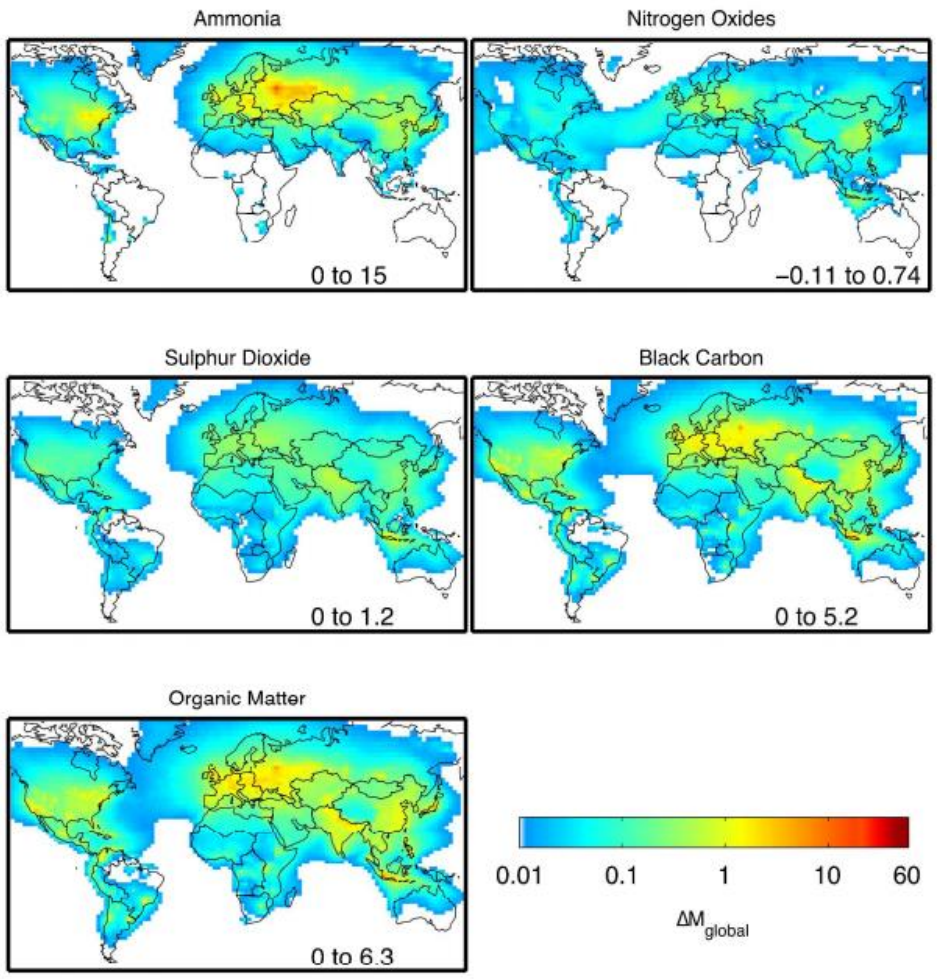
Response of global particulate-matter-related mortality to changes in local precursor emissions

Colin Lee, Randall Martin, Daven K. Henze, Michael Brauer, Aaron Cohen, and Aaron van Donkelaar

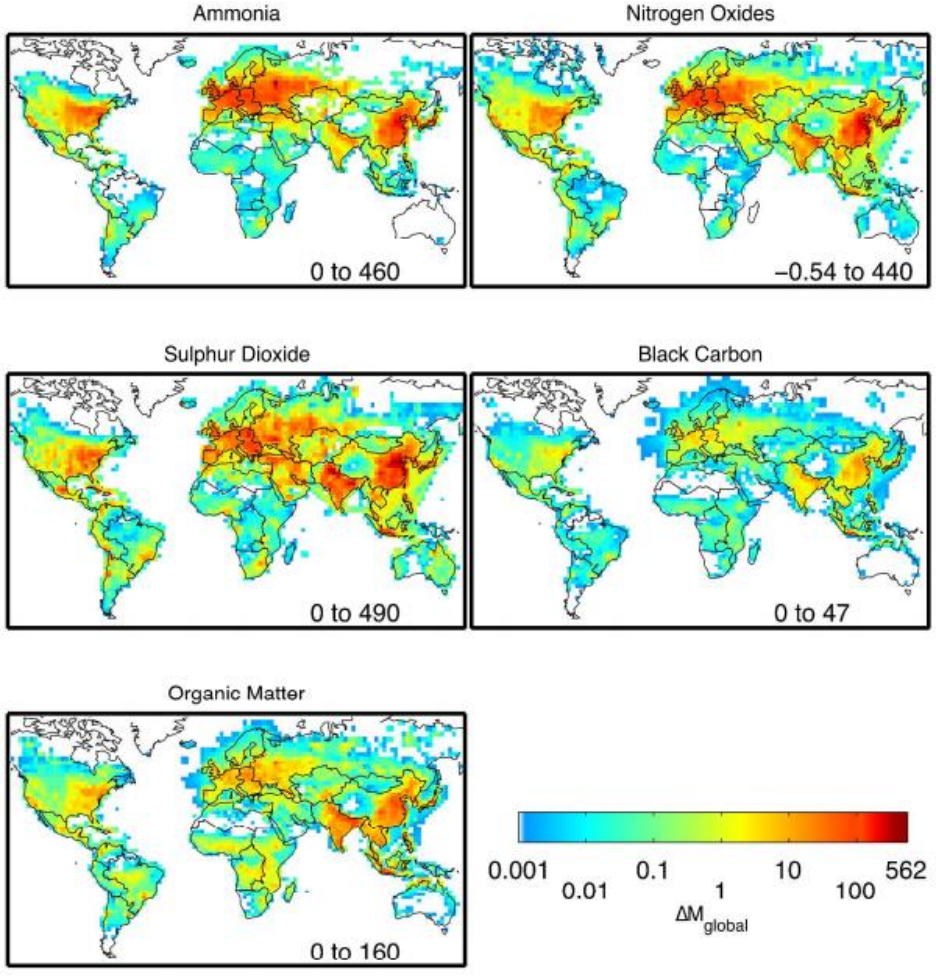
Environ. Sci. Technol., **Just Accepted Manuscript** • DOI: 10.1021/acs.est.5b00873 • Publication Date (Web): 02 Mar 2015



Absolute (1 kg/km^2 yr) reduction



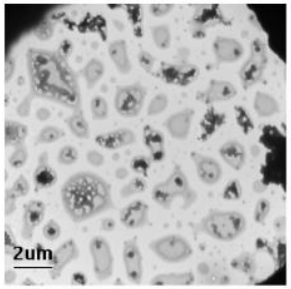
Relative (10%) reduction



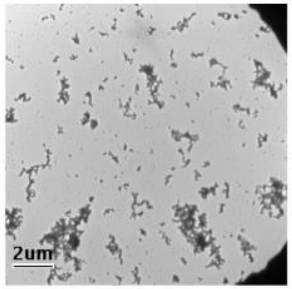
Characterization of Ultrafine Particulate Matter from Traditional and Improved Biomass Cookstoves

dx.doi.org/10.1021/es304351p | *Environ. Sci. Technol.* 2013, 47, 3506−3512

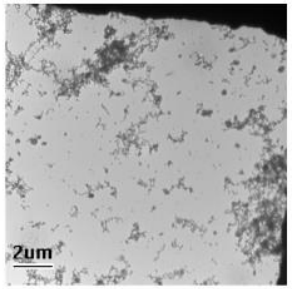
Brian Just,*,† Steven Rogak,† and Milind Kandlikar‡,§



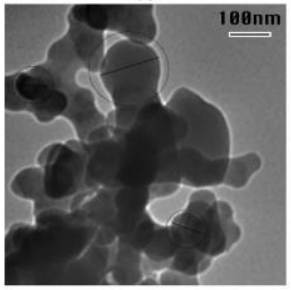
(a)



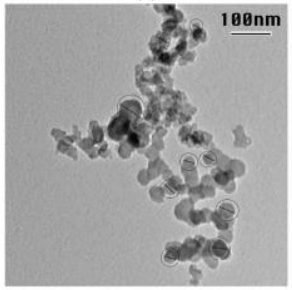
(b)



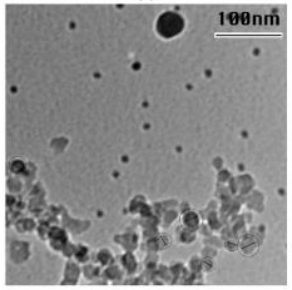
(c)



(d)



(e)



(f)

	three-stone	rocket	gasifier
Concentrations			
DustTrak raw PM averages (mg/m^3)[a]	28.5 ± 5.6	4.63 ± 0.84	1.07 ± 0.17
DustTrak "error"[b]	+172 ± 13%	+21 ± 4%	−16 ± 10%
corrected and normalized PM (mg/m^3)[c]	8.25	3.81	1.18
Form of Carbon			
EC/TC (NIOSH 5040)[d]	0.15 ± 0.07	0.80 ± 0.05	0.70 ± 0.04
TC/PM (NIOSH 5040)[e]	0.56	0.67	0.86
EC/PM (NIOSH 5040)[e]	0.08	0.53	0.60
BC/PM (aethalometer)[f]	0.06	0.20	0.41
Emission Factors			
PM (g/kg dry fuel)	8.44	2.38	0.86
OC (g/kg dry fuel)	3.98	0.32	0.22
EC (g/kg dry fuel)	0.70	1.27	0.52
Particle Size			
mobility diameter, SMPS (nm)[g]	61	35	24
primary particle diameter, TEM (nm)	57.7 ± 23.6 (N = 52)	46.1 ± 19.2 (N = 83)	27.2 ± 10.5 (N = 105)